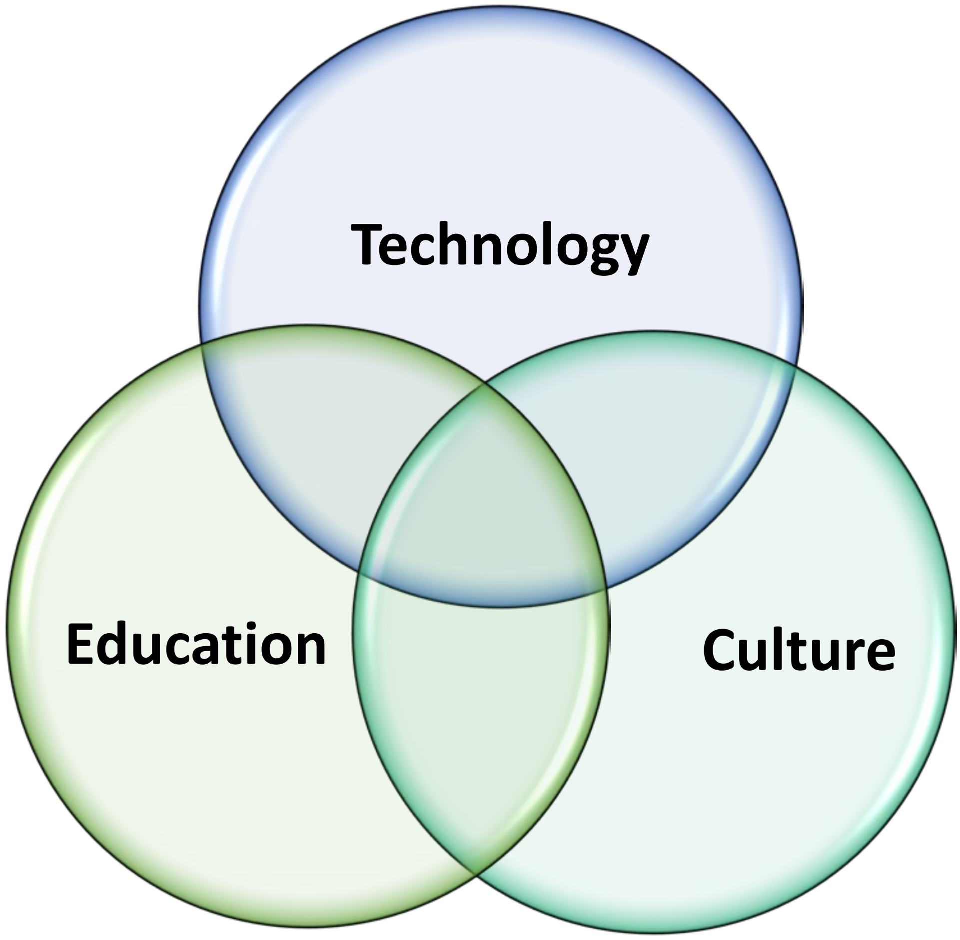
TENZ-ICTE CONFERENCE

Technology: An holistic approach to education



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International Conference on Technology Education (ICTE) Asia-Pacific Region

TENZ TECHNOLOGY EDUCATION NEW ZEALAND

TENZ – ICTE Conference

Technology: An holistic approach to education

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About TENZ

Technology Education New Zealand

Technology Education New Zealand is a professional network, promoting and supporting technology education in New Zealand. This is achieved by fostering development of technology in the New Zealand Curriculum, and maintaining national and international links between those working in technology education and with the wider technological community.

It aims to:

- foster the development of Technology Education in New Zealand
- develop and maintain national and international links between those working in Technology Education and with the wider technological community
- support professional, curriculum, and resource development in Technology Education
- encourage and support research in Technology Education
- organise a national biennial Technology Education conference
- work closely with other subject associations for mutual benefit of technology education.

About ICTE Asia Pacific

International Conference on Technology Education (Asia Pacific)

The aim of this professional group is to promote communication and academic exchange in Technology Education amongst Asia-Pacific countries which have professional associations of Technology Educators. Current members of ICTE are Japan, New Zealand, Korea, Taiwan, Australia, USA and Hong Kong.

The first conference was held in Otsu, Japan in 1995. The next conference in Taipei, Taiwan in 1997 was when the ICTE organization was constituted. Conferences then were held in Canberra, Australia in 1999, Daejeon, Korea in 2001, Auckland, New Zealand in 2003, Hong Kong, China in 2006, San Antonio, USA in 2007, Taipei, Taiwan in 2009, Aichi, Japan in 2011, Nanjing, China in 2013 and Hong Kong in 2015.

About this Conference

TENZ / ICTE Conference

The opportunity arose for both these conferences to be held in New Zealand in 2017, and they have complemented each other well. The professional development focus of TENZ has resulted in many practice papers and practical workshops to be included in the conference program, and the academic papers of both TENZ and ICTE members have resulted in a well balanced conference program with something of interest to all professionals working in all areas of Technology Education.

The papers published in this proceedings have all undergone a peer review at the abstract stage, and then a blind double peer review of the full papers, to comply with the verification requirements for a conference publication – full written paper refereed.

Editor: John Williams

Proceedings Editor: Kerry Goodwin

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The conference convenors woud like to thank the reviewers for their diligent work. This is one of the activities of academics that goes unrewarded, but is very important in maintaining standards of research practice.

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New Paradigm or Old Wine? The Development of STEM Education and Maker Movement in Technology Education in Taiwan

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Keywords**:** Maker movement, STEM education, Taiwan, Technology education.

In 2001, when addressing the transformation of education in the United States from the "Industrial Arts" to "Technology Education," Sanders (2001) raised the question of "New Paradigm or Old Wine?" to stimulate the reflections of the technology education community. Today, in 2017, two important trends, "STEM education" and "Maker movement," will also have an impact on our technology education community. The main aim of this keynote speech is to introduce the development of STEM (Science, Technology, Engineering, Mathematics, STEM) education and Maker movement in Taiwan as I personally view them, and to provide solutions for the difficulties that we face in the implementation of STEM education and Maker movement in Taiwan, which can serve as a reference for the audiences. It is hoped that more attention will be paid to technology education through the trends of STEM education and Maker movement. The topic of talent cultivation in the STEM field has been of great significance in recent years. A trend of constant decline has been observed in student quality, enrollment rates, and research funding for STEM talent in a number of developed countries. In the field of engineering, this situation is particularly serious and worthy of attention (Holmes, Gore, Smith, & Lloyd, 2017). Based on two reports published by the National Science Board (NSB) and the President's Council of Advisors on Science and Technology (PCAST), Raju and Clayson (2010) pointed out that the US has seen a trend of cultivating STEM innovators. However, many researchers have also found that although greater attention has gradually come to be paid to STEM education in recent years, technology and engineering were frequently overlooked in its actual implementation. Consequently, issues regarding talent cultivation in technology and engineering fields may still be difficult to solve (Strimel & Grubbs, 2016).

Regarding the issue that technology and engineering might be overlooked in the implementation of STEM education, the prevalent "Maker movement" that has emerged in recent years could be one feasible solution. Taylor (2016) analyzed the benefits of the Maker movement for the development of K-12 STEM education and suggested that the Maker movement could help students to connect with STEM education and develop the key competencies required in the 21st century. Undoubtedly, the viewpoint that Taylor (2016) proposed based on his research and findings was an extremely exciting proposal for academics and teachers in the field of science and technology. As hands-on activities are emphasized in the field of technology, there are many commonalities between the concepts of the Maker movement and technology education. Therefore, using the Maker movement to assist the implementation of K-12 STEM education is an important issue worthy of investigation.

In the process of implementing the Maker movement, many makers have frequently applied 3D printing technology to creation. Therefore, based on the research by Taylor (2016), it is believed that the proper application of 3D printing technology for the implementation of STEM education and the cultivation of future STEM innovative talents could be a feasible practice. However, Nemorin (2016) might disagree with this argument. According to Nemorin's study findings (2016), if 3D printing technology were applied at the school site, the following problems could occur: (1) lack of pragmatic engagement; (2) affective labor of failing; (3) mediated alienation (Nemorin, 2016). Nemorin's results show us an extremely important fact: if 3D printing technology were directly applied to replace hands-on activities in the technology field, students might be unable to participate in hands-on activities and hence lack the important failure experience obtained from hands-on processes. Thus, the proper integration of 3D printing technology with hands-on activities to cultivate important STEM talents needed in future society is a key point for the future implementation of STEM education and Maker movement.

Based on the above analysis, technology and engineering are frequently overlooked when implementing STEM education. However, if only 3D printing technology is used in the Maker movement, we will face the problem of a lack of practical hands-on experience. In order to explore possible solutions to this, two feasible approaches are provided below.

Implementing technology and engineering education in STEM education via project- based learning activities

When implementing STEM education, it is of great concern to ensure that students have equal opportunities to access knowledge and competencies in all four fields of technology, science, engineering, and mathematics (English, 2017). However, many teachers are often unable to clarify the roles that technology and engineering should play. The main reason is that technology is already a subject, whereas engineering is not a subject in K-12 education and its contents are only implemented through science or technology. Therefore, regarding the content of K-12 engineering education, many scholars believe that the focus should be on the cultivation of engineering design abilities. Therefore, ensuring that students have the correct cognitive structure for the engineering design process is often the focus of relevant researchers (Song, Becker, Gero, DeBerard, Lawanto, & Reeve, 2016). In order to highlight the connotations of engineering design in engineering, Dutson, Todd, Magleby, and Sorensen (1997) primarily applied project-oriented capstone courses to explore how to implement the teaching of engineering design. In addition, Kist (2014) also believed that if project learning activities could be properly used to enhance student engagement, students would be more willing to learn when they can consolidate their STEM knowledge and competencies through hands-on activities. Therefore, if STEM education could be implemented through STEM project learning activities, not only would the connotation of engineering design in engineering be highlighted, it would also enhance the students' interests in consolidating their knowledge and competencies related to STEM.

Enhance the learning of modeling through 3D printing technology.

Although the connotation of engineering design in engineering could be highlighted via project learning activities, "modeling" is the most important and key step in engineering. The development of models could help to cultivate among students the crucial high-level concepts required in the field of engineering (Moore, Miller, Lesh, Stohlmann, & Kim, 2013). In addition, Kaiser and Sriraman (2006) also argued that students must properly apply their knowledge of science, mathematics, and other areas in the process of modeling in order to solve real-life problems they have faced. Therefore, modeling is key to the engineering design process. During hands-on activities in the technology field, problems are most commonly solved by conforming to the problem-solving process. However, in the course of problem solving, the importance of modeling was not mentioned. This has led to the fact that when students evaluate a design concept, many can only evaluate the optimal concepts based on previous experience or intuition. Based on the above analysis, students would gain more valuable benefits if the engineering design process were integrated with STEM project learning activities and the importance of modeling were strengthened. Based on this argument, 3D printing technology can play an important role in the step of modelling. Students can build models using 3D printing technology to evaluate the feasibility of the design concepts, thereby reducing the possibility of subsequent production problems. In addition, according to the viewpoints of Kaiser and Sriraman (2006), students also need to apply their knowledge of science, mathematics, and other areas in the process of modeling, which could assist in implementing the concept of STEM integration.

Through the analysis and case study of STEM education and Maker movement in Taiwan, my main goal is not to promote these practices in Taiwan for imitation, but to raise some important issues that are worth thinking about during the rational application of STEM education and

Maker movement. We also hope that through the current trends of STEM education and Maker movement, a new paradigm could be proposed for the core value of technology education, so that more of the public can realize the core value of technology education.

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Universities as Drivers of Innovation, Economic Transformation

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Keywords: Innovation, Entrepreneurship, University research

Universities all over the world are undergoing a dramatic transformation. In addition to the traditional, "ivory tower" pillars of discovering new knowledge and educating the next generation, universities now strive to have a positive economic influence on their cities, regions, nations and the rest of the world. Although more people attend universities today than at any other time in history, universities find themselves in the unpleasant position of having to continually defend or explain the value of a university degree.

> *"Universities across the world in the early twenty-first century find themselves in a paradoxical position. Never before have they been so numerous or so important, yet never before have they suffered from such a disabling lack of confidence and loss of identity." (Collini, 2012)*

The worth of a university degree has not always been so closely tied to economic benefits to society or to vocational benefits to the degree earner. In fact, from the Platonic academy to the 1950's, a liberal arts university degree was valued in much more abstract terms. A university degree at Harvard, Oxford, Cologne conferred wisdom. The benefits to society derived from the immersion in history, literature, language, science, mathematics – a thorough grounding in humanities intellectual pursuits. In establishing the new culture in America, Thomas Jefferson advocated a "crusade against ignorance" as the most important way to ensure "the preservation of freedom and happiness." *(Jefferson, 1786)*

As Jefferson was exhorting his colleagues in nascent America to support the growth of democracy through broad access to higher education, Wilhelm von Humboldt was articulating the formulation of what became the modern university in Europe, the United States, and the (former) British Empire. In this model, the university stands on two pillars: (1) the education of the next generation in skills, critical thinking and cultivation, and (2) the creation and discovery of new knowledge through hypothesis-driven research.

Today, though, the modern university rests on a third pillar. At the University of Auckland, this is articulated in the mission statement as "its commitment to serve its local, national and international communities." *(University of Auckland, 2015)* The form this service takes is most often in the form of economic impact. Increasingly, universities are tasked – indeed, have tasked themselves – with driving the economy through commercialisation of its research innovation.

This third pillar is quite a recent development in what society sees as the purpose of a university. The revenues these commercial activities generate are particularly attractive to university leadership, as governments continue to reduce funding (relative to cost) for higher education. Further, students are increasingly interested in university degrees as vocational training and a way to enhance financial reward. At the University of California – Los Angeles, for example, first year university student surveys reveal something quite interesting. In 1971, only about a third of these students rated "being very well off financially" as an "essential" or "very important" outcome from a university education. In contract, over 70% rated "developing a meaningful philosophy of life" that highly. By 2015, those percentages had inverted – the crossing point was in about 1978 – and now many more students now say that a university degree should provide a pathway to riches. *(Berrett, 2015)*

In New Zealand, the transition can be seen in the evolution of the names of our government science funding structure. In 2011, the Ministry of Research, Science and Technology was disbanded. The Ministry of Science and Innovation replaced it, for a short while, to be superseded quite quickly by the Ministry of Business, Innovation and Employment – no "science" or "research" in its name at all.

The Photon Factory, the laboratory I direct, has embraced and experienced some success with this transformation of what universities are good for. We do very fundamental, blue-skies chemical physical research with our exotic femtosecond lasers. However, we also do research targeted for advancing industry, and very applied research in the form of spin-off companies. Engender Technologies uses microfluidics and photonics to sort sperm by sex for the dairy industry. This technology is in the cusp of full commercialisation. Engender has been valued at $9.8m, and has national and international awards, including the gold medal in a Silicon Valley World Cup Tech AgTech competition, and being named an emerging company to watch by the TIN100 in New Zealand and internationally by AgFunder. Our second company, Orbis Diagnostics, co-founded by Prof. David Williams, is in the early stages of the R&D of "point of cow" diagnostics, detecting the composition of milk every cow, every milking. Our third commercial project, not yet a spin-off, just won a "Smart Ideas" award, $1m over 3 years to perform the high-risk, high-yield research to demonstrate proof-of-concept. The Photon Factory is rapidly becoming an early innovation hub nurtured within the University of Auckland.

The "ivory tower" of pure research in the service of knowledge, culture, society, human endeavour – the pursuit of understanding for its own sake – is no more. Humanity does not go backwards, so how do we look forward into a future in which higher education must manage the tensions that come from merging the high-brow "ivory tower" culture of the modern university with the economically imperative and high-impact, commercially-facing contracts and entrepreneurial spin-offs like Engender Technologies.

What does it mean to be at a university? Is all of this change bad? Do we still value classical ideals? Is the economic mandate undermining the ivory tower? Or does the ivory tower have something to offer to the commercially-focused world? The answer to that last question is certainly affirmative, and I argue it is essential.

We can see the consequences of anti-intellectualism all over the world, perhaps most strikingly in the United States. How astonishing it is to see racial intolerance, white supremacists marching in Charlottesville, at the University of Virginia – the very university started by Thomas Jefferson, who advocated a classical, higher education as essential for combating the kind of prejudice that undermines the modern democracy.

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Holistic approaches to learning, teaching and assessment in Technology Education: authenticity, challenges, supportive approaches and tools

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This presentation will make a case for learning in technology education to be holistic: embedded in authentic learning activities that develop capability and criticality in design and technology. It will be in three parts. First I will make a case for starting with human potential and how this can be nurtured through formal schooling, focusing on the importance of relevant contexts, a view of designing as an iterative process and the place of knowledge skills and understandings in such an approach. Next I will focus on the issues this raises for structuring learning and teaching and finally I will present some pedagogic strategies and tools that support the approach.

I will begin by considering the importance of holistic approaches in technology education by stepping aside from formal education to consider the ways in which humans draw on their design and technological capacities when faced with a challenge or inspired by an idea. The aim will be to set the scene for making a case for taking an holistic approach to technology education that nurtures the design and technological capability that is inherent in human beings by building on that potential capability with as much authenticity as possible. In taking this starting point it is possible to see the capability that can be nurtured through technology education as a rounded capability, one that can reach beyond the boundaries of a school subject and develop a broader range of skills such as those described as 21st Century skills such as collaboration, communication, critical thinking and creativity.

Taking the perspective of human capability, rather than what might historically have been packaged as a school subject was an approach that was taken by the technology education research team at Goldsmiths in the 1980s when faced with a major research challenge of assessing the design and technological capability of fifteen year olds in England, Wales and Northern Ireland. This research was undertaken at a time when schools in these countries had no compulsory subject called ‘Design and Technology’. The team was faced with the challenge of assessing a sample of 10,000 learners, selected randomly, through a combination of short (between 90 minutes and 3 hours) design and technology tasks. We knew that some of the learners selected would have never undertaken such a task in a formal school setting. While we wanted to make effective assessments, we didn’t want to set any learners up to fail. We wanted to make the tasks as authentic as possible.

Through early explorations and school trials we identified two key principles: that the tasks should be set in relevant, meaningful contexts that were rich in issues and motivating challenges and that the tasks should be embedded in an iterative, not linear, process of designing. Taking this research as a starting point, I will expand on the value of setting tasks in authentic, rounded contexts that have socio-cultural relevance for learners and that are both challenging and inspirational, making a case for how a well-developed context can provide support throughout the whole of a technological project, not just serving as a starting point. A design context that allows learners to see societal needs, problems and challenges alongside opportunities for development, provides a strong base for authenticity. It also allows for an holistic approach to drawing on existing knowledge, understanding and skills, but also for extending these, as the need to know new things to address the task in hand emerge. The problems that need to be solved are different to those that have right and wrong answers, and are often described as 'wicked problems' that have the possibilities of many and varied outcomes. Such problems bring a level of uncertainty to a project that makes it unhelpful to specify a process for a project too tightly. Viewing processes of designing that iterate between thought and action, rather than as a linear, managerial process, will be explored to show how taking this stance on designing allows the development of the project and the knowledge, skills and understandings needed to respond to the demands in the task.

From a teaching perspective, while holistic approaches support authentic learning opportunities, they can be complex and demanding. The structure and management of learning and assessment need to align with the fundamentals of the approach. Through the next section of the presentation I will provide more developed insights into some critical aspects of structuring learning in ways that help manage authentic, holistic approaches and the value that this has for learners. Tasks can be set on a continuum from broad, open contexts to more specified scenarios. At either extreme, there are challenges for structuring learning to enhance affordances for learners while enabling teachers to manage the learning situation. Open ended starting points allow learners to establish ownership but they can get lost in the scope and complexity. Tightly defined tasks reduce initial decision making for learners, but can appear over-simplified and lead to superficial outcomes. Structuring activities with an awareness of the challenges and potential of different levels of specificity allows for scaffolding learning appropriately and, through a range of tasks at different levels, providing a 'mixed diet' of projects that build capability, criticality and confidence. Structuring progress through an iteration of active and reflective tasks can allow teachers to choreograph the process of designing, rather than either tightly prescribe 'steps' or leave the learners to work things out for themselves. Having a set of pedagogic tools that can be used flexibly to support action and reflection has an additional advantage of supporting different learning and designing styles.

In the final part of the presentation I will present a range of pedagogic strategies for using a context as a reference point throughout a project, from tools that help in using a context to set the scene for a project, developing a rich understanding of the needs in a task as it progresses and also reflect on the effectiveness of outcomes that respond to the context. I will also provide insight into approaches that support ideation, imaging and modelling of ideas as they develop. Drawing from both design and educational settings, suggestions will be presented that support imaging and modelling through talk, making, drawing and writing and those that disrupt thinking in ways that fire imagination and innovation such scenario building, inspirational handling collections and bodystorming. The value of dialogue – learner/teacher, peer/peer, learner/avatar - as a tool for both reflection and speculation will be explored as well as tools that support dynamic portfolio-based documentation of processes.

Throughout the presentation research and case studies will be utilised to illustrate the both validity and application of the ideas and approaches presented.

Teachers’ Perceptions of Assessment in Design and Technology

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Abstract

Little classroom-based investigation has been conducted to determine the effectiveness of assessment in Mauritius secondary schools. Despite having inspectors and principals monitoring and checking teachers’ practices, very little is known about teachers’ assessment for learning (AfL) practices. This research aimed to address specific assessment concerns by looking at the AfL practices of Design and Technology (D&T) teachers in Mauritius state secondary schools (SSSes). The main research question was as follows: How are D&T teachers implementing AfL in SSSes at various levels? In light of this question, an interpretivist theoretical perspective and ethnographic methodology (Crotty, 1998; Fetterman, 2010) was used to investigate teachers’ beliefs and practices in their natural settings. The mixed methods QUAL-quan (Punch, 2009) study was carried out in eleven schools and involved twenty-nine D&T teachers. A range of data collection methods including survey, interviews, observations, and analysis of secondary documents was used. The data reported in this paper are from the teachers’ interviews. An analysis of the interviews revealed that D&T teachers’ perceptions of assessment led them to concentrate on improving their instructional decisions rather than transforming their practices, as well as implement AfL ineffectively. The implications of their AfL practices are also explored in this paper.

Keywords: Assessment for learning; Design and Technology; perceptions; ethnography; interpretivism; mixed methods; teaching.

Introduction

The purpose of this study, which started in 2015, was to explore and understand the teachers' assessment for learning (AfL) practices and potentially identify gaps in teachers' assessment knowledge and practices. Assessment is considered to be "a bridge between teaching and learning" (Wiliam, 2013, p. 15), and teachers are expected to be acquainted with and use several types of assessments, since no single measure gives sufficient evidence about a particular student's growth (Popham, 2014). It has been argued that AfL is useful as it can promote teaching and learning (Bartlett, 2015; Earl, 2013; Larrivee, 2000).

To facilitate teachers' assessment practices, Newton (2007, 2010), identified twenty-two purposes of assessment, the main set of purposes being monitoring students' progress towards goals (Andrale, 2013; Wiliam, 2013). In Popham's (2014) view, when teachers monitor learners' progress towards intended goals, there should be a "formal attempt" (p. 8) to collect the evidence, meaning that information should be collected in systematic ways. Popham (2014) adds that teachers should not solely rely on tests or judge students based on their opinions when collecting such information, but use several methods such as portfolio assessment, hands-on-experiences, continuous assessment, peer assessment, and self-assessment.

Despite international evidence on the importance of different types of assessment, not much is known about Design and Technology (D&T) teachers' assessment practices in Mauritius. This paper reports some preliminary findings of a study that sought to explore the types of assessment methods that D&T teachers use and to determine if AfL was being effectively implemented. The results from this study are part of a larger investigation exploring the AfL practices of D&T teachers in Mauritius SSSes.

The paper consists of five main sections. First, the paper describes the significance of AfL for learners. Second, the Mauritian context, its education system and assessment expectations in D&T as stated in the *National Curriculum Framework: Secondary* (NCFS) are presented. Third, the methodology used is described. Fourth, the survey results on D&T teachers' qualifications in education followed by the interview results are reported under two main themes: using AfL to refine teaching, and using AfL to enhance students' learning. Fifth, D&T teachers' AfL practices are discussed.

Assessment for learning

Educators and researchers currently recognise three different but intertwined main assessment purposes: assessment for learning (AfL), assessment as learning (AaL), and assessment of learning (AoL) (Earl, 2013; Harlen, 2009; Klenowski, 2009). AoL is not used to support learners during their learning (Fenwick, 2017), but involves making a final judgement about students' learning through grading and reporting (Gardner, 2012). Conversely, AfL and AaL involve making assessment part of daily teaching to assist students in carrying out the next step in their learning (Earl, 2013; Gardner, 2012). AaL is considered to be a subset of AfL (Fenwick, 2017) and is concerned with developing the students' cognitive and metacognitive competence in self-evaluating their learning (Lam, 2016).

A review of the literature indicates that systematic AfL helps students learn (McDonald & Boud, 2003; Nortvedt, Santos, & Pinto, 2016). Students benefit from AfL as it: motivates them to engage in their learning, encourages them to keep trying, provides them with appropriate and timely feedback, and gives them the opportunity to assess their own learning (Black & Wiliam, 1998; Crooks, 1988; Earl, 2013; Hattie & Timperley, 2007; Hill, Cowie, Gilmore, & Smith, 2010).

AfL has several definitions, and how the words of these definitions are interpreted in educational policies and translated in practice has often led to distortions of teachers' AfL practices in several contexts (Klenowski, 2009). For this reason, during the Third International Conference on AfL held in New Zealand in 2009, the following definition of AfL was recommended:

> Assessment for learning is part of everyday practice by students, teachers, and peers that seeks, reflects upon and responds to information from dialogue, demonstration and observation in ways that enhance ongoing learning. (Klenowski, 2009, p. 264)

In this definition, learning is considered as a social process, where the teachers' role is about providing scaffolding to students for them to participate in their learning (James, 2008). The definition also suggests that AfL practice is accomplished by teachers, with the intention that students should be actively involved in their learning to enable them to become autonomous learners.

AfL is characterised as a process focused on providing qualitative insights into students' understanding. To gain the necessary insights, teachers should embrace five key approaches:

> clarifying and sharing learning intentions and criteria for success; engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding; providing feedback that moves learners forward; activating students as instructional resources for one another; and activating students as the owners of their own learning. (Warwick, Shaw, & Johnson, 2015, p. 41)

With the awareness of these five key approaches, it might appear that AfL is a simple concept, yet, Willis (2010) warns that it is hard to accomplish in practice. Several reasons might be the cause of teachers' assessing the way they do, such as their habitus (Bourdieu, 1977), perceptions (So & Lee, 2011), and familiarity with concepts (Cumming & Maxwell, 1999). In Earl's view (2013) teachers apparently have difficulties in developing and using AfL practices and this phenomenon is not country, culture, school or subject specific, but more generalised (Black & Wiliam, 1998; Nortvedt et al., 2016). For example, research conducted by James and Pedder (2006) indicates that several teachers faced difficulties in fostering learners' autonomy. To promote autonomy, Hill et al. (2010) recommend that teachers should assist their students in developing strategies that would: enable them to assess their learning, set goals for future learning, and learn individually as well as collaboratively.

Focus and context of this study

In recent decades, several studies have been conducted in the field of AfL. According to Norvedt (2016, p. 377), these studies may be categorised as follows: "research aimed at understanding whether the practices of AfL improve student performance; and … practice that attempts to understand whether teachers can transform ideas from research into productive practices." Our study investigated D&T teachers' AfL practices in Mauritius SSSes because little is known about this practice in the local context. Our aim was to find out how teachers implemented AfL in D&T. The investigation would contribute to improving the teachers' AfL practices and student learning in Mauritius.

The Mauritius education system is based on the British schooling system and comprises of four main categories: two years pre-primary, six years primary, seven years secondary, and formal tertiary education (Ministry of Education and Human Resources [MOEHR], 2012). Students are assessed on the one hand by continuous assessment, end-of-term tests and end-of-year internal examinations, and on the other hand by four external examinations (MOEHR, 2009; MOEHRTESR, 2016). One of the external high-stakes examinations is at the end of primary at 11+ and provides access to the secondary level. The other three high-stakes examinations are at 14+, 16+ and 18+ (MOEHR, 2009; MOEHRTESR, 2016).

In 2009, educational reforms were introduced into the Mauritius secondary school curriculum through the *National Curriculum Framework: Secondary* (NCFS) (MOEHR, 2009). The NCFS recognised that D&T enables students to "become creative, innovative and reflective individuals … [and]… integrate the society as responsible citizens" (MOEHR, 2009, p. 107). The policy document highlighted that D&T "allows students to apply knowledge, skills, experience and resources to design and develop technological solutions to cater for the needs of individuals, societies and environments" (MOEHR, 2009, p. 107).

The NCFS provided a clear indication to teachers about the assessment expectations in D&T. For example, the NCFS recommended that D&T teachers use holistic and user-friendly assessment approaches to encourage students to engage in reflective thinking. The document stipulated that assessment criteria should be explicit to the students, and assessment methods should include students' self-evaluation, interviews, observations and portfolios. The NCFS also stated that D&T students should be allowed to apply a range of skills in problem-solving (MOEHR, 2009). Therefore, this mixed methods study also explored whether the NCFS framed the D&T teachers' AfL practices.

Methodology

The aim of this study was to gain an understanding of D&T teachers' AfL interpretations and actions in their sociocultural context. An interpretivist theoretical perspective was deemed appropriate (Crotty, 1998), as AfL is typically situated within a socio-cultural theoretical framework (James, 2008; Poskitt, 2014). Conducting the inquiry in the participants' societal and cultural context (naturalistic perspective) allowed a more comprehensive understanding (Owen, 2008) of D&T teachers' AfL practices to be gained.

A mixed methods design was used as it provided an opportunity to gather a more accurate picture (Creswell, 2014; Leech & Onwuegbuzie, 2007) of the D&T teachers' AfL practices. An embedded design (Creswell & Plano Clark, 2011) was used, involving collecting data in three stages. The primary research method was qualitative and ethnographic (Grenfell et al., 2012). An emic (insider) approach was chosen for describing and analysing phenomena, within the field of social activity, from the viewpoint of the teachers and students whose beliefs and behaviours were explored (Hammond & Wellington, 2013; Sockett, 2013). Multiple methods including survey, classroom observations, document analysis and interviews were used. The interviews involved teachers and students from the observed classrooms.

As the data analysis is still underway, only the teachers' interview and questionnaire data are reported in this paper. Twenty-nine teachers from eleven SSSes agreed to fill the questionnaire and participate in the interviews (group and individual), which were organised at each school with the aim of increasing participation. The interviews were conducted using a semi-structured interview protocol to explore the teachers' AfL understanding and practices. Once the teachers approved the transcripts, these were coded and themes identified.

Saldaña's (2016) first and second cycle coding methods were used to analyse the data. Initial codes were developed using the first cycle methods by going back-and-forth on NVivo 11. New codes emerged as the analysis progressed. Finally, the second cycle coding methods were used to reorganise and reanalyse the coded data (Saldaña, 2016). During the coding process, patterns were identified that led to the two themes which are elaborated in the next section.

Results

The survey data indicated that twenty-two D&T teachers (75.86%) had teacher-education qualifications, which included Bachelors, Postgraduate Certificates, and Masters qualifications. The findings revealed that the twenty-two teachers studied in Mauritius and completed the modules of 'curriculum studies', and 'assessment and evaluation' for their initial teacher education. As a result, the Ministry of Education, secondary school inspectors and principals would expect these teachers to use the NCFS, implement AfL, and reflect on and transform their AfL practices.

The aim of the interviews was to gain an insight of the teachers' AfL understanding and practices. Two broad themes emerged from the interviews: whether AfL used to enhance students' learning; and if AfL used to refine teaching are discussed next.

Lack of the use of AfL to enhance students' learning

Teachers reported that all three key AfL ideas were used to enhance learning. These AfL characteristics were: sharing learning intentions and criteria for success, using discussion and learning tasks, and providing feedback.

The participants provided different responses when questioned about the timing for communicating the learning intentions (learning outcomes, LOs) and criteria for success.

Twenty teachers (68.97%) explained that they communicated the LOs when the lessons began. Four teachers (13.79%) stated that they emphasised on the LOs during the lessons. One (3.45%) added that the LOs were used to guide the students through the tasks. However, four teachers (13.79%) claimed that the LOs were mentioned only when the tasks were corrected. One teacher highlighted that he cited the LOs when allocating marks and giving feedback to the students. The remaining five teachers (17.24%) revealed that they only communicated the LOs at the beginning of each term and topic.

Several teachers claimed to clarify and share the criteria for success with their students. However, only one teacher (3.45%) seemed to be providing AfL criteria for the students. Surprisingly, the criteria for success were provided only when the students had difficulties completing the activities. Tapu explained, “if [the activity] is [wrong] there are the criteria.” For nine teachers (31.03%) the criteria for success were in the form of marks, and if the majority of learners obtained satisfactory marks, then the teachers considered that their teaching was successful.

The twenty-nine respondents claimed to monitor their learners’ progress. The focus on students’ level of understanding dominated (eighteen teachers, 62.07%). For example, Grey stated, “we need to know where the learners are in the learning process.” Conversely, eleven teachers (37.93%) focused on the content delivered and how the learners ‘absorbed’ it.
However, when monitoring learners’ progress, there was a difference in the approaches at different levels. In monitoring progress in upper secondary classes (aged 15+), teachers seemed to concentrate on organising practical activities as they formed part of the external high-stakes examinations (16+ and 18+). For lower secondary students, the teachers merely displayed the tools, asked several oral questions and instructed the students to sketch specified tools and explain their functions by referring to the prescribed textbooks, although, three teachers (10.34%) from one school mentioned that they encouraged lower secondary classes to work with paper products.

The feedback given to students by the D&T teachers seemed to focus on providing the correct answers to the task questions. Twenty-three teachers (79.31%) claimed to provide verbal feedback where they pointed out individual student’s mistakes and followed this by explaining how to complete the activities correctly. Eighteen teachers (62.07%) claimed to offer written feedback on how to accomplish the task correctly. Dev explained, “I need to put a remark which part is not correct and tell the student how he should have done it.” Three teachers (10.34%)

gave marks when verifying students' activities and indicated where the students lost marks. For example, Laurent claimed, "… these marks provided feedback [to the students]."

Lack of the use of AfL to refine teaching

Despite the data from teachers revealing that they used some of the characteristics of AfL to support learning, several D&T teachers mentioned using AfL to refine their teaching. These teachers illustrated three main features: improving teaching, transforming practices, and planning to teach.

The teachers used different approaches to improve their teaching. The teachers mentioned three approaches: redirecting their teaching, shaping subsequent lessons, and addressing the learning objectives. Fewer than half of the teachers (44.83%) interviewed reported upgrading or redirecting their teaching by various means including changing teaching strategies, reducing the explanation pace, re-explaining the lesson(s), and providing reinforcement tasks. Several teachers claimed that they adjusted their subsequent lessons. Ten teachers (34.48%) explained that they used AfL information as a base for preparing the subsequent teaching session(s). The teachers also organised remedial classes for students who had difficulties understanding the lessons. The teachers claimed they explained these lesson(s) by providing simpler examples for the students. However, no teacher noted integrating content and AfL tasks. Only two D&T teachers (6.9%) mentioned simplifying the learning objectives to improve their teaching implying that they considered that learning outcomes should be adapted to students' experiences and be reformulated (when required) to help students learn.

Several respondents (four teachers, 13.79%) were convinced that transforming their practices would improve student learning. These teachers used different approaches: using assessment information to plan the curricula, conducting an ongoing assessment to adjust their lessons, and justifying their teaching decisions. These teachers claimed that AfL information provided sufficient details to allow them to plan the curriculum and improve their yearly schemes and daily lesson plans. However, AfL information was not considered to select or design activities. One respondent (3.45%) acknowledged using students' continuous assessments to modify the future lessons. For example, the teacher explained that more time was spent explaining the topic/sub-topic when students struggled. Another teacher (3.45%) revealed using AfL information to reflect on his teaching. This respondent claimed to reflect on 'what was done' and 'what could be done' to improve both teaching and learning in the classroom.

Most of the respondents mentioned preparing their yearly, term, weekly and daily (lesson plan) plans. Twenty-three teachers (79.31%) explained about preparing the weekly and daily plans based on the year and/or term plans. The remaining six respondents were not writing weekly and daily plans. For example, Rex revealed, "I do not believe in lesson plans … I know the basics…" Khalil added that instead of lesson plans, he used the syllabus (topics) and tasks from the prescribed textbooks.

Discussion

The results reveal that the majority of the D&T teachers did not value clarifying and sharing the learning intentions and success criteria with students. In Hartell and Inga-Britt's (2014) view, for learning to take place, both teachers and students should be mindful of the learning intentions and success criteria before, during and after completing the activities. If teachers do not write down (or plan) the learning intentions and criteria for success, then it can be argued that they will have difficulty in providing the type of effective feedback which closes the gap between actual and potential learning (Vygotsky, 1978), thereby affecting the extent of student learning. The teachers not clarifying and sharing the learning intentions and success criteria with students was an unexpected finding. It seems that the teachers were not familiar with how to apply their AfL knowledge. It could also be that the D&T teachers AfL practices were influenced by their past experiences (as a student) and/or the assessment perceptions of their colleagues and principals.

An analysis of the findings suggests that when providing feedback, the teachers did not intervene through questioning and discussions, but provided answers to task questions, thus removing opportunities for students to reflect on their learning. As emphasised by Moreland, Jones and Barlex (2008), one fundamental principle of learning is that students must be active; learning has to be done by the students, it cannot be done for them. Teachers may have focused on providing answers to questions because of contextual constraints where they are held accountable for students' performance in high-stakes examinations.

There was no evidence from the data that D&T students were engaged in meaningful D&T experiences. The D&T teachers, especially at lower secondary level, focused on assessing students' sketching and drawing, and cognitive skills. The lower secondary students appeared to be deprived of opportunities to engage in problem-solving and authentic activities through designing and making. It could be that lack of space within the specialist rooms, and appropriate equipment were barriers preventing the teachers implementing appropriate D&T activities. However, the teachers were also not using the NCFS as a guideline to implement their AfL practices, which leads one to assume that it might be the teachers' perceptions of what students should learn at different levels that framed their AfL practices.

Several teachers did not plan activities that would meet the intended goals. If a teacher is not writing weekly or daily plans, and simply selecting activities from prescribed textbooks, then one could ask what the intended goals were, and if known, how far these goals were in line with the activities. The evidence illustrated that teachers were not identifying and planning technological learning outcomes to any extent. According to Moreland et al. (2008), articulating clear technological goals allows teachers to know what to teach, which in turn enables them to design or select appropriate activities to accomplish these aims. Certainly, if AfL activities are not planned, students' learning will be affected. One possible cause could be that the teachers' habitus influenced the way they provided feedback (Maton, 2008). Another reason for teachers to follow a certain set of procedures accepted by the school could be what was perceived as 'truth' and valid (AfL practices). Foucault's concept of 'games of truth' clarifies how agents (teachers) create and recreate identity and subjectivity that they opt to engage in (Stirling & Percy, 2005).

The results indicated that most teachers were not refining and transforming their practice effectively. Furthermore, the teachers' responses show that students were not given enough opportunities to reflect on and discuss what they did; what they were doing; and what they might do next as suggested by Moreland et al. (2008). It could be that the D&T teachers' perceived that they already possessed all the required knowledge and skills, or they simply lacked the self-confidence to refine and transform their practices.

Conclusion

The findings revealed that the majority of D&T teachers were not implementing AfL effectively in Mauritius schools. The teachers seemed not to follow the key approaches of AfL recommended by Warwick et al. (2015). Moreover, it appeared the teachers were not implementing what they acquired through their initial teacher education. The D&T teachers were more focused on completing tasks and adjusting their teaching in response to immediate learning requirements**,** than transforming their practice and guiding students to become autonomous. If D&T teachers do not use the AfL information to reflect on their practices, they cannot challenge their assumptions and question their existing practices. They thereby prevent themselves from accessing new lenses to view their practices and potentially alter their perspectives on the students and their learning (Larrivee, 2000).

Arguably, there might be various causes leading to how AfL practices are implemented in Mauritius. First, the superficial understandings of AfL (by teachers and principals). Second, the political emphasis on accountability, and performance standards for teachers and students, which is associated with high-stakes testing (Poskitt, 2014). Third, the lack of professional development of teachers in the area of AfL (Popham, 2009, 2011). Fourth, the perceptions of teachers that they already possess the required knowledge and skills to assess students.

Given that AfL has the potential to improve both teaching and learning, some measures are required to change the teachers' AfL practices positively in Mauritius. It seems reasonable that provisions should be made to offer teachers continuous professional development in assessment. To strengthen teachers' assessment literacy and change the teachers' current perceptions of AfL, measures such as collaborative practices within and across schools, communities of practice and mentoring need to be established in the local context. Teachers could also be encouraged to be involved in action research practices, thus allowing them to reflect on their practices and share their experiences with other teachers. Finally, further in-depth research studies are needed to explore the factors that are affecting teachers' AfL practices in Mauritius.

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Development of a Flipped Classroom Approach for teaching Foundational Engineering Dynamics

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Abstract

The flipped classroom approach has been touted as a method of delivering teaching to students within the mechanical engineering programme at the University of Canterbury. In 2014, a pilot of the approach was implemented in an engineering dynamics class for first year engineering students.

Existing traditional lecture notes were transposed to video PowerPoint presentations with animated annotations and recorded audio. The videos condensed 50 minute lectures to an average length of 33 minutes. The videos were released on an online platform to students two days prior to scheduled problem sessions. The students were expected to watch the videos before attending the problem sessions that utilised the video content to successfully analyse real-world scenarios. Due to cultural barriers within the student cohort, a lot of encouragement was required to generate a collaborative environment.

While the generation of video content was very arduous, this cost was mitigated in the subsequent years of use. Student academic success was not significantly altered from the traditional approach. However, the student experience was significantly improved by the flipped classroom. In particular, increased collegiality between students and direct communication between the academic and students were noted benefits of the approach.

Keywords: flipped classroom, engineering education, mixed methods research

Introduction

In a tertiary education setting, the flipped classroom approach to teaching contrasts from traditional lectures, as content delivery is usually undertaken outside of scheduled class-times, at the students' own time and pace. Content is generally delivered via written or multimedia resources that are prepared or collated by the class coordinator (O'Flaherty & Phillips, 2015). Scheduled sessions usually include activities that allow students to apply and extend their understanding of the content. In these sessions, typically students are encouraged to collaborate with peers and interact with the lecturer. The approach has been tested in a number of scenarios and has exhibited a number of positive traits (Cunningham, 2016; Kerr; Mason, Shuman, & Cook, 2013; O'Flaherty & Phillips, 2015; Yelamanthi & Drake; Yelamarthi & Drake, 2015).

In the past, the efficacy of flipped classroom approaches that use videos was limited due to issues with content delivery and perceptions of the role of technology in education (Lawrence & Lentle-Keenan, 2013). Hence, the flipped model relied on predominantly written material and thus, compliance to the approach was limited. However, recent increases in internet accessibility for students and a reduction in the cost of technology has removed this barrier to using multimedia content (Group, 2017).

While the recent technological advances enable wider use of the flipped classroom, this does not necessarily imply that it should be used. In contrast, the efficacy of the approach must be considered in terms of teaching culture, burden of establishment, student cohort acceptability and compliance, and teaching effectiveness. This paper describes the development and efficacy of a flipped classroom approach in a New Zealand tertiary engineering dynamics cohort of first year students.

Class

The flipped classroom approach was utilised in a first year engineering mechanics class at the University of Canterbury in the summer semesters of 2014/2015, 2015/16, and 2016/17. The mechanics class was divided into two sections, statics and dynamics with only the latter being taught with the flipped approach. The dynamics section contained kinematics, kinetics, and energy methods, which are all considered threshold subjects. The course included 48 hours of contact time with 24 hours for the dynamics sections. The dynamics section has 22 lectures of novel content and two revision lectures. At the end of the sections, there were summative tests for statics and dynamics. Minor formative assessment was undertaken during the sections in the form of online computational quizzes and laboratory experiments. Success in the course is a pre-requisite for invitation into the second year of civil, natural resource, forestry, mechatronics and mechanical engineering. Specifically, invitation to the second year of engineering at the University of Canterbury is competitive based on first year grade point average.

The College of Engineering at the University of Canterbury recognised the flipped classroom as a potential method for increasing student achievement and experience, and were encouraging pilot schemes assess the efficacy of this approach. The lecturer of the dynamics section (author, PD) responded and utilised the classroom in the summer iteration of the class. The summer cohort was selected as it is smaller than the semester 2 cohort (~60 vs ~450) and would thus be more easy to monitor student success and participation. In 2014/15 and 2015/16 class sizes were 54 and 69 respectively. The lecturer estimated average attendance in the help sessions was approximately 60%. Thus, the lecturer was able to facilitate the learning of the class effectively. However, in the 2016/17 iteration of the course, there were 80 students enrolled, and the lecturer felt that the help sessions would be too big for a single lecturer to facilitate. A tutor was therefore recruited to aid with student support in the class teaching.

The lecturer received support from the University of Canterbury electronic-learning support group to generate the videos used in the flipped classroom approach. To meet university regulations, the summer iteration of the course needed to provide identical content to the semester 2 iteration. In traditional dynamics lectures, the prepared notes were annotated under a document camera with explanations and clarification. To mimic this approach, PowerPoint with animation and audio recording was selected as the media for the flipped approach. The prepared notes from the traditional delivery were used with animated annotations appearing as the audio file described the content. The videos were typically 25-35 minutes long. Students were provided with the prepared notes, and were expected to annotate them while watching the relevant video before coming to the each of the scheduled help session.

The summer cohort was compressed from 12 weeks to 8 weeks of lectures. Students had three two-hour scheduled help sessions per week. An initiation lecture introduced the flipped classroom to the students. They were expected to watch two lectures before each scheduled help session and were strongly encouraged to work in groups. The help sessions involved a question and answer section with the lecturer for the first 20-40 minutes. Following the question and answer section, engineering scenarios were presented to the students who were expected to undertake some kind of analysis in a group setting with the aid of the lecturer on a ‘by-request’ basis. Solutions were presented after the majority of students had completed their analysis. Students underwent the same examination processes as the semester 2 class. The lecturer put a lot of effort into ensuring that the class was relatively informal and that students were encouraged to work in groups.

The lecturer’s view of the flipped approach is also described below. In particular, the burden of converting the class from a traditional to a flipped approach is an important consideration for those considering the approach. The pedagogical contrasts across the approaches noticed by the lecturer are also described.

Statistical analysis was undertaken on the dynamics marks to see if there was any significant distinction across the performance of students from the different teaching methods. Due to the non-normally distribution of outcomes, the Kolmogorov-Smirnov test was used. A significance threshold of 5% was used. Focus group interviews were undertaken to gather the views of the students that underwent the flipped classroom approach. The interviews utilised a semi structured approach, which provided interviewers with a guide for discussion with the students. The semi-structured format of the questions provided interviewers the flexibility to further explore emerging aspects of interest that the students shared. Ten students from the 2014/15 cohort and ten students form the 2015/16 cohort were recruited into the study. Due to the ongoing authority of the lecturer over the students in the focus groups, interviews were carried out by the second and third author and student identities were withheld from the first author. Post-processing of the interview data involved the collation of common or controversial themes. Ethical approval for the study was provided by the University of Canterbury Educational Research Human Ethics Committee (UC-ERHEC).

Outcomes

Quantitative

The t-test indicated that student marks were indistinguishable across the traditional and flipped iteration of the course ($p>0.05$). Furthermore, the student performance in subsequent dynamics courses was also indistinguishable from those who undertook the flipped classroom course and those in the traditional at the foundational level ($p>0.05$).

Qualitative – students

Students reported a number of positive factors for the flipped classroom approach. Importantly, a significant majority of students felt as though the approach enabled them to have a greater efficiency of learning. Furthermore, most students specifically noted that the approach increased their participation in collaborative learning.

> I was doing it with a very good friend of mine. We spent a lot of time we'd watch them together and we'd hit a problem and we'd both work through what [the lecturer] was trying to get towards, and the next day we'd be very confident in what we'd got. (Student D)

Students typically appreciated the independence of self-paced learning of the flipped classroom and recognised benefit of the expectations of self-directed study. In particular, one student noted the self-motivation needed in professional engineering practice.

> For quite a lot of jobs that you're going to get coming out of a degree like this, you don't wake up whenever you want and go to work. (Student J)

Ten students specifically mentioned that they appreciated the increased revisability of the content. While some student feedback indicated that the presentation method and online repository was generally good, many indicated that the mistakes in the content damaged their confidence and reduced their appreciation of the methodology.

> … it was frustrating trying to learn on videos that have mistakes. (Student L)

However, some students noted the benefit of the videos over written recourses.

> I would struggle with a written resource. I'm quite dyslexic, so a written resource, having to read it and understand it, without it being in a video would be a lot more difficult. (Student L)

A mistake finding competition in the 2016/17 cohort elucidated 12 minor mistakes across the 22 course content videos. The mistakes included things like a line of algebra containing a '+' where a '-' should have been used, or a shifted decimal place (0.12 vs 0.012). Three students individually mentioned that the videos should be developed by audio visual experts rather than the lecturer who's expertise lies in other areas.

Many students also appreciated the individual academic support that they received from the lecturer.

> I got a lot out of the 1-1 help in the tutorial sessions. (Student M)

The lecturer's informal approach was also considered a positive element of the course delivery.

> [The lecturer] .. was great. He's informal, he's nice and direct, and I found him really helpful. (Student P)

Qualitative – lecturer + department

The lecturer estimated that approximately six hours per lecture was required to convert the written lecture notes to a video comprising a PowerPoint presentation with audio. The preparation of video content was very difficult to fit around typical student support, research and administration duties of academia. Ultimately, much of the video preparation was done outside typical work hours. Each face to face session required approximately 30 minutes to prepare, which is similar to traditional lectures. Subsequent iterations of the course used the same video lectures and thus the time burden of generating the videos was not an ongoing burden.

The lecturer was able to closely gauge the learning of those that attended the help sessions. This meant that the lecturer was able to precisely set examples with appropriate difficulty levels. Since dynamics contains a number of threshold subjects, the lecturer was able to recognise when students first understood the topics taught. This was quite rewarding and contrasts significantly with a traditional lecture scenario where feedback is typically gained predominantly via assessment.

Discussion

While it was not possible to prove that the flipped classroom approach was superior to the traditional approach in terms of quantitative measurements, there was generally positive feedback from the lecturer and the students. In particular, most students noted that the flipped approach allowed a greater efficiency of learning. In order to progress to their preferred engineering discipline, the students required certain grades across their first year papers. Hence, each student applied sufficient effort to achieve the grade that they felt that they needed. This contrasts with some scenarios where students apply a certain effort level based on their interest and receive the grade that this effort corresponds to. Ultimately, in this case, the marks were the driver, and student effort the variable, whereas in other papers, the effort is typically the driver of the marks. Hence, it is appropriate in this case to measure the efficacy of the approach in terms of learning efficiency. While ethical approval limited our ability to directly measure the time spent by each student, self-reported efficiency of the approach was very positive (12 vs 2 respondents).

Perhaps the key functional difference between traditional and the flipped classroom approach is the ability of the student to self-modulate the rate of content delivery (Blair, Maharaj, & Primus, 2016; Cunningham; Johnson & Renner, 2012; Lavelle, Stimpson, & Brill, 2013). In particular, the video lectures enable pausing, fast-forwarding, replaying, and variable speed delivery. This enables students to achieve their particular goals in the most efficient manner possible. In particular, those that aim for top marks may pause and rewind the videos. In contrast, those with a particular strength in dynamics, or those who are not interested in top marks, are able to speed up the videos and watch a 30 minute video in 15 minutes with adequate comprehension. In this study, such efficiency conscious students could also predict whether attendance at a particular help session would be beneficial after watching a particular video. Furthermore, the videos used in the flipped classroom formed a dual purpose as an exam preparation resource.

The development of the flipped content was a significant burden to the lecturer involved. Since production of the videos was undertaken concurrently with the delivery of the 2014/15 class and typical academic duties, the time burden on the academic was significantly greater than for traditional lecturing. However, the videos could be used the following year without the need for any preparation. Thus, the efficiency of the approach increases after each iteration that the materials are prepared over.

The quality of the videos was brought up as a negative element of the overall flipped approach. The videos were developed by the lecturer who had no expertise in video production and multimedia design. Issa et al. (2011) found that applying multimedia design principles in medical lectures increased student understanding, particularly in terms of their long-term transfer and long-term retention of knowledge. Using multimedia design principles in engineering education may prove to be equally beneficial for student learning. Many students noted the particularly harmful impact that mistakes in the videos had on them. In a traditional lecture, these mistakes are typically brought to the attention of the lecturer immediately and do not confuse other students. In the flipped approach there is no such ability to clear up mistakes in real-time and in such a way that would allow students freedom to watch the videos whenever they like.

The teaching methodology reduced the barrier between the lecturer and the students in such a way that the lecturer was able to accurately gauge the academic progress and attitude of each student. It also allowed the lecturer to determine ways that individual students learn best (Akkoyunlu & Yilmaz-Soylu, 2008). This increased relationship was very positive in terms of learning efficacy for the students and job satisfaction for the lecturer. Furthermore, relationships between students and staff have been recognised as a significant positive contribution to the impression that tertiary institutions have on their alumni (Roberts & Styron Jr, 2010). However, while facilitating the 2015/16 class, it became apparent that a single lecturer would struggle to meet the needs of a larger class within the flipped classroom environment described in this paper. Hence, the subsequent year utilised a second facilitator to ensure that the students received all the support that they needed. Utilisation of the approach in large classes may become difficult as the density of expertise in facilitators required may become an issue.

The collaborative environment purposefully induced by the lecturer in the help sessions ultimately meant that a significant amount of teaching and learning was on a peer-to-peer basis. Peer-to-peer learning has been recognised as a powerful educational tool. In particular, it has been determined that when students with superior knowledge instruct those with inferior knowledge, both students benefit (Doise & Mugny, 1984). Students that justify their viewpoint to peers find that the process ultimately solidifies their own understanding. Furthermore, engineering practice often occurs in highly collaborative environments (Dunlap, 2005; Fisher, Maltz, & Jaworski, 1997). Hence, the collaboration that occurs in the help sessions effectively contributes to the preparation of students for professional practice.

The current technological environment means that most students are able to access the video lectures at home. The remainder of students were able to access the videos in their own time, but needed to be on university grounds. Ultimately, the use of video lectures in flipped classrooms in recent years has become increasing prevalent as the costs of technical equipment and internet access suitable for video downloads have become feasible for the majority of students (Group, 2017). For example, the use of mobile devices for teaching and learning has increased over the last few years and new technologies give rise to new pedagogies in higher education (Herrington, Herrington, Mantei, Olney, & Ferry, 2009). Hence, while the flipped classroom concept is quite old (Bergman & Sams, 2014; King, 1993), the technology to support videos in out-of-class settings has been a barrier to wider uptake. While early incarnations of the approach used written media for student preparation, more recent incarnations utilised video, or multimedia content. The use of videos rather than written text may be culturally much more acceptable to tertiary students who tend to have a relatively low compliance to the use of textbooks for independent study (Falconer, deGrazia, Medlin, & Holmberg, 2009; Sappington, Kinsey, & Munsayac, 2002).

Recommendations

- The flipped classroom should be considered a viable approach for teaching threshold subjects in engineering.
- Generation of a collaborative environment in help sessions is critical to optimal implementation of the approach
- The burden of setting up the lecture content is arduous, but cost becomes increasingly viable as the content is utilised in subsequent iterations of the course.
- While the flipped classroom did not exhibit any significant improvements in student academic performance, it yielded significant benefits in student experience.
- The increased direct engagement with students improves the lecturer's ability to gauge comprehension and ultimately improves the experience of the lecturer as well.

Declaration

Paul Docherty (the first author) was the lecturer and Pinelopi Zaka (the third author) was the e-learning support person mentioned in the text. The authors declare that they have no conflict of interest regarding the contents of this manuscript.

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What's in the soup? I look into fusion within different STEM programs

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Key words: STEM; holistic; multidisciplinary; interdisciplinary; transdisciplinary; fusion

Abstract

STEM education is a pedagogical approach that regularly incorporates technology education as well as the other disciplines to contextualise content. However, what constitutes a STEM program can be confusing as it can differ greatly from program to program. Some examples of this difference can adopt multidisciplinary versions of STEM, whereas other programs may be more collaborative such as interdisciplinary, or even holistic and offer a transdisciplinary STEM approach.

This paper presents an analysis using a mixed method research approach that reports on the level of fusion experienced by technology teachers involved in STEM programs. The approach to the research asked teachers to categorise their STEM program experience as a multidisciplinary, interdisciplinary or transdisciplinary approach in its implementation.

The intention of this paper is to provide an insight into the types of disciplinary approaches that have been occurring in schools labelled as STEM education. The key findings of the research indicate that the majority of integration of fusion between the individual STEM disciplines in STEM education programs are either multidisciplinary or interdisciplinary, with the individual STEM discipline still visible within the programs.

Introduction- Interpreting and labelling STEM

According to Gomez & Albrecht (2013), STEM as a pedagogical approach is "rooted in interdisciplinary application of knowledge" (p. 8) where the disciplinary contributions are collaborative, but the literature (Marrero, Gunning, & Germain-Williams, 2014; Barlow & Ellis, 2016; Bybee, 2013; Williams, 2011; Pitt, 2009) suggests that there is confusion regarding how STEM education is commonly viewed, or implemented.

To define what role the individual disciplines play in a STEM approach is difficult to describe, as the composition of a STEM pedagogy is often inconsistent. According to Sanders (2009), the United States National Science Foundation (NSF) who was responsible for the development of the acronym, used it to "simply refer to the four separate and distinct fields" (p. 20), whereas others have taken it and “suggested that STEM education implies interaction among the stakeholders” (p. 21). The others quoted by Sanders refer to examples within the literature and policy stating that STEM education requires an interaction between the individual disciplines (Gomez & Albrecht, 2013). This interactive, cross-disciplinary approach is also described in Australia’s National STEM School Education strategy, as “a cross-disciplinary approach to teaching” (COAG Education Council, 2015, p. 5).

Part of the confusion surrounding STEM is that “the meaning or significance of STEM is not clear and distinct” (Bybee, 2013, p. 10). This is evidenced where STEM refers to the four disciplines, and in other instances, it may only refer to one discipline (Barlow & Ellis, 2016). In the instance where STEM is referring to one discipline, one may ask why the STEM label is used at all? And whether in this particular case, it may be less confusing (and more accurate) to use as an example the disciplinary label of Science or Engineering?

Bybee (2013) discussed the ambiguity of STEM education, where in some programs the four STEM disciplines may be separate but equal, and in other definitions the program may “identify STEM as an integration of the four disciplines” (p. 10). Considering this degree of interpretation amongst teachers and researchers, it is not surprising that variations of the STEM pedagogy have re-calibrated to focus on other areas of education, and again offering alternate interpretations and definitions such as ISTEM and STEAM. ISTEM, or ‘Integrative STEM’, that is a pedagogical approach incorporating two or more of the STEM context areas (Sanders & Wells, 2010). STEAM education, builds upon the STEM concept of systems thinking and connectedness, and is inclusive of all disciplines including the Arts (Yakman & Lee, 2012). Therefore when considering what makes up the ingredients of a STEM program, sometimes what is ‘in the mix’ is not necessary easy to distinguish, and is a contributing factor to why Sanders and Wells moved to ‘Integrative STEM Education’ (Sanders, 2015). Variations of STEM Education include programs where the individual disciplines are easy to identify and little fusion (or integration) between them has taken place. In other programs, the level of fusion has integrated the disciplines to a point where their disciplinary characteristics and outcomes are not the focus, but rather have transcended the STEM disciplines into something else. Given the original NSF intention, and the “inescapable” ambiguity of STEM (Sanders, 2009, p. 21), differences in interpretation and focus has contributed to the evolution of STEM variants.

The position that this paper has taken was not to challenge or advocate one version of STEM or another, but to determine the perceived level of integration of the individual disciplines by teachers who have been personally involved in STEM education programs.

Classifying the levels of fusion

To establish a scale that enables teachers to determine the level of fusion of the individual STEM disciplines within their STEM experiences, a search of the literature was undertaken for appropriate terms of difference.

The introduction provided a foundation for the classification of integration by considering the definitions of STEM that contained one to two disciplines maintaining disciplinary distinctions, while other programs such as iSTEM and STEAM are more collaborative and even extend beyond the four STEM disciplines (Sanders, 2009; Yakman & Lee, 2012). As a result, this article has built upon established definitions to clarify and support the directions of this paper. As a first step, to determine the level of integration between the individual STEM disciplines, a review using respected online dictionary definitions was undertaken to define the word ‘fusion’. The online site ‘Oxford Living Dictionaries’ defines the term fusion as the “process or result of joining two or more things together to form a single entity” (Fusion, English Oxford Living Dictionaries, 2017). From an education perspective, rather than the focus on the output being the single entity, this paper focuses on the fusing or blending of the two or more things – being the STEM disciplines. This focus is supported by the Cambridge online dictionary that defines fusion as an “occasion where two or more things are combined” (Fusion, Cambridge Dictionary, 2017). A third and final dictionary search involved the Merriam-Webster online dictionary. This dictionary defined fusion as an act or a process of union similar to that of the Cambridge definition, focussing more on the verb or action of the combination or union of two or more disciplines in this case. This act or process supports the definition of what Sanders would define as ‘integrative STEM’ (Sanders, 2009).

The traditional individual disciplines of Science, Technology, Engineering and Mathematics are entirely ‘visible’ when the STEM acronym is deconstructed, indicating that the disciplines claim an educational space independent from each other. According to Yakman & Lee (2012), “it is important that each subject still maintain its own educational base in the disciplines” (p. 1075), so that scholars can continue to address discipline specific issues and contribute to the growth in knowledge for that discipline. With the introduction of the STEM acronym, whether it was initially the intentional of the NSF that the four disciplines be integrated for improved educational outcomes or not, the intention of this article, is to establish the level that these disciplines are perceived to be ‘fusing’ in school STEM programs.

As stated previously, the intention of this paper was to determine to what level are these disciplines interacting and collaborating with each other? At a minimalist level, the clarity of the individual STEM disciplines would still be entirely noticeable in a STEM program, whereas at another school, the program may be fused to a degree where the individual disciplines are difficult to distinguish.

To establish a scale of integration, the description of STEM by Gomez & Albrecht (2013), that a STEM pedagogy is an "interdisciplinary application of knowledge" (p. 8), provides a point of difference in the level of fusion (intergration), through the use of the term 'interdisciplinary' as a disctinction from the term 'disciplinary'. The article by Choi & Pak (2006), 'Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness' reviewed online dictionaries and research literature to define the terms discipline, interdisciplinary, and transdisciplinary. This article established a definition for each term to reduce the ambiguity as they found that these terms were often used "interchangeably" (p. 351). Even though this article was not written for a STEM education context, it has provided an excellent distinction between the terms. As a result the following definitions of researh drawn from the article by Choi and Pak, (2006) will be used to guide this paper:

- The NSERC (2004) defintion of *mutlidisciplinary* research as one that "draws on the knowledge from different disciplines, but stays within the boundaries of those fields." (Choi & Pak, 2006, p. 359)
- The CIHR (2004) definition of *interdisciplinary* research as one that "analyses, synthesises and harnmonises links between disciplines into a coordinated and coherant whole." (Choi & Pak, 2006, p. 359).
- Soskolne's (2000) definition of t*ransdisciplinary* research as one that "integrates the natural, social and health sciences in a humanities context and in so doing transcends each of their traditional boundaries" (Choi & Pak, 2006, p. 359).

To apply these research definitions in the pedagogical context of STEM education, a multidisciplinary pedagogical approach would aim to satisfy the learning outcomes for one discipline, such as Science, but may incorporate additional knowledge and/or methods that are common to another discipline such as Technology.

In an interdisciplinary STEM pedagogical approach, the boundaries between the individual disciplines begin to become less defined due to a fusion between them. Interdisciplinary approaches incorporate much more collaboration between one or more discplines to meet a shared goal (Lansiquot, Blake, Liou-Mark, & Dreyfuss, 2011; Sanders, 2009). This may also result in the satisfaction of educational outcomes from more than one discipline area, and could address educational outcomes from more than one disciplines to provide contextualisation of disciplinary concepts to improve student learning (Wilhem, 2014). Examples of interdisciplinary approaches include Project-Based Learning (PBL) or Problem-Based Learning (PBL) where ‘real-life’ situations require integration from multiple disciplines, however the educational goals are still derived from a school curricula (Gresnigt, Taconis, van Keulen, Gravemeijer, & Baartman, 2014).

The greatest level of fusion was represented by the term transdisciplinary. Using this pedagogical approach breaks the contraints of the four disciplines that make up STEM to incorporate other learning areas. These approaches may also represent other variants of STEM education such as STEAM, “with no fixed borders between the disciplines, but instead insisting on illlustrating the necessary cross-links” (Yakman & Lee, 2012, p. 1079). According to research by Gresnigt, Taconis, van Keulen, Gravemeijer, & Baartman (2014), Transdisciplinary programs establish learning goals that are ‘cross–disciplinary’ (not just STEM in this example), and pitched to address a ‘real-world’ context with an emphasis on the student experience (Harden, 2000). In its purest sense, it is anticipated that the realities of a transdisciplinary approach may not prove to be practical for teachers who are accountable for the assessment and reporting on a student’s educational outcome. This is not to say that there are not STEM education programs offered in schools that don’t transcend the four disciplines, however the analysis of the data will indicate whether this is true.

Methodology

This paper incorporates the use of a mixed-method online survey to capture the data from teacher participants. The teachers were contacted via an online teacher association forum called ESNET (Engineering Studies Network), to contact over 1300 members from Public, Catholic and Independent education systems in NSW, Queensland and Victoria(Ellis & Boyd, 2015). No identifiable information was collected in the data, however participant responses to Q.3 were coded to enable a qualitative content analysis.

A short online survey, using the ‘Qualtrics’ site was given to technology education teachers who had self-selected as a volunteer sample of the population. A first question (Q.1) was a yes or no question designed to eliminate any potential participants who had not read, or understood the initial information on the survey’s intent, and the participant criteria. To do this, all participants answered the first question, *“Have you personally been involved in any STEM education programs at your school?* If the participants responded with a *‘no’* they were gratefully thanked for their participation and prevented from continuing in the survey, if they answered ‘yes’ they were allowed to continue onto the second question.

The second question (Q.2) was a multiple choice question seeking information from teachers who answered 'yes' to question 1. As these teachers stated they had personal experience in a STEM program at their school, they were asked to select from three (3) multiple choice answers designed to seek their opinion on the level of fusion in the STEM program that they were involved in. To reduce the risk of participants not understanding what the question was asking, or to ensure the participant possessed the required level of comprehension regarding the terms used, the question provided definitions of the three terms. These definitions are located in the Appendix of this article.

To synthesise the results of the data from Q.2, the frequency of the participant's choice was tallied to collate the total number of STEM programs that have been categorised as either multidisciplinary, interdisciplinary, or transdisciplinary.

The final question (Q.3) was intended for the participants to justify why they had determined that the STEM program delivered at their school was multidisciplinary, interdisciplinary, or transdisciplinary? The question asked the participants to, "*Briefly describe what your STEM program involved and why (in your opinion) you have interpreted the outcome to be multi, inter or transdisciplinary?"* The intention of this justification was to enable the participants to reflect on their answer to Q.2 and go back and self-correct their answer if necessary.

A content analysis of the Q.3 qualitative data was analysed to determine the accuracy of the participants answers in question two compared to their justification in Q.3. Answers that evidenced individual disciplinary contributions were coded as a multidisciplinary approach. Answers that evidenced a cooperative and coordinated approach towards a common goal were coded as interdisciplinary approach. Answers that described a surpassing of the four disciplines were coded as transdisciplinary. The frequencies were adjusted following this analysis. Following the justification of their chosen category in Q.3, a secondary synthesis of the adjusted data was intended to correct the initial tally created by the data from Q.2. It is from this secondary, adjusted synthesis that the discussion and conclusion was be drawn from.

Results

Of the initial 57 participants in the survey, 50 participants had indicated that they had been personally involved in STEM programs at their school. The seven participants who had selected 'no' were thanked for their participation and were not permitted to continue with the survey.

Question 2 asked the participants to categorise the level of fusion between the four individual STEM disciplines that make up the 'STEM' pedagogical approach. There was a distinct drop in the number of participants who had progressed to Question 2, and those who had taken the time to read the definitions and select a level of fusion from the terms multidisciplinary, interdisciplinary and transdisciplinary. This resulted in a 30% reduction in the number of participants from 50 to 35 (*n=35)*.

Using the data from the online survey for Question 2. The results of the categorisation in the level of fusion indicate that the level of fusion across the participants programs was relatively even.

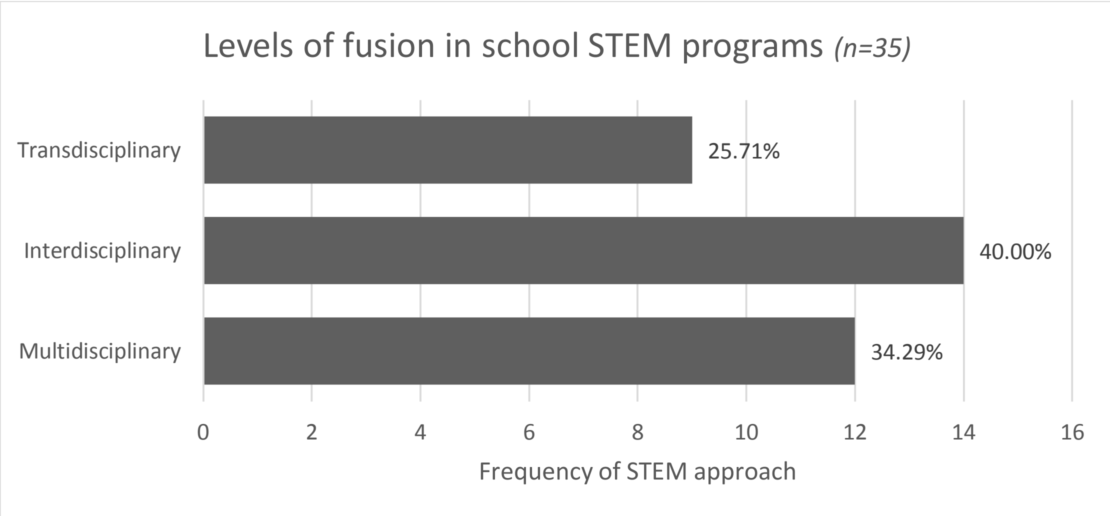

Figure 1 Initial synthesis of the level of fusion in STEM programs

To determine whether the differences in the categorisation of levels were significant, a 95% confidence level was used with 1.691 being the number of standard deviations away from the mean based on 34 degrees of freedom (df) and the critical values found in a Student's t distribution table (Biddix, 2009; NIST, 2012). To determine significance, the greatest difference in the results was the frequency of values between Transdisciplinary (9) and Interdisciplinary (14) categorisations were compared. The T-value formula and values were used in the calculations:

$$t = \frac{p1 - p2}{SE}$$

- p1 (% of transdisciplinary categorisation) = 40
- p2 (% of interdisciplinary categorisation) = 25.71
- n1 (# of participants surveyed) = 35
- n2 (# of participants surveyed) = 35

As the T-value of 1.1 was less than the number 1.691 the differences between the categorisation of STEM programs that have been categorised as transdisciplinary, compared to those that have been categorised as interdisciplinary are 'insignificant'. The meaning behind this is that there is not a significant difference for differentiation between the participant answers, indicating that the occurrences between the three levels of fusion amongst STEM education programs were relatively even.

The final question (Q.3) asked participants to justify why they categorised their STEM program outcomes as either multidisciplinary, interdisciplinary, or transdisciplinary. This secondary analysis was used to determine the accuracy of the participant responses, and provide an opportunity for participants to self-correct their answer in Q.2. As this data was qualitative, a content analysis classified the participant responses according to the alignment of their responses against the definitions of multidisciplinary, interdisciplinary or transdisciplinary as stated by Choi & Pak (2006).

As a result of the secondary content analysis, there were eight changes made to the initial results, with an increase in both multidisciplinary and transdisciplinary, and a decrease in transdisciplinary STEM programs. The secondary analysis 'adjusted data' was used to determine if there are any significant changes to the categorisation of fusion amongst STEM education programs.

Table 1 Initial and Adjusted values

Participant answer	Multi-disciplinary	Inter-disciplinary	Trans-disciplinary	No Justification	Total (n=35)
Initial Frequency (f)	12	14	9	N/A	35
Initial %	34.29 %	40.00 %	25.71 %	N/A	100 %
Adjusted Frequency (f)	13	16	5	1	35
Adjusted %	37.14 %	45.71 %	14.29 %	5.71 %	100 %

The differences between the initial and adjusted frequencies following the secondary content analysis are documented in **Error! Reference source not found.**. In addition to the initial data, one participant did not justify their response to Q.2. As a result, this participant was categorised as 'No justification'. The most significant change to the data was the reduction in transdisciplinary frequencies. This reduction was attributed to a misunderstanding of what transdisciplinary is according to the definitions used in this study. An example of this misunderstanding found in the content analysis include:

ak – "…Yr 8 build environments: tas build a tiny house model, science complete the electrical components on the house and maths work out the costings and materials required to complete each component of the build."

The response from participant *ak* demonstrated a multidisciplinary STEM program where according to the definition, teachers contribute independently towards a shared goal. As a result, the transdisciplinary value from this participant was relocated to the multidisciplinary tally.

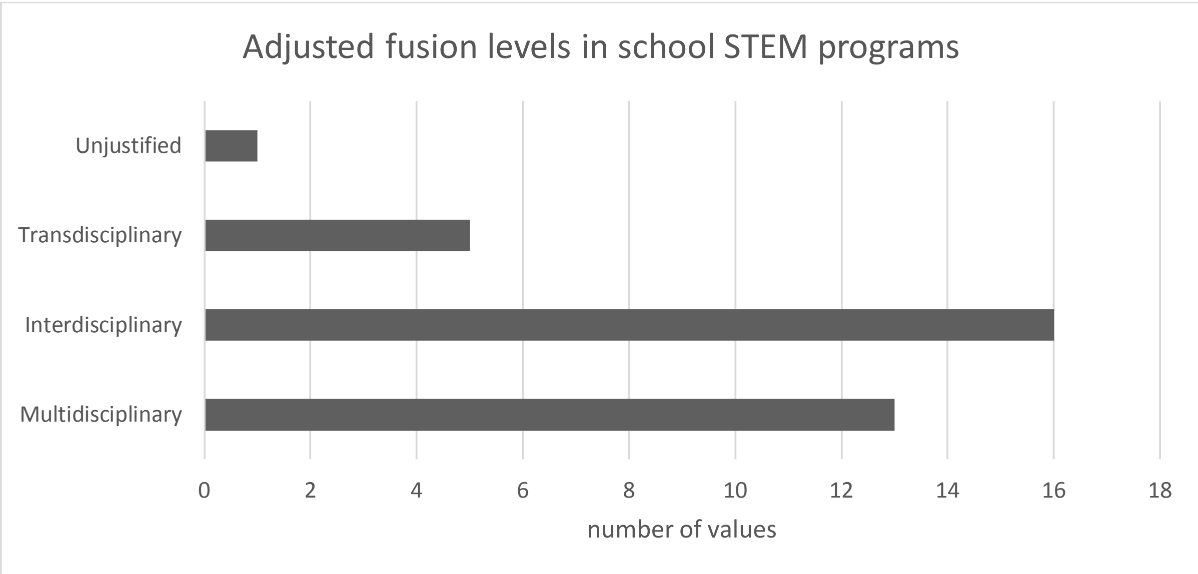

Figure 2 Adjusted fusion levels in school STEM programs

The secondary synthesis used the adjusted to determine whether there is a significant difference in the participants' choices. Given the reduction on the number of transdisciplinary programs, there was the possibility that the differences between transdisciplinary and interdisciplinary approaches were significant. The following calculations were used to determine this:
To replicate the initial analysis, a 95% confidence level was used with 1.691 being the number of standard deviations away from the mean based on 34 degrees of freedom (df) and the critical values found in a Student's t-distribution table (Biddix, 2009; NIST, 2012) . To determine significance, the adjusted frequency values between Transdisciplinary (5) and Interdisciplinary (16) categorisations were used in the T-value formula and the following calculations:

- p1 (% of transdisciplinary categorisation) = 45.71
- p2 (% of interdisciplinary categorisation) = 14.29
- n1 (# of participants surveyed) = 35

- n2 (# of participants surveyed) = 35

The secondary calculations have resulted in a t-value of 2.68. As this value was greater than 1.691, it indicated that there was a statistical significance between the outcomes of interdisciplinary and transdisciplinary STEM programs according to the participants surveyed. The intention of the statistical calculations was adopted as the t-test is a commonly used form of statistical data analysis (Creech, 2003). Given the small population sample of 35, the calculation was used to support the claim with a 95% degree of confidence that the majority of STEM education programs undertaken in schools were either multidisciplinary or interdisciplinary programs.

Discussion

The data generated from volunteer sample of 50 participants have provided some insights into the approaches schools have taken in implementing a STEM education program. The data revealed that according to the sample provided, school STEM education programs are more interdisciplinary and multidisciplinary in their approach. In addition, the content analysis provided additional insights into technology teachers' comprehension, and understanding of the level of integration (fusion) among individual STEM disciplines.

In defence of any potential bias as the participants volunteered from a sample technology education population, the responses asked for information on the integration with the other disciplines, rather than an evaluation or judgment of the other disciplines (Best & Kahn, 2006). To support this, in terms of participation in a STEM education program, the ESNET online forum consisted of teachers who commonly taught, or were familiar with technology education and engineering, ensuring that the sample more 'appropriate' with experience rather than biased. Fusion as a definition was a term that was incorporated throughout this paper to describe the level of integration (Gresnigt, Taconis, van Keulen, Gravemeijer, & Baartman, 2014; Flogie & Abersek, 2015) that occurred with the four individual STEM disciplines. Communicated from the outset, was the intention not to critique the quality or the outcomes of the STEM education programs undertaken at participants schools, but to categorise the level of discipline fusion. This approach was used to improve the reliability of the data, as the participants would be able to give their answers 'free' from any concerns around judgement and criticism.

The intent of this article was to build on the existing research rather than seeking to find alternate definitions for multi, inter and transdisciplinary. The application of the terms in a STEM education sense adds to the definitions established in the comprehensive review by Choi & Pak, (2006). Similar to their research review of the online dictionaries, this paper also used an online approach to determine an acceptable definition for fusion. The definition accepted and used was also consistent with other research in this area (Harden, 2000; Gresnigt, Taconis, van Keulen, Gravemeijer, & Baartman, 2014; Drake, 2007).

To improve the reliability of the survey data, and assist the participants in the interpretation and categorisation of the different levels of fusion, explanations of the terms were provided to the participants. Some of the Q.3 justification data indicated that this may have been helpful, however there were still some misunderstanding leading to the adjustment of frequency values in Figure 2 and Tables 4 and 5.

According to the initial synthesis of the data provided in Table 1, the difference between the three levels of fusion (multidisciplinary, interdisciplinary and transdisciplinary) was insignificant with the smallest number of value being transdisciplinary at 9, and the largest number of values being interdisciplinary at 14. As a result, the differences between these approaches in a small sample of 35 participants were not significant enough for the study to be confident enough to claim that schools prefer to implement one particular approach over another.

The intention of Question 3 in this small study was to scrutinise the teachers' justifications of their level of fusion categorisation. The rationale behind this question was to improve the reliability of the data through the incorporation of 'equivalent forms of reliability' (Best & Kahn, 2006). As the participants initial answers to Question 2 were justified in Question 3, there was an intended level of self-correction as the participants correlated their answers.

A final reliability strategy, an "inter-scorer" (Best & Kahn, 2006, p. 298) reliability strategy incorporated a comparison of the participant's answers to Question 3 with the answers of the researcher (myself) by using the definitions of the terms published by Choi & Pak (2006). As a result of this comparison, there was a slight adjustment made to the overall frequency of values for both interdisciplinary (+2) and transdisciplinary (-4) STEM programs, as the descriptive data from Question 3 was valued over the particpant's answers to Quesiton 2 due to the potential for miscomprehension of the meanings of multidisciplinary, interdisciplinary and transdisciplinary.

To discuss the implications of the results highlighted in Figure 2, as mentioned previously, it is not important for this paper to determine the intention of the STEM education program, nor how successful it was, through a measure of educational outcomes. What was important was to determine 'what' levels of disciplinary fusion that has occurred as schools implement STEM education programs. An interesting finding that emerged from the content analysis was the intention that some schools had to make their STEM programs more interdisciplinary in the future, even though is was currently delivered in a multidisciplinary way.

ac –"We have an Integrated STEM Project that runs with the Gifted and Talented class in Stage 4, Year 7. It is only our second year running it and we are aiming for a more Interdisciplinary/Transdisciplinary as an ideal approach as we develop it further and become more experienced, however, at this stage I feel it is only at the multidisciplinary level because it is not fully collaborative in sharing of methodology and pedagogy at the moment, we are extending into primary school so it does have some elements of Transdiciplinary."

Other responses described some of the realities of implementing STEM education programs, citing challenges associated with the timetable and/or teacher relief from normal duties. These contraints appeared to have hindered the implementation of a interdisciplinary approach , or the implementation of a more collaborative efforts was 'not practical' at this point in time.

It could be argued that the educational outcomes in a multidisciplinary program are more curriculum specific, where the outcomes of the individual discplines are the focus of the program and more easily accounted for. As a result, student knowledge within the discpline domains may be strong, but their understanding of the relationships and links with other discplines are not the focus, or underdeveloped.

The data revealed that the interdisciplinary STEM approaches were the most common approach compared to multi and transdisciplinary STEM at 45.71%. As a result, commentary from Question 3 supported previous definitions from the literature that STEM is an interdisciplinary approach to education (Sanders, 2009; Gomez & Albrecht, 2013). Justifications for selecting interdisciplinary STEM education approaches decribed more collaboration between the teachers from the different disciplines, and suggested that the jump from multi to interdisciplinary education was not a problem for the students, but rather a systemic, environmental and teacher issue as evidenced by particpant *ac*'s quote.

From a shared perspective, the staging of a Project-Based learning (PBL) task was idenitifed as the 'common goal' that was prevalent in interdisciplinary STEM education programs. Other features suggested that rather than being entirely extra-curricula, other comments reflected on the delivery of dedicated STEM courses that students can elect as part of their offical course of study. Examples of this included the iSTEM program offered to students in Years 9 and 10 in NSW.

The adjusted values of the transdisciplinary STEM programs compared to the other two integrative alternatives did result in a t-value that was significant. According to the literature, the opportunity to integrate STEM more holistically with other areas of learning (transcending the STEM disciplines), can provide opportunties for students to engage in systems and critical thinking that leads to improved learning outcomes (Wagner, Baum, & Newbill, 2014; Marrero, Gunning, & Germain-Williams, 2014; Yakman & Lee, 2012). It is opportunities such as these that enable students to understand reality-based relationships between STEM in cultural and social contexts (Barlex & Pitt, 2000; Yakman & Lee, 2012; Flogie & Abersek, 2015; Gresnigt, Taconis, van Keulen, Gravemeijer, & Baartman, 2014). In support of this, responses from the Question 3 data indicate that some schools have been transcending STEM through the integration of other areas of learning such as History and Religious Education, however the number appears to be small. The impediments of challenges such as timetabling, staffing, politics and accountability issues compressed into a tight time frame may be a disincentive for schools to integrate beyond interdisciplinary STEM educatio programs. According to Yakman & Lee (2012), some visibility of the individual discplines in the mix is needed for scholars to "address field-specific issues" (p. 1075) and if multidisciplinary and interdisciplinary STEM is meeting the needs of individuals, then some disciplinary visibility in the mix may be enough to whet the STEM appetite – for now!

Conclusion

The intent of this research paper was to determine what level of fusion among the four individual disciplines was being delivered in school STEM education programs. The adjusted data displayed in Figure 2, and summarised in Table 4 indicated that the majority of STEM programs were interdisciplinary and multidisciplinary in their approach. As a result, this pedagogical soup containing content, methods, and pedagogy from the individual STEM disciplines are still clearly visible in the mix. It has been discussed that STEM education activities that are not 'extra-curricula' are challenged by the constraints of time, teacher accountability and the reporting of student achievement that is aligned with explicit curriculum outcomes. As a result, these challenges do impact on the ability and/or desire to offer a more transdisciplinary STEM education program. As a follow up to this paper, a future study could determine whether there is any correlation between the level of fusion and student achievement. Only more research in this area will be better enable us to comment on this.

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Appendix

Definition of terms used in the survey to assist with teacher's comprehension:

"To clarify the terms, an explanation will be provided below based on peer-reviewed literature (Choi & Pak, 2006). Please use this explanation to inform your choice:

Multidisciplinary STEM is where teachers representing different fields contribute ideas, methods, and teaching to STEM common projects independently to a shared goal.

Interdisciplinary STEM requires more collaborative exchanges where teachers from separate disciplines combine their knowledge and share methodology and pedagogy towards a common goal.

Transdisciplinary STEM is much like interdisciplinary STEM but the integration and sharing of concepts, knowledge and pedagogy extends beyond (transcend) the STEM boundaries into other areas of learning."

Enhancing Formative Assessment of Learning in Technology

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Abstract

This paper describes a study based on teaching and learning in technology education. The study aimed to assist teachers' understanding of learning in technology through the use of an observation and questioning framework, a tool to formatively assess aspects of technology. Assessment of students' learning and understanding in technology involves intelligent observation of and conversation with students by teachers with the purpose of improving students' technological literacy. The tool works on the premise that it is desirable to facilitate the building of learning power within students through the development of dispositions and attitudes including the building of students' confidence and self-belief in their capabilities, within four domains of learning rather than the building of specific sets of skills.

This study applied aspects of the above thinking directly to technology education. It employed qualitative research methods to assist teachers through the use of a conversation and observation framework aiming to improve teacher understanding in technology and the giving of formative assessment feedback in technology. The research took place in three countries, England, Sweden and New Zealand, all with a high reputation in technology education. The study offers an international perspective on ways to assist teachers' abilities to facilitate students' understanding in technological literacy and contribute significantly to the field of formative assessment in technology education.

Key words: formative assessment, teachers' understanding, dispositions, primary, aspects of technology, technology education

Introduction

This paper presents a formative assessment tool, Technology Observation and Conversation Framework subsequently known as TOCF, to assist teachers' understanding of students' learning in technology education using the identification of behaviours across multiple aspects of technology. In the study learning behaviours in technology were explored through the use of the TOCF to assist teachers with focused observation of and interaction with their students and subsequently improve their ability to formatively assess aspects of technology education in lower primary education sector (subsequently referred to as primary). In the primary classroom informal assessment occurs continually. Kimbell (2012) suggests that formative teaching occurs with every exchange between students and teachers and is therefore an opportunity for teachers to learn more information about their students' learning. Teaching and learning in technology should enable all students to build a strong base of understanding and internally driven interest and abilities related to the technological world. Formative assessment is dependent on teaching and assessment practices that explicitly aim to improve learning (Stables, 2015). To do this teachers must have a deep understanding of technological pedagogical and content knowledge. Forret, Fox-Turnbull, Granshaw, Harwood, Miller, O'Sullivan & Patterson (2011) identify a huge concern in New Zealand that pre-service primary teachers in initial teacher education (ITE) institutions are getting less and less curriculum coverage in their ITE programmes and thus beginning teaching with little pedagogical and content knowledge in technology. This study indicates that the TOCF assists teachers' ability to gain insight into students' ideas about technology, assists their personal understanding of technology, improve their ability to give formative feedback to students and facilitating ways to extend students' understanding of the technological world and their place within it.

Technology education for the current century

Learning technology for current and future times presents teachers with a challenge of equipping students with skills and knowledge necessary to thrive in the digital age and beyond. Students no longer need to rely of the memorising of facts or learn bodies of knowledge readily available to them on the internet. Rather they need to be able to work with others to engage with, critique, and analyse technologies and materials. Hattie and Donoghue (2016) state that cogitative, metacognitive and motivational strategies assists students in dealing with vast array of information available to them. Technology education should recognise and enable students to be mindful custodians of the future as they design and develop technological outcomes which impact the world in unimaginable ways. Wagner (2008) advocates seven survival skills for the twenty-first century which are particularly relevant to Technology .These include:

- Critical thinking and problem solving
- Collaboration across networks and learning by influence
- Agility and adaptability
- Initiative and entrepreneurialism
- Effective oral and written communication
- Accessing and analysing information

- Curiosity and imagination.

These skills need to be taught to our children. Claxton and Carr (2010) suggest thinking about goals of learning or dispositions as verbs rather than nouns so that dispositions are seen not as 'things' to be acquired but rather a 'way of doing' that increases in frequency and complexity and which are described with applicable adverbs. These tendencies can be seen as changing over time allowing us to consider what teachers can do to assist their students' progress and how they might go about this. Three adverbial dimensions: robustness, breadth and richness advocated by Claxton and Carr can be used to measure progress. Claxton, Chambers, Powell and Lucas (2013) discuss the building of learning power within students through the development of dispositions and attitudes including the building of students' confidence and self-belief in their capabilities, within four domains of learning rather than the building of specific sets of skills. Within Claxton et al.'s four domains: resilience, resourcefulness, reflectiveness and reciprocity sit a number capabilities, a number of which are particularly relevant to technology education such as: noticing, perseverance, managing distractions and absorption in the resilience domain; making links, questioning and imaging in Resourcefulness; planning and distilling in Reflectiveness and collaboration, empathy, inter-dependence in Reciprocity. Increasing students' curiosity, sense of adventure, perseverance, and independence along with teaching students how to be better learners increases also capabilities (Claxton, Chambers, Powell, & Lucas, 2013).

Assessment of students' learning and development in technology involves intelligent observation of and conversation with students by teachers with the purpose of improving students' technological literacy (Compton & France, 2007). Understanding the relevant dispositions in the context of technology is useful in assisting teachers' ability to understand and develop ideas of students' progression. Progress in technology is not linear, but rather a holistic process which can be difficult to assess (Kimbell, 1997). Achievement in technology includes a students' conceptual understanding of subject matter and their ability to transfer concepts to future learning and new and unfamiliar situations (Pellergrino, 2002). National or state curricula such as New Zealand's national curriculum technology achievement objectives (Ministry of Education, 2007) and the United Kingdom's Key Stages (Bishop & Verleger, 2013) in design and technology (d&t) go some way to identifying progression in technology. Compton and Harwood (2005), Jones (2009) and Pellegrino (2003) suggest more research is needed around the notion and specifics of progression in technology. The tool developed during this research hopes to offer some assistance for teachers in understanding some underlying key concepts in technology through the use of key aspects by looking at them through a modified and blended version of Claxton and Carr’s (2010) perspectives and Claxton et al.’s (2013) domains and capabilities.

International perspectives of technology in primary

In the New Zealand curriculum (NZC) (Ministry of Education, 2007) the primary curriculum is organised around three strands: Technological Practice, Technological Knowledge and the Nature of Technology. Students work on developing technological outcomes to meet identified needs and opportunities. They are required to develop an understanding of technology and the impacts and influences it has on people and the environment. Finally they are required to have knowledge of key concepts unique to technology such as understanding the purpose and type of modelling and understanding how properties of materials can impact on the functional nature of outcomes. Students work across a range of technological areas and contexts.

In England d&t programmes of study in primary begin with Key Stage 1 (Years 1 and 2). It aims to ensure that all students: develop the creative, technical and practical expertise needed to perform everyday tasks confidently and to participate successfully in an increasingly technological world, build and apply a repertoire of knowledge, understanding and skills in order to design and make high-quality prototypes and products for a wide range of users, critique, evaluate and test their ideas and products and the work of others and understand and apply the principles of nutrition and learn how to cook (Department of Education, 2013, p. 181). Students also work within a range of relevant contexts when designing and making, and should be taught to: design, make and evaluate technological outcomes.

In Swedish elementary (primary) schools technology is aimed at helping students develop expertise and awareness of the technical world. Students are expected to develop stills to enable them to analyse technological solutions, identify technological problems and needs, use concepts and expressions of technology, assess the consequences of technology and identify the driving forces of technology. In primary schools students are also required to take arts and crafts subjects which included working in wood, metal and textiles (Fahrman, Gumaelius, & Norström, 2015).

Although clearly different, each of the above primary technology curricula do have commonalities. Listed below are the most significant. By studying technology students should gain:

1. an understanding of their technological world;
2. the ability to evaluate (analyse and critique) current technologies;
3. the ability to identify potential technological problems, needs or opportunities;

4. the ability to design and make technological outcomes to meet identified needs using a range of materials; and
5. understand key concepts and processes unique to technology and deploy these in their practice where applicable.

The Study

The research that informed the development of the Technology Conversation Framework (TOCF) was undertaken in three countries, New Zealand, England and Sweden, all with a high reputation in technology education. Teachers of five and six year old students were given the proposed framework, which they used to inform their conversations with their students while engaging in technological activity.

This research was situated within a sociocultural paradigm and employed interpretative qualitative research method (Ritchie, Lewis, McNaughton Nicholls, & Ormston, 2014) through the application of the TOCF by teachers to assist them in broadening their understanding of students' thinking in technology and to facilitate the giving of relevant feedback to students as a part of the formative assessment process. Data was gathered over a six month period in 2016. The main data came from semi-structured interviews with six teachers. The teachers were initially interviewed to identify their current knowledge of and experience in teaching technology. They were then presented with the TOCF which was discussed with the researcher to ensure clarity and commonality of understanding. Teachers then used the TOCF to inform their observations of and conversations with their students. Data was triangulated through researcher observations and video recording of teachers' conversations with students. Data analysis occurred through repeated coding and recoding to enable a rich description of the teachers' experiences using the framework. After the analysis of early data from New Zealand the framework was slightly modified before further data gathering occurred in England and Sweden. The framework presented in this paper was again modified resulting from feedback by participants in the final interviews in Europe.

The Participants

Six teachers took part in the study, two each from New Zealand, England and Sweden. All teachers taught five and six year old children, In Sweden this was in an Early Childhood setting, in New Zealand it was in a primary setting and in England the school included both early childhood and primary children. Pseudonyms are used to protect the identity of the students.

- Teacher 1 (M) had taught for nine years and learned technology education as a part of his initial teacher training. He enjoyed teaching technology although admitted he was not hugely experienced at it.

- Teacher 2 (A) was a beginning teacher who had no specific technology education in her initial teacher training programme. She had never taught technology before the study but did observe it being taught on one of her practicums.
- Teacher 3 (K) was an experienced primary teacher of nine years who moved into entirely teaching technology three years previously. K had no formal training in technology before obtaining this position. She took a number of classes to upskill herself in technology but was given a limited professional development in the technology curriculum.
- Teacher 4 (J) was a very experienced primary teacher with 19 years' experience. She then took an 18 year break before joining her current technology department as a specialist teacher assistant. When entering her current department she was given some ad hoc professional development in safe use of machinery.
- Teacher 5 (Je) had 18 years teaching experience and worked with students from 1-6 years of age. As an ECE trained teacher she received no technology education training in her initial teacher education programme.
- Teacher 6 (An) was also an experienced teacher of 19 years who worked with students from 1-6 years of age. Again as an ECE trained teacher she received no technology education training in her initial teacher education programme but was heavily influenced by the Reggio Emilio philosophy of teaching.

All participants understood that technology was about the 'made world' and that students not only designed and developed technological outcomes but also needed to understand the impacts of technology on people and places.

Technology conversation framework

Developing the Framework

The dimensions and domains discussed in previous sections were applied to the assessment of technology education in the primary setting. Formative and summative assessment of Technology in primary occurs through a range of strategies such as observations, work samples and student portfolios of technology practice (Moreland & Jones, 2000). In New Zealand teachers assess students' learning against a set of achievement objectives identified in Technology (Ministry of Education, 2007), which are extrapolated into indicators of progression at each level of the curriculum (Ministry of Education, 2009) to assist teachers in the assessment judgements and feedback. Assessment occurs as teachers and peers listen, watch, and interact with each other. Continuous observations provide the basis of information for more in-depth assessment and evaluation that is integral to making decisions on how best to meet students' needs. Assessment should always focus on individual students over a period of time and avoid making comparisons between children (Ministry of Education, 1996). In this research teachers used the TOCF to inform ongoing formative assessment through reflection of action and learning.

The framework presented in this paper draws heavily from the works of Claxton, Chambers, Powell and Lucas (2013) and Claxton and Carr (2010) and identifies five behaviours: resilience, transference, flexibility, reflection and socialisation identified as necessary for successful learning. These behaviours incorporate cognitive, metacognitive and motivational strategies as well as social and physical behaviours. Within each there are a number of capabilities to assist teachers in the recognition of the behaviours. The behaviours and capabilities are outlined in Table 1. These behaviours were then extrapolated across the common aspects of technology, taking the form of questions for teachers to ask, say and look for, when working with their students in technology.

Table 1: Potential behaviours underpinning success in technology

Behaviours	Resilience	Transference	Flexibility & Sophistication	Reflection	Socialisation
Demonstration of capabilities	Perseverance Managing Distractions Absorption	Making links Imaging Noticing Questioning	Planning Distilling Reasoning Imagining Capitalising Evaluating	Questioning Distilling Revising Meta-learning Evaluating	Empathy & listening Collaboration Interdependence Imitating

The first, resilience, includes capabilities of perseverance especially after initial failure, managing distractions from peers, other activities and people around them, and absorption in any given task. Absorption can be likened to Csikszentmihalyi’s (1990) state of ‘flow’ and is described as a state of deep absorption in an activity that is intrinsically enjoyable, as when artists and athletes are focused on their play or performance (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). When totally absorbed in tasks students often do not hear or respond to what is going on around them. Transference includes making links to technologies experienced or seen, and experiences undertaken previously such as using existing cultural knowledge and experiences or Funds of Knowledge (González, Moll, & Amanti, 2005). It also includes questioning the relevance of previous experiences and imaging how existing knowledge and skills might be transferred to new situations to assist and or improve performance.

Flexibility and Sophistication indicates an increased depth to understanding as well as an openness to new and potentially strange ideas. It involves use of reasoning to evaluate and distil information received in order to understand what is learned from an experience. It also includes the questioning of relevance and asking questions of others to learn more by getting below the surface of ideas and artefacts. Planning ideas and actions and capitalising or making the best use of resources also characterise this behaviour. Recent research suggests there is an intuitive connection between creativity and cognition (Lewis, 2008; Runco, 2014) and Spendlove (2015) identifies strong societal benefits of being creative within technology education. Increased sophistication of ideas therefore may lead to improved creativity.

Reflection, the fourth behaviour identified describes the strategic and self-managing aspect of learning. Reflection includes the planning and anticipating of needs and potential issues and distilling information for potential of future use. It includes the revision of prior learning and its evaluation as a part of the distilling process to identify relevant learning that can therefore be transferred to a new context. Finally this will involve self-generated questioning and self-monitoring of progress through being cognisant of what, how and why learning is taking place (Claxton et al., 2013).

The fifth and final behaviour is Socialisation. The inherently social nature of technology and technology education and the huge physical, social and environmental impacts of technology make inclusion of this behaviour vital (Fox-Turnbull, 2013). Whether engaging in the use or the development of technology students will be interacting in a social manner. They may be collaborating with others to develop single or parallel technologies, they will experience interdependence, or the balancing of self-reliance and socialisation, as the need for resources and skills arise. Even when interacting with technology in a solitary manner students are still engaging with people. Their evaluation of the technology and decisions about whether to come back for further engagement or not will impact other people in the long-term if not sooner. For example teachers will not purchase a technological device, toy or piece of equipment that their students choose not to engage with (Fox-Turnbull, 2016).

Findings and conclusion

During the study the framework was used by all teachers as they worked with their students undertaking technology activities. Four main themes emerged from the analysed data: insights into student learning gained by teachers, insight into technology education gained by teachers, recommendations for using the framework and recommended improvements for the framework. A number of subthemes, summarised in Table 2, were identified within each theme.

Table 2: An Overview of Research Findings

Themes	Insights into student learning and benefits for students when teachers were using the TOCF.	Insights into benefits for teacher when using the TOCF	Teacher Recommendations for use of the Framework	Proposed Improvements or disadvantages by using the framework.
Sub-themes	• Understanding Technology Practice process and concepts Reflective Practice • Working Collaboratively/ Interactions between Students including modelling • Role of Questioning • Transference • Motivation and Engagement including using creativity and imagination • Importance of resilience and ability to make mistakes without failing.	• Developing a deeper understanding of technology content and pedagogical knowledge • Assisting students understanding of technology • The role of questioning in broadening students' knowledge of technology • Value of student centered learning • Role of modelling positive attitudes in technology • Increased confidence in teaching technology	• For implementation of teaching and learning • For the framework • Teacher Planning	• Time • Balance • Contextualising • Familiarisation • Modification to assist parents' understanding

The teachers felt that they needed to be familiar with the framework before using it with the students and found the questions more useful that the aspects to 'look for'. Most said this was because they were easier to recall. All teachers indicated that framework assisted in developing their understanding of the breadth and depth of learning in technology as illustrated below.

> I have learned that there [is] more for me to learn about how children learn technology. That we are not used to ask children questions about the made-world and make them reflect about how to develop already made things…… I now see how valuable it is for the children to be able to develop more of their technology skills on a deeper level and that I as their teacher has to make it possible for them (An).

It also assisted their questioning and teacher/student conversations about technology, they also benefitted by developing deeper self-understanding of technology education and they gained insight into how and what students learn in technology. This was illustrated by teachers in all three countries. Jn from Sweden stated "I asked them how they learned to build so fantastic together. For a month ago we built separately, and now we build together. So we have learned to use each other" (Jn).

> So we often ask things like why does it work, how does it work what materials/ the properties of materials, things like that. The questions like 'What would you like to ask the person who made this' to find out about how and why it works?.... different questions, that we hadn't thought of, different perspectives, and then sort of going that bit deeper with, certainly the older children, but as you say, even starting too with the younger chn" (K- England).
>
> They were really reflective and quite honest during that process…. They were very self-critical, which was interesting as it doesn't come naturally to this age. So we were able to seem them develop those skills of being critical of their own work and their own thinking. It was quite incredible (A- New Zealand).

A number of recommendations for using the framework were suggested as well as feedback on potential disadvantages or issues with using the TOCF were also identified. For example M and A suggested having the framework available at the planning stage of the unit would have been useful. "I would start with it earlier in the planning stages and have a clear plan of where things would go in" (M). "Yes I would say the same, it would be useful in the planning and using it from the start. Then I would have incorporated it in many ways and just more questions" (A). Am suggested that the tool could be modified and used to assist parents' in their understanding of technology "I think that you could change the wording slightly so that you know that you could make parent friendly language or you could have a discussion with the parents to guide them through the language" (Am).

For quality formative assessment to occur in the classroom teachers must have a deep and rich understanding of the subject matter. The above results suggest that the framework assist teachers' understanding of students' learning in technology. The work supports Claxton et al (2010) notions of building learning through a range of dispositions and attitudes. The findings also support Compton and France (2007) and Kimbell (1997) and Stables (Stables, 2015) ideas around the need for deep and rich teacher knowledge in technology to facilitate deep understandings of technology in their students. The teachers in the study found particularly useful the questions from the framework as it assisted their questioning of the students in order to determine students' views and understandings of technology. Had they had more time with the framework particularly a planning stages it is hoped that the "look for" sections would be equally useful.

It is hoped that further analysis of the data generated by the study will assist the identification of the specific areas in which assistance was rendered and thus lead to further refining of the framework, which will then be used with a wider range of students and teachers. As suggested above, any further studies must introduce the TOCF to teachers well in advance of the proposed planning and teaching. Potential areas for further research include measuring students' achievement in technology before and after teachers have used the framework and applying the framework to all levels of primary schooling and modifying the framework to use in secondary contexts.

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Appendix A: Technology Conversation Framework

Behaviours *Aspect*	Resilience	Transference	Flexibility & Sophistication	Reflection	Socialisation
Understanding of the technological world	Look for: using *technology* and having repeated goes at getting it right or improving use of an existing *technology*. Total absorption while others are playing / working around them. Not letting others distract them. Hunting for the best device to do a particular job. Ask: How might You get better at using this ? Who might help you with this ? What might be a better thing to do this job ?	Look for: transferring knowledge and skills in the use of one *technology* to another technology that might involve similar skills. Recognition of the similar skill sets. Deploying skills and knowledge used at home with a different technology at school. Recognising a range of 'made' things. Ask: Where else might you use this (action/ skills)? Have you done anything like this at home or with your family ? Where have you seen this before ? Have you used this before ?	Look for: increasing understanding that *technology* is made for purpose. Different needs lead to different outcomes Students finding relevant information from unexpected sources increasing understanding that *technology* is made for purpose. Understanding different needs lead to different outcomes Ask: Who might benefit from this *technology* ? Why ? How else might this be used ? What are the benefits of this ?	Look for: talk about why some things are made by people and some things are not. Questioning of how and why things work. Thinking about their thinking about technology. Ask: Tell me why this is *technology*? How might this be improved ? What works well ? What does not work well ?	Look for: understanding that *technology* is usually made by groups of people working collaboratively. Technology is made for people. Understanding that many people influence *technology* design. Attempting to use technology by copying the actions of adults. Ask: Who makes stuff (technology)? why ? Do you think people worked together to design and make this? How do you know ? How do people work together to make this *technology*?

	What can I do to help you with this ? Say : Have another go. You are just not there yet. You can learn from getting things wrong.	Imagine what this might look like in 20 (50/100) years' time. What did you notice about the way that works ? What questions would you like to ask the people who made this ?	What would you like to ask the person who made this to find out about how and why it works ? Which do you think is the better/ best (comparing a range of similar items) ? Why ?	What do you think about when you use this technology ? How can thinking help you understand this ?	Give me an example of something that is/ is not made by people.

Behaviours *Aspect*	Resilience	Transference	Flexibility & Sophistication	Reflection	Socialisation
Evaluate current technologies	**Look for:** willingness to have a go at articulating the physical and functional features and nature of existing *technologies.** Having several attempts at explaining the success or not, of *technologies* Having several attempts at getting something to work.	**Look for:** use of evaluative language used to discuss *technologies* in one context transferred to another. Ability to imagine a better version of technology. Noticing similar features from one technology to another.	**Look for:** increased awareness about the complexity of *technology* and that evaluations from different people will be very different. Understanding why what works for one person might not work for another. Imaging a more complex version or different version to better meet identified need.	**Look for:** the ability to experiment with a *technology* and talk about how they might make it better. Children asking of questions as to why technology is the way it is. Questions about functional features. Questions about physical features.	**Look for:** recognition that designing and making *technology* is frequently undertaken in teams. Understanding that to evaluate *technology* a range of stakeholders - groups of people with a stake in the *technology* need to be considered. Comparing technology using language of more advanced peers or adults. **Ask:** How might this *technology* have been better if more people helped make it ?

	Ask : What will make you better at using this ?	**Ask:** How could you improve this for another group of people (state actual group)? Why was this *technology* made ? Who else might want to make this ? What changes would they make ? Why ?	**Ask:** Why does this *technology* work so well ? Who might this *technology* not work for ? Why ? Who might it work better for ? What makes this *technology* safe to use ?	**Ask:** What makes this *X* a good one ? How could you improve it ? Why do you think this ? How could this *technology* be made safer to use ? Would your parents (Mum, Dad) use this *technology ?*	How could other people help you to talk about how this *technology* works ? What do you think Mum or Dad {or another important person in their lives) would think of this ? Why do you say that ? What features in this *technology* help keep us safe ?
	Say: Try again to see if you can get a different result. Use different words such as : better than, different to, similar to, not as good as …. when talking about this *technology ?*	Have you seen this feature in something else? How have you used what we found out earlier about *X* in your plan ?	**Say:** Talk about successful design and ideas.	Would your parents (Mum, Dad) like this *technology ?* Do you have the same or different ideas about this *technology* than your parents ? Why?	How do you know this made by people ?

Behaviours *Aspect*	Resilience	Transference	Flexibility & Sophistication	Reflection	Socialisation
Identify technological problems or needs	**Look for:** an understanding that investigation is need to identify potential solutions.	**Look for:** the ability to transfer potential solutions from other situations to an identified need.	**Look for:** ability of offer a range of innovative solutions to a single problem.	**Look for:** Recognition of what circumstances led to a particular technological need.	**Look for:** the understanding that conversation and working cooperatively can assist the

Understanding and practice that the design process may have to be repeated to obtain eventual success.	Ability to recognise that a problem can be solved with a technological solution.	Ability to recognise that a technology solution is needed. Imaging a more complex version or different version to meet a different need. Recognising that a solution in one area might be modified to assist in another.	The ability to recognise a range of possible solutions and that some solutions are better than others Ability to justify the above. Recognising opportunities for developing technologies.	process of problem/ solution identification. Understanding that working together can mean doing different tasks on the same project. Imitating adults in the articulation of a technological problem and /or solution. Listening to others for ideas.
Ask: How many ideas do you think you need ? What would you change the second time if the first idea does not work ?	**Ask:** What have you seen that is a similar problem/need to this ? What do you know about recognising a *technology* problem from doing technology in school another time ?	**Ask:** Rank the ideas you have to this problem from best to worst ? Tell me why they are in this order? What do you think might be the best solution to this problem ? Why ?	**Ask:** Which is the best solution to this need ? Why do you think this ? What might be a better idea ? Within this situation or scenario what is the technological need ? (What needs to be developed ?)	**Ask:** How can working together help you decide the best solution to the problem ? Who might help you think about doing this better ? How might you help others to recognise an opportunity or identify the need ?

Behaviours *Aspect*	Resilience	Transference	Flexibility & Sophistication	Reflection	Socialisation
Design & make technological outcomes to meet needs including evaluating their design ideas and outcomes	**Look for:** ability to continue working on a *technology drawing/ model/ outcome* to improve quality. Total absorption while others are playing / working around them. Not letting others distract them. Repeatedly giving things a go after inititally failing. **Ask:** If your first idea does not work what will you do ? What other detail can you put in your *drawing/ model*? How might you improve the quality of your *technology outcome* ?	**Look for:** skills learned in skills based lessons such as drawing, gluing, etc. used when making the actual *drawing/ model/ outcome.* Transferring identified attributes from *design* to the *technology outcomes*. Use of safe practices Use of research/investigation findings evident in planning/ drawing. **Ask:** What have you/we already learned that might help you with your *drawing/ model/ outcome?* Why/ How will this be useful ? How did you determine the attributes ? Who taught you to do that ?	**Look for:** detail in designs, ability to draw in 3D and annotate design ideas. Use modelling to inform technology practice and improve *technology outcomes*. Understand how modeling helps improve *technology outcomes.* Ensure design reflect required or desired attributes. Students drawing on relevant information from unexpected sources. **Ask:** Improve your design so that another person could make your *technology outcome.* Why and How does making a model improve you *technology outcomes ?*	**Look for:** ability to self and peer evaluate outcomes against established attributes or characteristics. Ability to recognise and justify changes for the next iteration of the design. **Ask:** What are the best features of this *drawing/ model/ outcome ?* Why do you think this ? If you/ they were to redo this or make improvements what	**Look for:** ability to work collaboratively with others. Ability to engage in inter-cognitive conversations, let own ideas go if necessary and move to new thinking with others. Embrace knowledge and skills brought to the group by others. Listening to others for ideas. **Ask:** How does working with other people help you ? What ideas did you change after talking to *X/group* ? What knowledge and skills did you know that the others didn't know and that helped your group ?

	Say : Try again to do this, but in a safer way. Like this (demonstrate skill)	How did you know that ? Can you use (a feature) from something else? How can we do this safely ? How have you used in your planning what we learned about ?	What attribute/ feature is the most important why? What is the best bit of your design ? What is your favourite part of the design/outcome ?	changes should you/ they make ? Why ? Can you make your plan ? What help might you need ?	How can other people help you make your design ?
Behaviours *Aspect*	Resilience	Transference	Flexibility & Sophistication	Reflection	Socialisation
Understand key concepts of technology & deploy in their practice	**Look for:** ability to continue working on problem solving or developing a solution repeatedly after failure. Ability to name alternative suitable materials used.	**Look for:** key concepts (these will differ according to curricula) learned in one unit transferred to another. Tasks that are identified in real *technology practice* transferred to students' technology practice Increasing complex drawing and modelling skills in subsequent units or projects	**Look for:** increased vocabulary sue when describing technology outcomes. Increasingly complex technologies recognised as technology. Increased complexity when considering factors that influence technology practice (theirs and others).	**Look for**: describe the *technological outcome* they are making Identify why they are making a *technological outcome.* Use of attributes to evaluate design ideas Discuss what is and is not technology and why Identify who might use a *technology* and why	**Look for**: understanding the social and collaborative nature of technology and technology practice. Understanding the technology influences people and people influence technological development

Ask: How can you make this better? What changes would you make next time ? Who will benefit most from this design ? Can you design it so others will benefit ?	**Ask:** What groups of people may not like this *technological outcome ?* What are the main tasks for a technologist (a person who designs stuff) ? What have we already learned that will help us with this design ?	**Ask:** What would a 'bad' *technology* look/ sound/ smell/ taste/ feel ?	Comparing of their outcomes with pre-determined attributes. Ability to undertake self and peer assessment against identified attributes. **Ask:** What groups of people may not like this *technological outcome ?* What groups of people will like this *technological outcome* best*?* Next time your made this what changes would you make? Why ?	**Ask:** What groups of people may not like this *technological outcome ?* What groups of people will like this *technological outcome* best*?*

*NB Where the words are italicised they may be replaced with the specific context the children are working in.

Design and Drafting Education for the Next Society in Junior High School

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Abstract

Drucker predicted that "the next society will be a knowledge society" and "a substantial amount of theoretical knowledge that can be acquired only through formal education".

We organized three experiments, in the field of technology for junior high schools that pertain to design and drawing education, the first experiment "using mainly 3D-CAD", the second experiment "using primarily paper models" and the third experiment "using 2D pencil drawing, paper models and 3D-CAD" via the formation experiment method based on Galperin's approach. Therefore, we were able to confirm that 3D-CAD and paper models supported the learning by students as "clues" and the effect of three experiments. Subsequently we suggested the design and drafting education for the next society in junior high school.

Keywords: 3D-CAD, 3D image ability

Introduction & Purpose

Drucker predicted that "the next society will be a knowledge society" and "a substantial amount of theoretical knowledge that can be acquired only through formal education" (Drucker, 2002). Then the national curriculum in England has shown "computer-aided design" by Key stage2 : Design, "3-D and mathematical modelling" by Key stage3 : Design and "computer-aided manufacture" by Key stage 3 : Make in subject content of design and technology.

It is said that engineering drawing is used as the language (graphical language) that communicates ideas and information from one mind to another. Furthermore, engineering drawing requires some training to understand like any language (French, 1911). Because engineer drawing is important education, 2D pencil drawing and CAD are taught in many countries. However it is pointed out that Japanese drawing education is fewer number of school hours and contents than other countries and regions where Korea, Taiwan, Hong Kong, Singapore and U.K (Fujita, 2008). We organized three experiments via the formation experiment method based on Galperin's approach, Figure 1. The purpose of this study is to suggest the design and drafting education for the next society in junior high school.

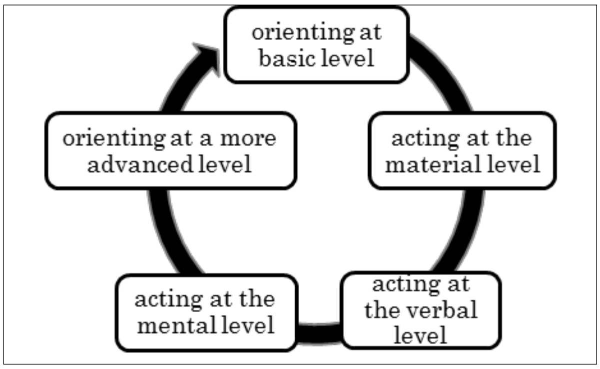

Figure 1: Galperin's approach

Methodology

The experiments were organized at a junior high school located in Kobe. First experiment (Fujita, Kagae & Joh, 2008, 2010) that 3D-CAD mainly was organized from April, 2007 to March, 2010. A total of 191 first-year students (male 112, female 79 / 12-13 years old) attended the technology course. The teacher has the experience of the technology field for 32 years. In addition, second experiment (Fujita, Kagae & Joh, 2014) that paper models mainly was organized from April, 2010 to March, 2013. A total of 153 first-year students (male 83, female 70 / 12-13 years old) attended the technology course. The teacher was same as first experiment. Then the third experiment that without partial in 2D pencil drawing, paper models and 3D-CAD was organized from April, 2014 to March 2017. A total of 230 first-year students (male 127, female 103 / 12-13 years old) attended the technology course. The teacher was same as the other. We designed the syllabus for the each experiment class (hours) 1-88 and the test 1 -5, Table1.

Table 1: Schedule of experiment

Hours	Grade	Experiment		
		First	Second	Third
Test 1	1st			
1-3		Guidance, Information technology	Guidance, Paper models 1	Guidance, Paper models 1
4-6		2D-drawing	2D-drawing,	2D-drawing
7-9		3D-CAD, Tutorial	Information technology	Information technology
Test 2				
10-13		Woodworking, Lecture	Woodworking, Lecture	Woodworking, Lecture
Homework		Idea sketch of objects	Idea sketch of objects	Idea sketch of objects
14-16		Drawing by 3D-CAD	Drawing by 2D-Drawing	Drawing by 2D & CAD
17-35		Production of objects	Production of objects	Production of objects
Test 3				+ CAD Test1
36	2nd	Metalworking, Lecture	Paper models 2	Paper models 2
37-38		3D-CAD, Idea sketch of objects	Nurturing living things	Energy conversion
39-40		3D-CAD, Drawing of objects		Nurturing living things
41-51		Production of objects	Metalworking	
52-70		Energy conversion, Machines	Energy conversion,	Metalworking,
Test 4				+ CAD Test2
71-80	3rd	Energy conversion, Electricity	Programming	Programming
81-87		Plastic working	Plastic working	Plastic working
Test 5				+ CAD Test3
88		Summary	Summary	3D-printer

In Test 1-5, we carried out three kind of tests that a projection ability test (Figure2), a construction ability test (Figure3) and a visual point transformation ability test (Figure4) for clarifying the effect of each experiments. The projection ability test (five tasks, 10 minutes) is that converting to orthographic projection from isometric projection and drawing an orthographic views. The construction ability test (five tasks, 10minutes) is that converting to isometric projection from orthographic projection and drawing an isometric form. The visual point transformation test (five tasks, 10minutes) is that converting to isometric projection which turning 90 degrees clockwise horizontally from the original isometric projection and drawing an isometric form.

After carrying out the Test 1-5, we analyzed results of each ability tests in detail. Then we replaced common five drawing levels as bellow. The result of the test did not feedback to students. Based on a precedent study, we judged that there was little influence of repeating the same test.

<Drawing level>

Level 0: To be unable to draw anything.

Level1: To be able to draw a little.

Level 2: To be able to draw incompletely.

Level 3: To be able to draw approximately completely.

Level 4: To be able to draw completely.

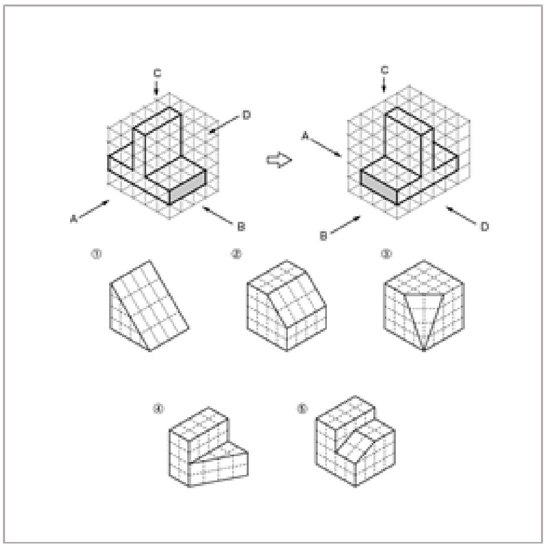

Figure 2 Projection test

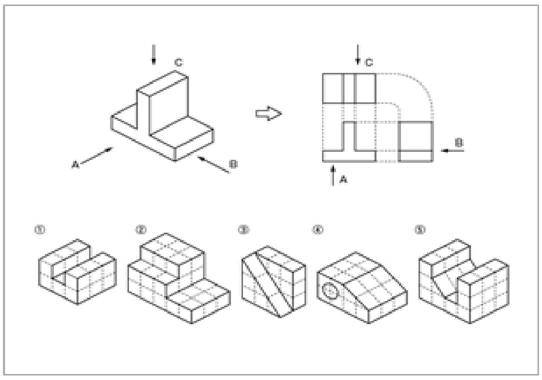

Figure 3: Construction test

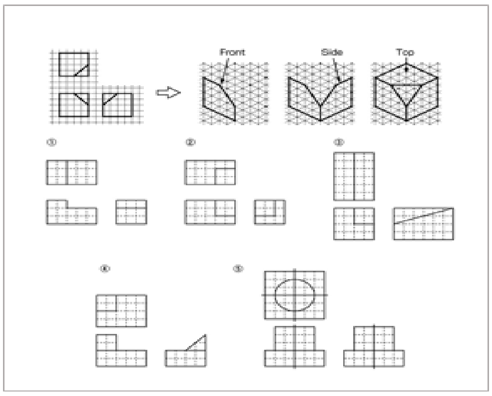

Figure 4: Transformation test

First experiment

In experiment hours 4-6, students learned about the 2D pencil drawing of cabinet projection, isometric projection and orthographic projection by the instruction of the teacher, using model and OHP. Then students watched the simple forms that teacher prepared in files of 3D-CAD files and confirmed the front elevation, the side elevation, the top elevation and perspective.

In experiment hours 7-9, students practiced commands and functions of 3D-CAD using the tutorial. In the first half of the class of experiment hours 37-40, students practiced the visual point transformation using 3D-CAD, students watched the simple forms then operated the view, confirmed different perspectives.

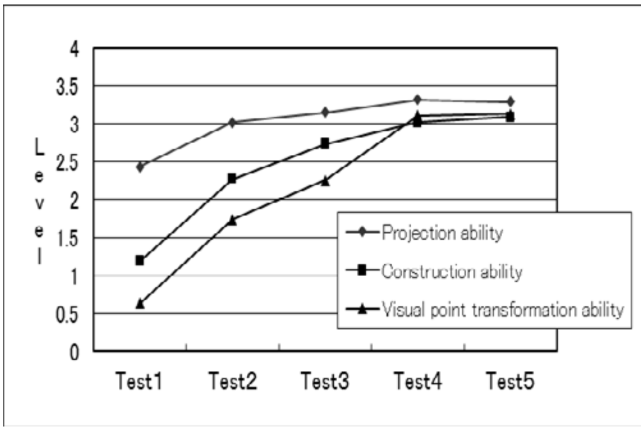

Figure 5: Drawing level of three kinds of ability

As a result of experiment, we clarified the formation process of the projection ability, construction ability, and visual point transformation ability by analyzing the change of the drawing level for each test of ability (Figure 5). It is formed with a turn of the projection ability, the construction ability and the visual point transformation ability.

Second experiment

In the latter half of experiment hours 1-3, students assembled paper models that RV Car and One box Car. In experiment hours 4-6, students learned about the 2D pencil drawing of cabinet projection, isometric projection and orthographic projection by the instruction of the teacher, using model and OHP. Then students confirmed the front elevation, the side elevation, the top elevation and perspective using paper models. In experiment hours 36 and the letter half of experiment 37-40, students assembled paper models that Cam and Crank. Then students practiced the visual point transformation by predicting a movement of Cam or Crank, and confirming their movement.

Third experiment

In experiment hours 1-6, students learned about the 2D pencil drawing as same as second experiment. In experiment hours 14-16, students practiced commands and functions of 3D-CAD, then made the drawings of objects of wood working. In experiment hours 52-70 metal working and 81-87 plastic working, students made the drawings of objects.

Comparison of each experiment about 3D image ability

We compared each experiment by “Drawing level of the 3D image ability” that the average of drawing level of projection test, construction test and transformation test, Figure 6. We analyzed drawing level 0 - 4 by the two-way ANOVA. The results of drawing level of the two-way ANOVA using between subjects factor “difference instruction” displayed not significant $F(2,413)=0.128$,ns. in addition within subjects factor “test 1, test 2, test 3, test 4, test 5” displayed significant $F(4,1652)=956.405$, $p<.01$. Moreover, the multiple comparison using the

Ryan’s method showed that there are significant difference between all pairs without “test5 - test4”. Therefore we confirmed effect of design and drawing education using 3D-CAD and paper models.

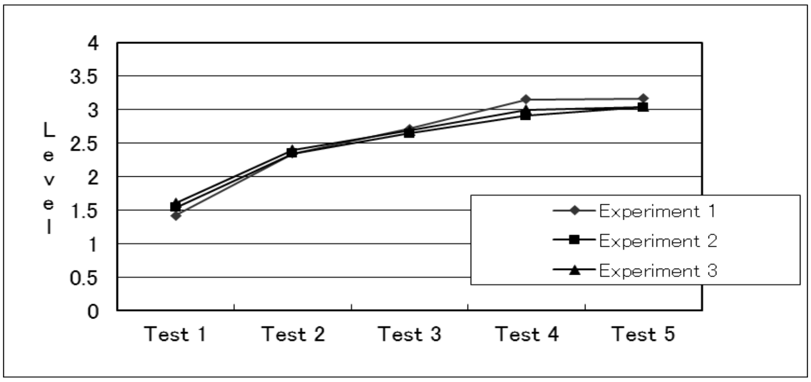

Figure 6: Drawing level of the 3D image ability

CAD Test 1 - 3

We carried out the CAD test 1 (Figure 7), CAD test 2 (Figure 8) and CAD test 3 (Figure 9) in the third experiment. After carrying out the CAD test1-3, we analyzed results of each tests by modeling levels as below.

<Modeling level>

Level 0: To be unable to model anything.

Level1: To be able to model “Sketch”.

Level 2: To be able to model “Extrude”.

Level 3: To be able to model “Circle, Chamfer and Fillet“.

Level 4: To be able to model “Assembly”.

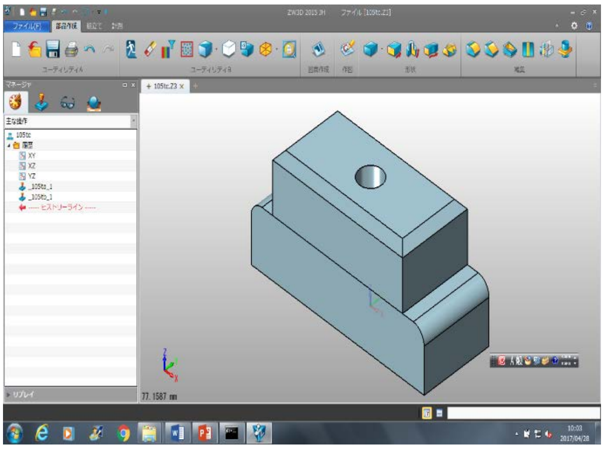

Figure 7: CAD test 1

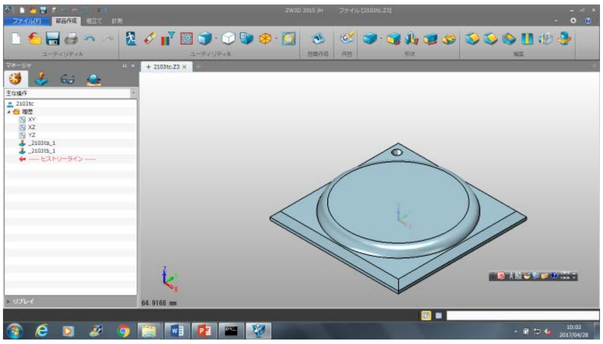

Figure 8: CAD test 2

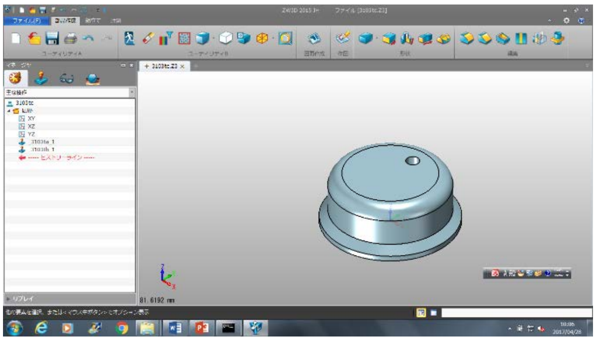

Figure 9: CAD test 3

We analyzed modeling level 0 - 4 by the one-way ANOVA. The results of modeling level of the one-way ANOVA, within subjects factor “CAD test 1, CAD test 2, CAD test 3” displayed significant $F(2,314)=15.812$, $p<.01$. Moreover, the multiple comparison using the Ryan’s method showed that there are significant difference between all pairs without “test1 – test2”. Therefore we confirmed effect of design and drawing education using 3D-CAD and paper models.

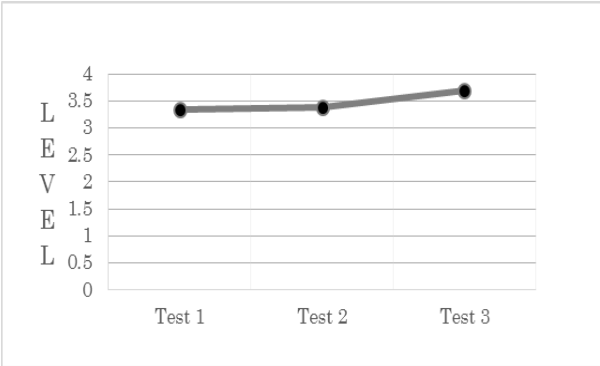

Figure 10: Modeling level

Discussion

As the result of 3D image ability and CAD test, the design and drafting education for the next society will be need an ability of operating 3D-CAD and 3D-modeling based on 3D image ability to be formed traditional 2D drawing through formal education.

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A critical review of the functioning of design teams from a Macro-cognitive perspective: Why is designing in teams hard?

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Abstract

The context for this study was a technology teacher education program. This study reports on two design cases (high/low performing) drawn from a pool of eleven teams undertaking design tasks during an action research project. A substantial body of research on team-based approaches to teaching and learning over the last 100years points to its value in improving both academic and social outcomes. A well-established set of principles that underpin effective teams has been enunciated and several theoretical perspectives that explain the functioning and performance of teams exist. The first section of this paper critically analyses the research on effective teams. The second section reviews research on design team activity and analyses this work in the light of the broad research on effective teams. A Macrocognitive perspective on team decision making is used as the analytical framework.

The third section presents a brief case study of teacher education student design teams undertaking authentic product design tasks in the context of a teacher preparation programme. Four distinct features of team designing are the focus of this case study: knowledge construction, collaborative team problem solving, team consensus and outcome evaluation and revision. Comparisons and contrasts are made with findings from the general literature on teamwork and that reported in the context of design. Findings generally followed those in the design literature with the more successful team showing greater externalisation of knowledge, more elaborated conversations, and broader participation in design. Some issues such as design decision making and intra-group conflict resolution processes remain obscure. Implications for the structuring and use of design teams in secondary and tertiary settings are presented.

Keywords: Design teams, collaborative learning, group functioning, decision making, Macrocognition

Introduction

The use of groups has been advocated in education and in technology curricula for some time. These calls reflect a prolonged interest in the use and functioning of groups in the context of design (see the landmark design protocol research on groups reported by Cross, Christiaans, and Dorst, 1996). This study reports on an action-research project located in a technology teacher education program that used groups to undertake authentic design tasks, advised, supported and assessed by experienced product designers. Data from this study sought to provide insights on the design processes, discussions, deliberations, conflicts, role-taking, and within-group interactions that enable or inhibited successful performance. A macrocognitive perspective on team functioning was used as the principal analytical framework (Klein & Wright, 2016).

Literature review

Cooperative learning, CL, is commonly described as the deliberate use of small groups of students working together to maximize their own learning and that of their peers (Johnson, Johnson, & Holubec, 2008). A substantial body of research over the last 120 years has critically examined the use of cooperative and other small-group approaches to learning.
A meta-analytic review on research on CL from 1995 to the present day across primary, secondary, and tertiary education in classrooms reports positive benefits on both achievement and attitudes (Kyndt, Raes, Lismont, Timers, Cascallar, & Dochy, 2013). These findings reflect earlier meta-analyses reported by Johnson, Johnson, and Smith (2006) who compared cooperative learning to competitive learning and individualistic learning in college students. The academic achievement measures defined in this analysis ranged from lower-level cognitive tasks (e.g., knowledge acquisition and retention) to higher-level cognitive activity (e.g., creative problem solving), and from verbal tasks to mathematical tasks to procedural tasks. The meta-analysis also showed substantial positive effects on self-esteem and positive attitudes about learning.

A meta-analysis by Johnson, Maruyama, Johnson, Nelson, and Skon (1981) showed the uniform benefits of cooperative learning across all subject areas, for all age groups, and for all tasks involving problem solving, conceptual understanding, categorizing and reasoning. There were both academic and social benefits. A later best-evidence synthesis by Slavin (1989, 1991) comparing cooperative and individual learning showed the overall effects of cooperative learning on achievement were clearly positive in 72% of the comparisons, whereas only 15% favoured the control groups. The consistent pattern of results supporting the use of deliberate cooperative learning constructively aligned with task/learning outcomes supports its use in the design and technology classroom.

Contributing factors in successful cooperative learning

Research on cooperative learning has highlighted important principles underpinning the effective use of CL approaches. These principles include positive interdependence, individual accountability, face-to-face promotive interaction, interpersonal and small-group skills, and group processing (Johnson & Johnson, 1981). If interpersonal and small-group skills are not developed and group interaction is disrespectful or unequal, achievement can suffer (Linn & Burbles, 1994).

Complementary research on team/group development has clearly demonstrated that teams change over time and in response to task demands, inter- and inter-personal factors and other variables. One common model of group development proposed by Tuckman and Jensen (1977) appears as Table 1. Each of the five stages in Tuckman and Jensen's model (forming-storming-norming-performing-adjourning) involves the development of interpersonal relationships and task-oriented behaviours derived from experience and reflection. Team learning and performance improves as groups mature.

Table 1: Tuckman and Jensen (1977) model of stages of team development (google.co.uk)

Stage	Characteristics
Forming	Members disclose information about themselves in polite but tentative interactions.
Storming	Disagreements about procedures and purposes surface, so criticism and conflict increase. Much of the conflict stems from challenges between members who are seeking to increase their status and control in the group.
Norming	Once the group agrees on its goals, procedures and leadership, norms, roles, and social relationships develop that increase the group's stability and cohesiveness.
Performing	The group focuses its energies on its goals, displaying higher rates of task orientation, decision-making and problem-solving.
Adjourning	The group prepares to disband by completing its tasks, reduces levels of dependency among members, and dealing with any unresolved issues.

Research in education, business, sport, the military, and other task-oriented contexts emphasizes the necessity of providing adequate training in group functioning (See for example Cannon-Bowers & Salas, 1998). This raises questions about how and when teams can be effectively used in the context of school-based design activities.

Research on design teams

Research on teams in general and design teams distinguishes between the learning and performance aspects of teams. Decuyper, Dochy, and Bossche (2010) argue that "Team learning is then primarily about the occurrence of interpersonal behaviours such as sharing information, asking questions, seeking feedback, challenging assumptions, framing, reframing, dialoguing, seeking different alternatives, etc." (p.116). Drawing on the acquisition metaphor, the participation metaphor, and the knowledge-creation metaphor for learning they go on to stress the building of shared mental models (shared cognition) through the process of collaboration. Co-creation, collaborative expansion, innovation, and transformation are the result.

The building or co-construction of shared mental models is highlighted in other research on design teams (see for example Dong, Kleinsmann, & Deken, 2013; Badke-Schaub , Neumann , K. Lauche , & Mohammed, 2007). This occurs in a shared workspace and involves verbal, non-verbal communication processes. Sketches, annotated drawings, and models can become the focus of shared conversations. They are also useful indicators of good design outcomes (Agogino, Song, & Hey, 2006). The volume and number of complex sketches positively impacts design outcomes.

Earlier research on shared understanding in co-design teams has found that a lack of shared understanding caused unnecessary iterative loops (Valkenburg & Dorst, 1998). Ultimately a lack of shared understanding reduced the quality of final product, because not all problems have been solved in the end (Dong, 2005). Wood, Chen, Fu, Cagan, and Kotovsky (2012) found that effective collaboration improved the consistency of mental models, especially in the early stages of designing. Song, Dong and Agogino (2003) found that the highest quality products came from teams with an increase in shared understanding. These findings have been echoed in research undertaken by Agogino, Song, and Hey (2006) who also report that successful design teams showed higher semantic coherence (p.620), and high variation in shared understanding during the early phases of design. They also argued that they design teams need to reflect on their own performance in terms of the patterns of shared understanding.

A striking feature of the research on both team learning and performance in the context of industrial design and engineering design in universities is the lack of time afforded teams to the development of group-processing skills. It is not possible to determine the stage (using Tuckman's scheme for instance) that teams are working at. Higher performance on a group task might reflect team maturity. Less mature teams might possess the requisite individual knowledge, skills, and experience to complete a task but not the social and interpersonal skills to achieve as part of a team. These needs are explicitly acknowledged in research on teams but there are no indications on the group-processes training, if any, that teams received. The closest finding is that reported by Agogino et al (2010) who emphasised the value of peer evaluations as a window into team dynamics and communication between team members. These evaluations occur after the task was completed. Yet establishing team training requirements has been explicitly acknowledged in the team effectiveness literature for a long period of time (see for example Cannon-Bowers & Salas, 1998).

Macro-cognition

Macro-cognition is defined "as the internalized and externalized high-level mental processes employed by teams to create new knowledge during complex, one-of-a-kind, collaborative problem solving" (Letsky, Warner, Fiore, Rosen, & Salas, 2007, p. 7). Figure 1 represents the phases of collaboration in the macrocognitive taxonomy. The principles phases are knowledge construction, collaborative team problem solving, teams consensus and outcome evaluation and revision. Sub-macrocognitive processes are located within each of the major phases.

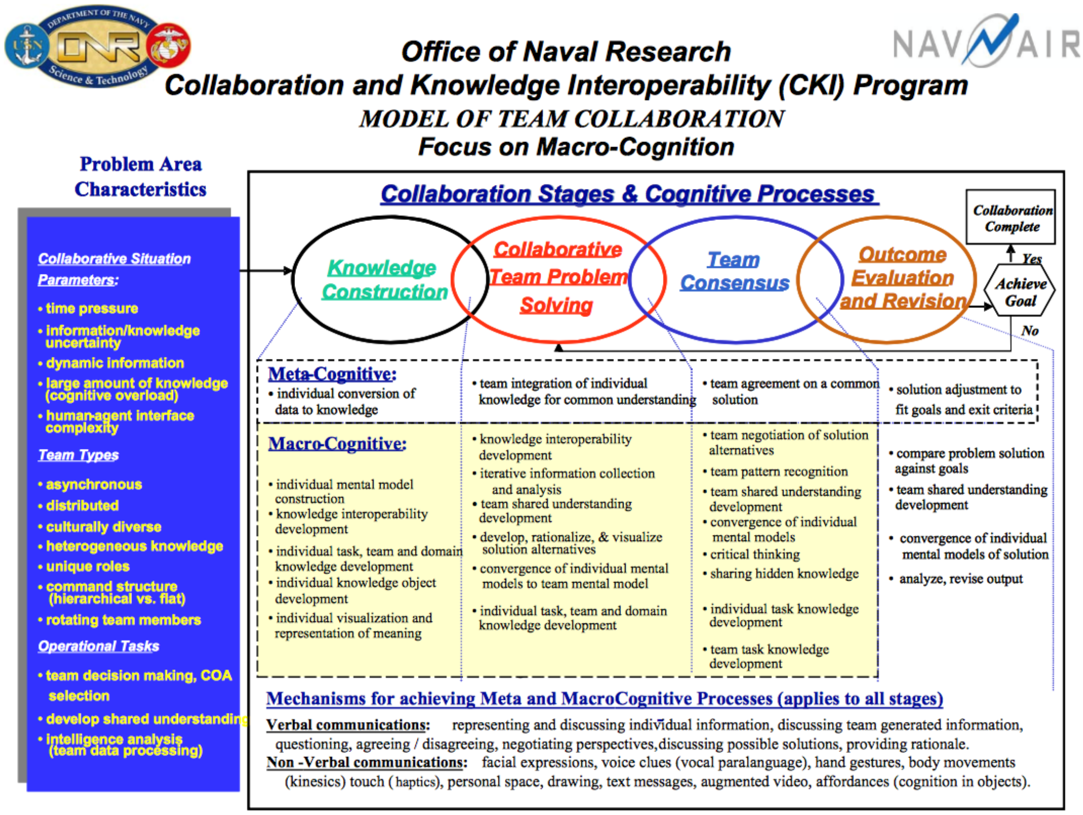

Figure 1: Macro-cognitive model of team collaboration (Letsky, Warner, Fiore, Rosen, & Salas, 2007, p. 4).

This model can be contrasted with the Tuckman and Jensen's model shown in Figure 1 (Tuckman and Jensen, 1977) that used a developmental perspective to frame the evolving maturity of groups/teams over time. Their model emphasis the processes by which norms are resolved and interdependency and trust develop between team members. There is no specific detail on knowledge construction, on the development of shared mental models, or on outcome evaluation. The model does however emphasise an optimal stage, the performing stage.
The macro-cognitive model used in this report explicitly acknowledges these issues as well as team problem solving and consensus building processes. The model focuses on the equivalent of the performing stage of the Tuckman and Jensen model. A noteworthy point of difference between the models is that the macrocognitive model has been constructed based on critical analysis of teams in action i.e., in naturalistic contexts. Here, hard data is available about the success and failure of teams, and the processes that have contributed to these results. Successful teams in naturalistic contexts demonstrate both learning and performance.

Methodology

The case studies reported below occurred as part of an action research project involving 55 technology teacher education students undertaking a second-year compulsory methods course in a Technology teacher education programme at the University of Sydney. Two teams were chosen, one from a pool of high-performing teams, the other from a pool of low-performing teams.

Team 1 in this report consisted of 5 students who had previously completed design or design-related degrees such as architecture, product design, or graphic design. They were from a Master of Teaching technology programme running in parallel with the standard undergraduate technology teacher education programme. No member of this team had commercial experience in their specialist design fields though industry experience components were part of their undergraduate degree programme. They could therefore be described as qualified but novice designers. Team 2 in this report consisted of four students who had entered university directly from high school. No member had any design experience and had only completed a design fundamentals unit in first year as part of their teacher education studies. The design fundamentals unit had a particular focus on the elements of visual design.

Prior to the implementation of design tasks, teams undertook a whole day workshop run by external specialists who focused on helping students work in teams. This was followed by a training programme run by the participant observer that involved learning from case studies in design drawn from the Australian Context.

Teams were required to develop designs to the concept design phase based on authentic designs reverse engineered from existing product designs. Team products consisted of annotated sketches and models. Team deliberations were recorded in audio and in some cases by video taping as well. They were later transcribed and coded. An external panel consisting of professional product designers with at least 5 years design experience scored the concept designs using a modified form of the Australian Design Award criteria along six broad dimensions (design, manufacturing, production, ergonomics, safety, aesthetics). Feedback was provided to each team on each design. General comments were also provided to the entire cohort.

The design task involved the design of a concourse seat suitable for use in a wide range of contexts including airports, train and bus stations and at public transport stops. This task was chosen on the basis that all teams members had personal experience of seating in these environments and would therefore possess prototypical mental models of seats. Data sources were annotated sketches, models, videotapes, semi-structured reflective journals, and transcripts of group conversations.

Findings

Knowledge Construction

Team A: Three of the five-team members contributed specific knowledge during design deliberations. This often took the form of a recommendation as to the type of materials to be used, some times with an analogous justification. It might also involve interplay between team members in considering the manufacturing process e.g:

F2 The seat shell should be in polypropylene or high-density polyethylene. I have seen them used in seats for the stadium.

M1 Yeah. Depends on the number needed. Probably injection moulded.

M2 You could even buy them off the shelf to save costs. Don’t think those would work in airports though – too cheap looking!

M1 Bus shelters. Lots of damage possible there.

F1 Yeah.

There is an explicit acknowledgement of the need to consider contexts (See M2 above). Design precedents are articulated by F2 but no systematic attempt to catalog or list the differing material requirements for each of the potential contexts takes place. Some situation assessment is occurring as a shared mental model of the task is being developed. Early sketches are annotated to reflect these issues. Annotations are made following verbal communications.

Team B: Although this team has four members, only two discuss ideas in any depth and then primarily along aesthetic criteria.

M1 It could look like this [sketching a simple line diagram] and be made of metal

M2 With cushions

M1 OK. …In airports.

Two members of the team remain silent during the early stages of the development design concepts. Entries in their reflective journals suggest they did not feel they could offer any concrete opinions on material choices or any other part of the design despite the fact they have first-hand experience in using seating in various forms every day.

Collaborative Team Problem Solving

Team A: There is constant interplay between team members. Ideas are offered and debated, clarified, and in some cases rejected. There is no dominant team member although only one team member does the sketching. His role is not challenged since his sketching and illustration skills are obvious.

M1 How will this work in airports. They ([seats] look much better and are more comfortable.

F2 So we will have to use better quality materials.

M2 How will that work out cost wise. [To other members] Has Nigel [participant observer] given us any guides?

F2 Not sure there.

There is no iterative information collection. The participant observer was not asked the question above and the separate information cards available to all teams were not accessed. Nor was there any attempt to critically examine extant designs that could have been used for comparative evaluations. The most elementary search for seating in airports would have revealed a wide range of designs including those made from pressed and stamped steel without seat cushions. Several separate solutions are sketched by the same team member (M1) and then critiqued.

Team B: No attempt is made to establish separate contextual requirements. Team understanding relates to the overall appearance and basic material choice.

M1 I think steel is the easiest material to use. Look at the tables we are working on now.

M2 Yeah. Let's go with that.

Only one potential solution is sketched but is not annotated until immediately prior to submission to the judging panel. There is no real collaborative problem solving as no extended conversations take place either verbally or non-verbally.

Team consensus

Team A: No attempt is made to unpack the brief in any detail although differing contexts are explicitly mentioned during team deliberations.

F2 OK, Bus shelters, airports, train stations.

No attempt is made to systematically debate the relative merits of each design since there is only one design that has been developed in any detail. There is an unwritten and unspoken consensus that their design will meet the requirements in the brief, even though it ignored some explicit requirements in the brief e.g., the seat must be easily broken down and transported. It is not clear how each team member's own ideas have been acknowledged and critiqued. This reflects a satisficing approach to design (Simon, 1956) where the first workable solution is adopted and developed.

Team B: In this team there is a silent consensus. There are no objections to the single design presented to the judges. Nor are there observations about the adequacy of the design in terms of the brief. It is not possible to ascertain the extent to which any shared understanding has been developed over time. The contribution of each team member is also difficult to assess.

Outcome evaluation

Team A: In evaluating their work, this team prioritises some aspects of the design brief over others.

F2 Looks good. Should work OK

F1 Good…strong

M2 Easy to build.

It ignores ease of assembly/disassembly and transport. Ergonomics are not considered at all. There are clear contradictions in how the design would work in different contexts.

Team B: There is no attempt to revise the design, nor judge it against the requirements of the design brief. There is no detailing of the design that has been shown to relate to design quality.

Discussion

Successful design teams reflect well coordinated actions which in turn speak to a more socially and cognitively developed group (Tuckman & Jensen, 1977). This was evident in the work of Team A and is consistent with the general literature on groups (Johnson, Johnson, & Smith, 2014) as well as the work of Kleinsmann, Deken, Dong, & Lauche, 2012, and Agogino, Song, and Hey (2006) in the context of design. Despite the relative success of Team A on the chosen task, there remain questions about how the intra-group conflicts were resolved in order that a consensus on team processes and outcomes could emerge (Yang, 2010). It was not clear how Team A harnessed and resolved interpersonal micro-conflicts in order to reduce uncertainty and progress designs despite research by Paletz, Chan, and Schunn (2017) making those very distinctions.

The lower quality of work displayed by Team B can in part be explained by a lack of shared understanding, itself a consequence of a lack of external models (models and or/annotated sketches, which can become the object and subject of group conversations. The lack of sustained interaction between members of Team B amplifies these problems. This result is consistent with the findings of Kleinsmann and Valkenburg (2008), Dong (2005), and Song, Dong, and Agogino (2003). It also speaks to a perspective on design that explicitly acknowledge the social dimensions of working in groups towards common goals (Singh, Dong, & Gero, 2013; Paletz & Schunn, 2010).

Conclusion

Despite the research described herein, as well as ongoing research on design groups, much more research needs to be undertaken to unpack the complex set of interrelated and interdependent factors that influence productivity and ultimately, success on design tasks (Dinar, Shah, Cagan, Leifer, Linsey, Smith, & Hernandez, 2015; DeChurch & Mesmer-Magnus, 2010; Agogino, Song, & Hey, 2006). This includes but is not limited to a more in-depth inquiry into the teaching and learning practices that can be constituted to support effective student team designing in authentic settings (Kleinsmann, Deken, Dong, & Lauche, 2012). Such investigations should take heed of the extant literature on the methods available to help externalise and represent knowledge, solve problems collaboratively (with a focus on promotive team interaction), build team consensus by establishing a shared understanding of design tasks/knowledge and resolving intra-group conflicts, and evaluate outcomes as a matter of priority. A complementary area for future research that would also extend our understanding of designing in complex domains is to investigate how novice designers (students and technology teachers) deal with uncertainty since this issue lies at the heart of abductive reasoning, the principal reasoning method in design (Kolko, 2010).

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A Distance Educational Support Method for Class with Practical Training using IoT

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Abstract

In recent years, it has been noted that children's communication skills are deteriorating to the pervasiveness of nuclear families and the declining birth rate in Japan. Integration of schools is required to ensure that students acquire and retain the communication skills necessary from the education perspective. In Japan, school instruction is sometimes conducted between remote schools using Video Conference System (VCS) via the Internet. An effective method for incorporating experiments and practical training into virtual classes has to be developed and evaluated. This study aims at developping a distance educational support method so that high quality education can be carried out regardless of the teachers' skills and the distance between schools. An example of the distance educational support method for teaching is demonstrated. For the purpose of this study, 'measurement and control by a program' is taught at junior high school using a small wheel mobile robot with a microcomputer. The IoT is newly incorporated into the robot in order to measure the state transition in the target by a sensor and to transmit its information to the server using wireless LAN. The learning process and results are mainly represented as the program and corresponding locus of the robot. A web application is employed to support the learning and the guidance by the teacher. The status of teaching materials incorporating the IoT is collected by the web server. This study suggests the possibility of collaborative distance educational support by examining the learning state of students in remote areas in real time.

Keywords: Distance education, Educational support, Internet of Things, Internet

Introduction

In recent years, it has been noted that children's communication skills are deteriorating to the pervasiveness of nuclear families and the declining birth rate in Japan (MEXT, 2008a). Japanese schoolteachers are actively fostering the communication skills. Integration of schools is required to ensure that students acquire and retain the communication skills necessary from the education perspective. However, small schools cannot be integrated according to the guidance on the appropriate size and arrangement of public elementary and junior high schools released by MEXT (Ministry of Education, Culture, Sports, Science and Technology in Japan) in 2015. The main reasons are as follows; (1) Distances between neighbouring schools located in isolated islands, or in mountainous and heavy snowfall regions are too great. (2) Since further declines in birth rates are predicted and the number of students will decrease, it is expected that several schools will be closed within several years. (3) Even if the target schools are integrated, significant educational and economic effects are not expected. (4) Residents request that the schools not be integrated, as the schools are instrumental for the survival and development of the local communities.

Hence, there are several unintegrated schools. Even after integration, the number of students is so small that the students may not be able to maintain their communication abilities. The schoolteachers are trying to improve educational activities by collaborating with teachers in different schools. For example, classes are conducted between remote schools using Video Conference System (VCS) via the Internet. It has been reported that VCS is particularyly useful for integrated studies. However, communication skills can be developed through various learning activities performed by an appropriate number of students in conventional education. This ability is formed by understanding each other's way of thinking. It is suggested that classes are simultaneously conducted among multiple schools located in remote areas.

One teacher at a junior high school is often in charge of multiple subjects with a small number of classes. A single teacher does not have anyone with whom to discuss subjects and teaching methods. It is necessary to discuss with teachers at other schools (Musset, 2010). Opportunities to discuss with teachers at other schools may be restricted by increasing distance between schools after the integration. Quality of teachers' skill may decline from the above-mentioned problems. High-quality classes using the Internet will be conducted to enhance teachers' skills (Wohlstetter, Malloy, Chau, & Polhemus, 2003). How to use VCS in the class has to be reviewed (Drexhage, Leiss, Schmidt, & Ehmke, 2016). A single camera in VCS has a very narrow shooting range and is not able to capture students' learning activities. Since the display can only show actual things small, it is difficult for the teachers to obtain the situation of individual learners in the class. Although multiple cameras in VCS can be adopted in the class, it is not realistic from securing the installation space of these cameras and its complicated operations. The method of supporting classes from a remote place using VCS was unsuitable for teaching the content of subjects. The activities of learners become dynamic in the classes with practical training. The teachers have to estimate the learners' stance to instruct promptly and appropriately while they are grasping the individual activity situation in detail. Therefore, the support method using only VCS is insufficient for the classes with the practical training from remote locations.

Distance educational support method

The remote class support system using humanoid robots and new business by the Internet of Things (IoT) were reported in the previous studies on introducing VCS (Augur, 2016; Toriyama, Sakoda, Nishihara, & Nakano, 2007). However, studies on the methods for supporting classes with experiments and practical training from remote locations have not been described. An effective method for supporting the classes with experiments and practical training has to be developed and evaluated by referring to the conventional class support method from the remote place. This study aims at developing a distance educational support method such that high quality education can be conducted in spite of the teachers' skill and the distance between schools.

An outline of the proposed distance educational support method is shown in Figure 1. The teacher of school A is the leader. Other teachers of schools $B_{i,\ I=1\sim n}$ work in cooperation with the leader. The leader is assumed to have higher skills than the other teachers. All schools are connected via the Internet. The leader performs lectures for all students using VCS as usual. The teacher of each school Bi is involved in virtual team teaching and simultaneously conducts the classes for the corresponding students. The students can ask questions of the teacher of the school to which they belong. If the teacher of school Bi cannot respond to a specific question, the leader teacher of school A answers the students instead. It is necessary to visualize this, so that all the teachers can have the learning situation including learners' practical outcomes in real time. It is also desirable for the students to be able to confirm the learning contents by themselves (Yakovleva, & Yakovlev, 2014).

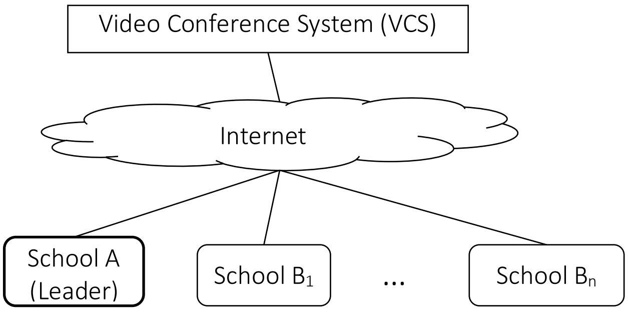

Figure 1 Outline of the proposed distance educational support method.

Figure 2 shows the proposed distance educational support method for the classes with the practical training. For making up VCS, the IoT is newly introduced to individual teaching materials and a server collects the learning process and results (Xia, Yang, Wang, & Vinel, 2012). The teaching material has various sensors and a wireless LAN module. State transition information in teaching material is sent to the server using wireless LAN and the Internet.

In accordance with the content of the classes with practical training, the collected state transition information in the teaching materials is analysed on the server and visualized. All teachers can confirm the collected data of the state transition information in the teaching material almost simultaneously. Each student can also confirm the learning results of its state transition information (Naps, Rößling, Almstrum, Dann, Fleischer, Hundhausen, Korhonen, Malmi, McNally, Rodger, & Velázquez-Iturbide, 2002). It is expected that all teachers of schools A and $B_{i,\ I=1\sim n}$ can cooperate with each other and be able to instruct, referring to the state of efforts for the learners' practical training. Even work that is instinctively created by students can be theoretically evaluated after the classes by referring to the learning process data stored in the server.

In general, the teacher evaluates students’ work within class hours. All work often cannot be evaluated within class hours for various reasons. At that time, the teacher evaluates the work by referring to the state transition information recorded in the server. It is also possible to employ the learning results obtained by the state transition in the teaching materials for the evaluation.

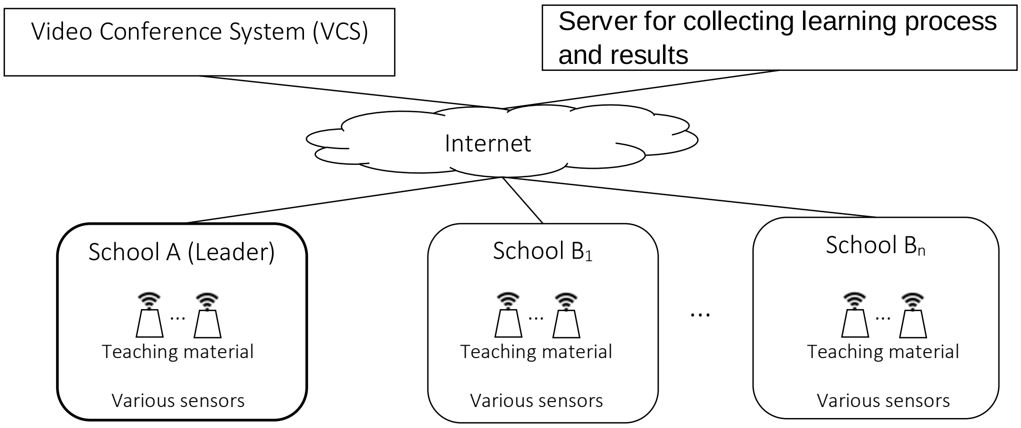

Figure 2: The proposed distance educational support method for practical training.

After actual classes employing the distance educational support method, improvements and problems compared with the conventional method are investigated based on the viewpoints of the teachers and students. It is expected that the proposed distance education support method is effective for the teachers who have little experience in education. Therefore, some of teachers with experience of the technology education from 2 to 4 years have to participate in the actual classes. The survey items for the teachers are related to preparation for the class, evaluation methods for the students, and effectiveness to teacher training, etc. The survey items for the students are related to interests, concern, and understandings on the learning contents, etc.

Teaching materials

Japanese junior high school students study Japanese language, mathematics, science, society, foreign languages, music, art, health and physical education, and technology and home economics (MEXT, 2008b). In the technical field of technology and home economics, improvement of education on programming needs to be improved as required by the recent Japanese educational policy issued by the strategic headquarters for the promotion of an advanced information and telecommunications network society (Strategic Headquarters for the Promotion of an Advanced Information and Telecommunications Network Society, 2013). The Japanese government course guidelines stipulated in 2008 have the contents of instruction on 'measurement and control by program' in the technical field education as follows (MEXT, 2008c).

> The following items should be targeted in the instruction with regard to automatic measurements and controls via computer programs:
>
> (a) To understand the basic mechanisms for automatic measurements and controls using computers.
>
> (b) To deliberate the procedures for processing information and be able to create simple programs.

However, according to the report on the attitude survey of teachers who are in charge of the technical field, teachers feel that knowledge and guidance skills regarding programming are insufficient and that opportunities for training are not enough. In particular, practical training including intellectual activities related to programming is required in the teaching of 'measurement and control by program'.

This paper focuses on this learning content and shows an application example of the distance educational support method. A small robot with a microcomputer is employed as the main teaching material. Figure 3 shows an overview of the robot. The size and weight of the robot are approximately 90mm(W) x 90mm(D) x 40mm(H) and 150g. The robot autonomously moves with two wheels connected to motors on the left and right sides. These motors can be individually controlled by the program. The power supply is two AA batteries. A touch and light sensors are attached at the front of the body. These sensors measure the condition around the body. An optical sensor measures intensity of an object located in the downward direction of the body. The robot can trace a line by using the optical sensor.

A total of 87.5 classes are allocated to the technical fields in three years in Japanese junior high school curriculum. In general, the learning of 'measurement and control by program' is carried out in 8 to 10 classes. In order to reduce the time to assemble the robot to secure much learning time for programming, the robot has a major feature that can be manufactured in a short time by not wiring and assembling gears. For instance, the electric power is supplied to the motors of this robot by bringing the built-in printed circuit board into contact with the terminals of the motor, and the reduction gears are just put in the chassis only.

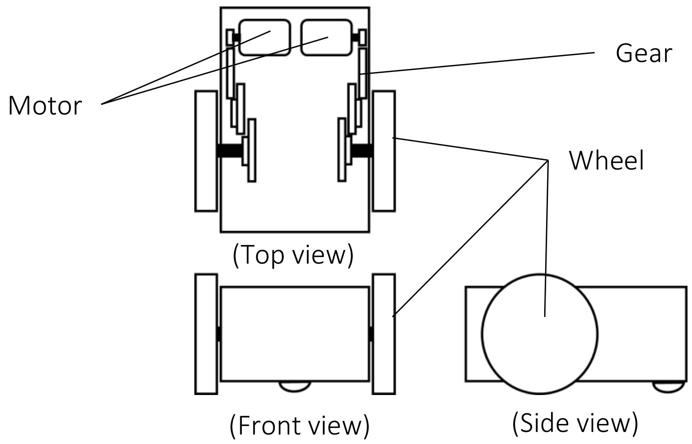

Figure 3: Overview of wheel mobile robot used as teaching material.

At first, the students study the function and mechanism of each sensor. In order to obtain the fundamental knowledge of programming, they know how to make the program presented as a flowchart drawn by a dedicated editor. The editor can be installed and invoked without any administrator privileges. It has several commands such as 'forward', 'back', 'right turn' and 'left turn' in advance. The editor has a function of correcting the motor rotation speed to compensate a rotation error occurring between the right and left motors. This function is useful to move the robot straight ahead. The students understand the importance of adjusting. Once the program is created, it is transferred to the robot through a USB communication line as shown in Figure 4. Next, they make the program that can solve some given learning tasks. The program is revised by rearranging parts consisting of the flowchart using simple drag and drop operations. Even the students unfamiliar with PC operations can revise the program easily.

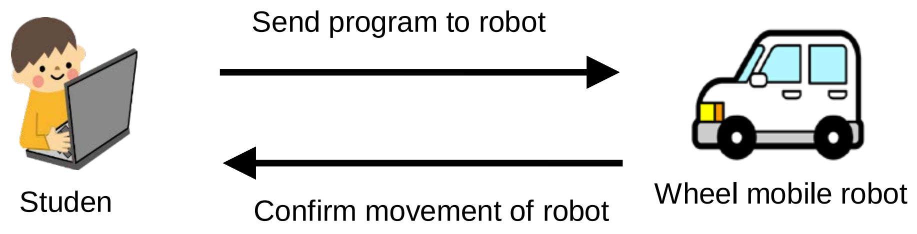

Figure 4: Learning processes.

After the teacher presents the learning tasks, the students create the program to solve them and obtain basic programming techniques. Examples of the basic learning tasks are 'sequential processing that linearly moves to a certain point', 'iterative processing that runs the same course', 'branch processing using sensors' and so on. 'Line trace using the optical sensors' is used as an example of an advanced problem. The student executes the program by pressing a tact switch at a top of the robot. The students confirm the movement of the robot and judge whether it matches the movement that they imagined. They solve the problem by repeatedly modifying the program until the desired movements are achieved. The teacher advises the students when they are unable to proceed. They study the contents of the program, take measurements, and control technology through training to move the robot.

The teacher evaluates whether the students are able to devise and improve programs to solve the problems. The IoT is introduced to confirm the movement of the robot, as shown in Figure 5. The students' learning process and results are mainly represented as the program and corresponding locus of the robot. All teachers and students can refer to the learning processes and achievements by introducing the IoT. The IoT measures the state transition of the robot with various sensors and has the function of transmitting information to the server via wireless LAN. A rotary encoder is attached to wheels of the robot, and information such as the measurement value and time is transmitted to the server. The power supply to each module for the IoT is also provided from the two AA batteries in the robot.

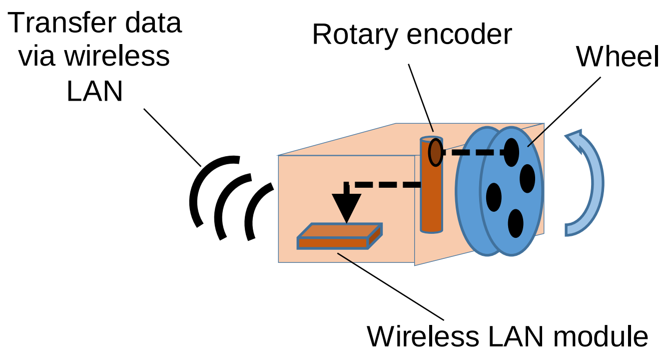

Figure 5: How to implement IoT in robot.

The learning process and results are visualized in the trajectory by a web application provided in the server. The server for the distance educational support is constructed by CentOS; this is provided free of charge, and it is a Linux distribution with a long support period. Apache is adopted as the http server. Scripts for the visualization are mainly written in PHP (Hypertext Preprocessor). CSS (Cascading Style Sheets) and JavaScript also enhance the visibility of learning processes and results. The main reason for adopting PHP is that it can receive and process the data from client computers and have high affinity with a database server. In addition, the database server has the capacity to accommodate cases where the number of schools and students increases. A drawing module was newly added since there was no drawing function in the initial setting of PHP.

Figure 6 shows an example in which the students' learning results are generated by the web server. The movement is tracked and detailed information regarding teaching materials is displayed. The information shown in the browser can also be used for review by the students after the classes and for evaluation by the teachers. The movement locus is displayed on the left side of the screen of the web application so that it can recognize the traveling direction and speed of the robot. The data sent from the robot are displayed on the right side of the screen so that they can supplement the details which cannot be read from the trajectory.

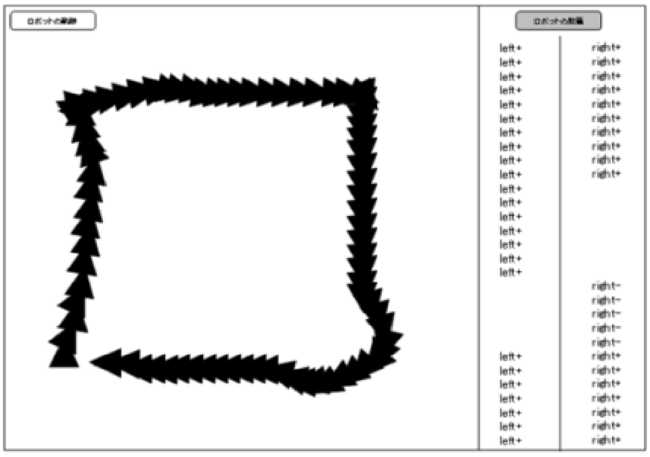

Figure 6: An example of learning results generated by the web server.

Conclusions

The status of teaching materials implemented using the IoT is collected by the web server constructed for distance educational supports. The teachers at the remote locations can refer to the learning processes and results displayed in the browser. This study suggests the possibility of collaborative distance educational support by grasping the learning state of students at the remote areas in real time.

As a result of the research, the teachers can support, not only classroom learning, but also practical training from remote locations by employing the proposed system. The lead teacher with the most professional knowledge can teach high quality classes regardless of the time and distance to travel by using the Internet. The proposed distance educational support method can be applied to more advanced classes regardless of borders (Dede, 1990). A new training style may be constructed so that the teachers participating in this class can see not only the state of the class from the remote place but also the record of the learning process stored in the server.

Future research should focus on adding database functions to the server so that it can support learning for many more students belonging to multiple schools. The proposed distance educational support method will be tested and run for classes; this should include contents and practical training of the subject. Based on the results, the developed server will be improved.

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Pre-service teachers' preparedness to use ICT: A Western Australian perspective

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Abstract

This paper reports on an ongoing project being carried out at Edith Cowan University (ECU) in Western Australia examining ECU Education students' ownership and use of Information and Communication Technology (ICT) since 2008. In particular the study to date has gathered information concerning students' hardware ownership, self-perceived software skills, frequency of use of hardware and software, and access to Internet use. In the 2016 phase of this project, an online survey was designed and delivered via Qualtrics survey engine. 148 ECU Education students completed the survey. In comparison to the previous years results, the outcomes from the 2016 survey indicate a continuing positive trend in applying digital technology in education. The increase in the possession of laptops, smart phones and tablets and the way that devices are accessed suggests that more students are using portable devices and it is also the time for the universities to change their ICT policies and practice. This research has benefits and practical implications for lecturers and pre-service teachers through their integration of technology in their classroom teaching and learning more effectively and would have policy implications for administrators, course coordinators and future teacher education programs.

Keywords**:** teacher education, online surveys, ICT skills, ICT ownership

Introduction

This study was an extension and enhancement of an ongoing project being carried out at Edith Cowan University (ECU) examining the hardware ownership, self-perceived software skills, and use of ICT by ECU Education students (Cooper & Pagram, 2009), therefore, some comparisons with data collected previously have been made.

The first phase of the study (2008) showed that most of ECU Education students were not early adopters who are the early users of new digital technologies, nor were they making use of its potential in their studies and this lead to similar research occurred in 2010, 2012 and 2014 respectively. In 2016, a modified survey was used to determine what had changed since the first phase of the research and this is the focus of this paper.

ICT use by Education students is important, as it is these students who are the future school teachers. Undoubtedly, teachers play a crucial role in the successful uptake of ICT in education and model it's use for their students. Teachers have always been the key stakeholders in the utilization of any educational development and innovation (Archibong, Ogbiji, & Anijaobi-Idem, 2010). Technology becomes important when teachers apply it. However, ICT has not been as effectively applied as expected even though it has been integrated into education for decades, many teachers are not using ICT effectively within their classrooms (Gosper, Malfroy, & McKenzie, 2013). Thus, it is necessary to investigate how current Education students use technology in their University studies. It certainly may inform University practices, to prepare pre-service teacher.

The research was intended to have benefits for pre-service teachers and their lecturers. For lecturers there are practical implications on how to integrate ICT effectively into teaching and learning as well as having policy implications for administrators, course coordinators and future teacher education programs.

Background

This study was conducted at Edith Cowan University (ECU). ECU is a large university, with more than 28,000 students. Its School of Education is the largest in Western Australia, with approximately 5,600 students and 104 academic staff (Edith Cowan University, 2016). Historically, ECU has the oldest foundations in teacher education and training in Western Australia, with more than 100 years of experience since 1902 when the Claremont Teachers College was established, which was the first education institution of higher education in Western Australia.

Pre-service teachers use of ICT is an important part of their university education because there are implications for their future practice as school teachers. Previous research had shown that ICT may not be successfully integrated into education if teachers are not willing to apply it in their teaching practice, even if they have been equipped with sufficient ICT infrastructure in schools (Rana, 2012). Teachers have an important role in the integration of ICT in education because the skills and attitudes around its application can significantly affect their pedagogical practices and students' technological skills and attitudes (Paraskeva, Bouta, & Papagianni, 2008; Pelgrum, 2001; Torkzadeh, Chang, & Demirhan, 2006; Zhang, 2007). If University Education students do not have positive experiences with ICT and its applications, they are less likely to employ ICT in their own teaching.

ICT skills are fundamental to pre-service teachers use of ICT in university learning and future school teaching. According to the Australian Professional Standards for Teachers (APST, 2013) teachers need to comprehend what professional ICT skills are required, to apply them to their teaching practice (Lloyd, 2014). Because the present and future teachers' ICT literacy and usage of ICT will influence their students, they need to have adequate ICT skills and model it's use for their students (Bamigboye, Bankole, Ajiboye, & George, 2013). Therefore, these skills must be emphasised and fostered in teacher education and training programs (Yusuf & Balagun, 2011). However, Finger, Proctor and Grimbeek (2013) found that many pre-service teachers were not fully prepared for teaching with technology because they had insufficient ICT skills. Surveys conducted from 2010 to 2014 in Western Australia indicated that although 50% of the pre-service teachers at ECU were competent in a variety of computer skills (email, online learning, word processing, and social media), they were still weak in some skills such as video editing (Pagram, Cooper, Vonganusith, & Gulatee, 2015).

A series of surveys conducted in the School of Education at ECU from 2007 revealed that pre-service teachers' hardware and software ownership had changed as new technologies were developed. For instance, students in the School of Education were mainly using desktops and laptops with Microsoft Windows operating system in 2007, while in 2014 there were more choices for computers with different operating systems and tablets such as the iPad had been introduced. In the era of third-generation (3G), mobile devices are more frequently used to assist learning (Pagram, Cooper, & Campbell, 2008; Pagram & Cooper, 2009; 2011; 2012; 2013; Pagram, Cooper, Vonganusith, & Gulatee, 2015). These changes in ownership indicate a need for pre-service teachers to further develop their ICT literacy and for universities to provide an increased focus on the use of these devices for pedagogical application.

Since teachers have a fundamental role in using technology in the classroom, it is necessary to investigate how ICT is currently used. This study focused on how ECU pre-service teachers used technological devices in their university learning and what technical support the university was required to provide, to facilitate this process. The investigation in 2016 was undertaken through an online survey of Education students at ECU and sought answers to the following questions:

1. What software do students use in their studies?
2. How do students perceive their ICT competence?
3. What hardware do students own and use in their studies?
4. Where and how do students access the Internet?

Method and participants

To address the research questions, the investigation was undertaken via an online survey which was developed and delivered via Qualtrics survey engine and housed on a university web-server. In the light of the technological focus of the study, the administration of an online student survey, communicated via the Internet, was appropriate. Education students were informed of the survey via a link placed on Blackboard, which is the learning management system that the students use for their studies. Figure 1 shows a screen capture from the survey.

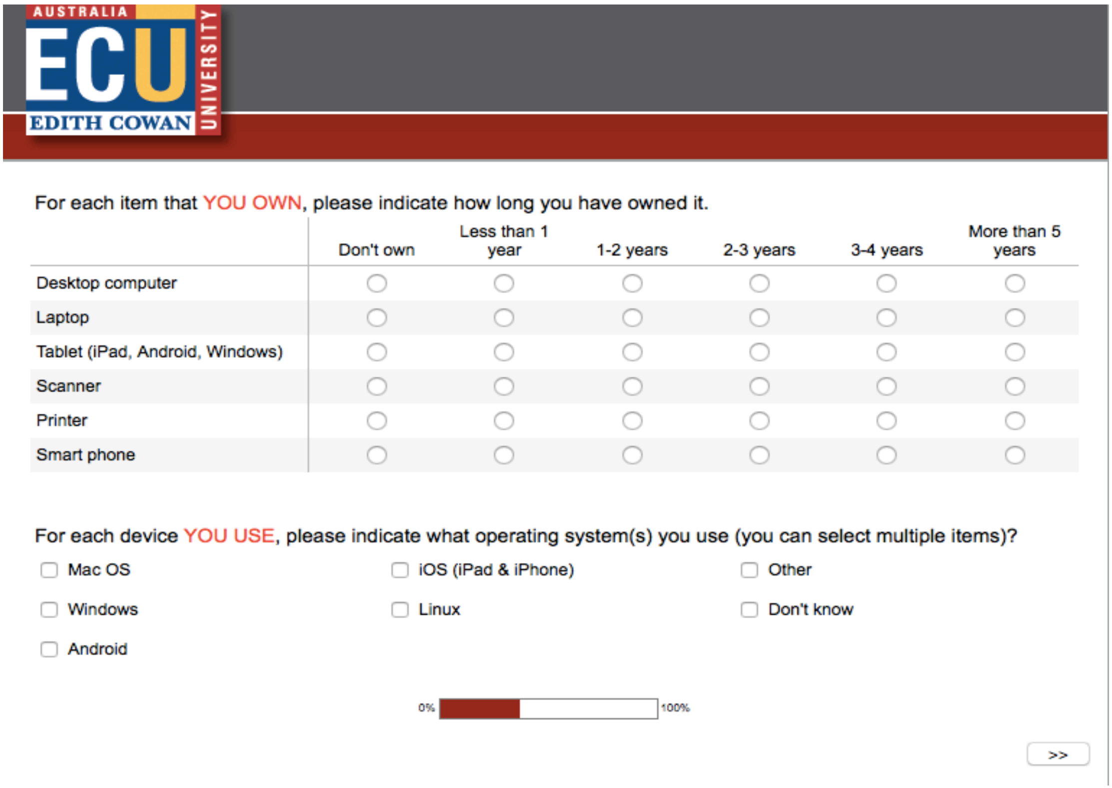


Figure 1: Example screen from the online survey

The survey consisted of 20 closed questions. These questions were grouped according to the following categories:

- ☐About you – to collate demographic data
- ☐Your Ownership –see above hardware ownership and frequency of use
- ☐Your Skills – perceived software skills and frequency of use
- ☐Your Access – type of Internet access, location of Internet access

148 students from the School of Education at ECU completed the survey. 29% of the respondents were male and 71% were female. This ratio of male to female students is representative of the ratio among Education students at ECU. The sample number of students were from a variety of courses and years of study. This indicates a satisfactory distribution of students from a range of years and courses.

Findings

This section represents the findings regarding the student hardware ownership, software skills, frequency of use of digital devices and software, and types of Internet access, as identified within this phase of the research. The previous years results have been provided, with a view to indicate the trends of technology use within ECU Education students' learning at University.

Student hardware ownership and frequency of use

The first section of the survey asked students to identify what hardware they owned, how long they had owned it, and how frequently the hardware was for their studies during semester. In 2016, over 91% of students owned a laptop with 20% of these obtaining it in the last year, and 48% owned a desktop PC with less than 5% obtaining this in the last year (Figure 2). The same happened in tablets and smart phones, only 9% obtained a tablet and 12% obtained a smart phone in the last year. This finding suggests that these pre-service teachers do not tend to upgrade their technology devices often, so are not early adopters.

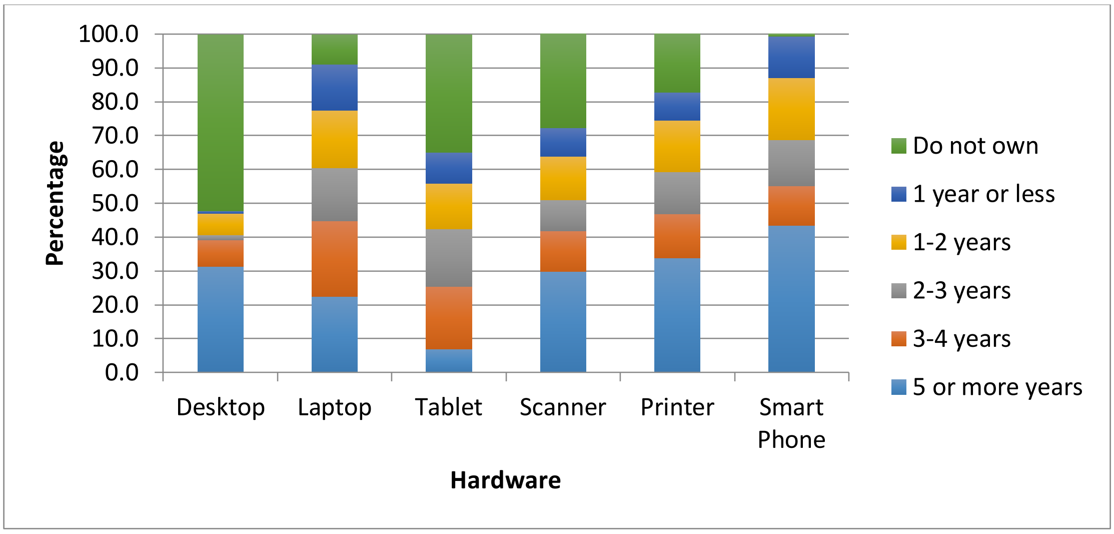


Figure 2: Student hardware ownership

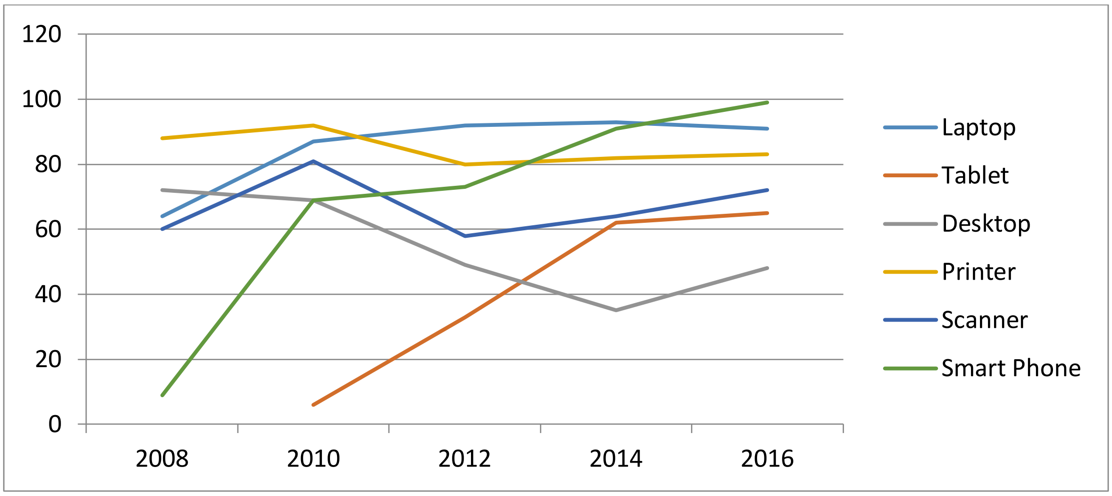


Figure 3: Trends in hardware ownership

This study has seen a rise in laptop use and a drop in desktop computer ownership. In the previous study in 2008, less than 65% of students owned a laptop and just over 70% of them owned a desktop PC (Figure 3). The greatest change however occurred in the smart phone area with less than 10% owning such a device in 2008 and nearly 99% of students indicating ownership in the current survey. This data shows a very significant move toward mobile technologies both in terms of current ownership and purchasing pattern. The same happened in tablets such as the iPad, with almost 60% rise in purchasing tablets within 6 years since 2010. The finding correlates with the 2012 research predictions, that the future student population would be using portable computing devices such as laptops, 3G phones and tablets.

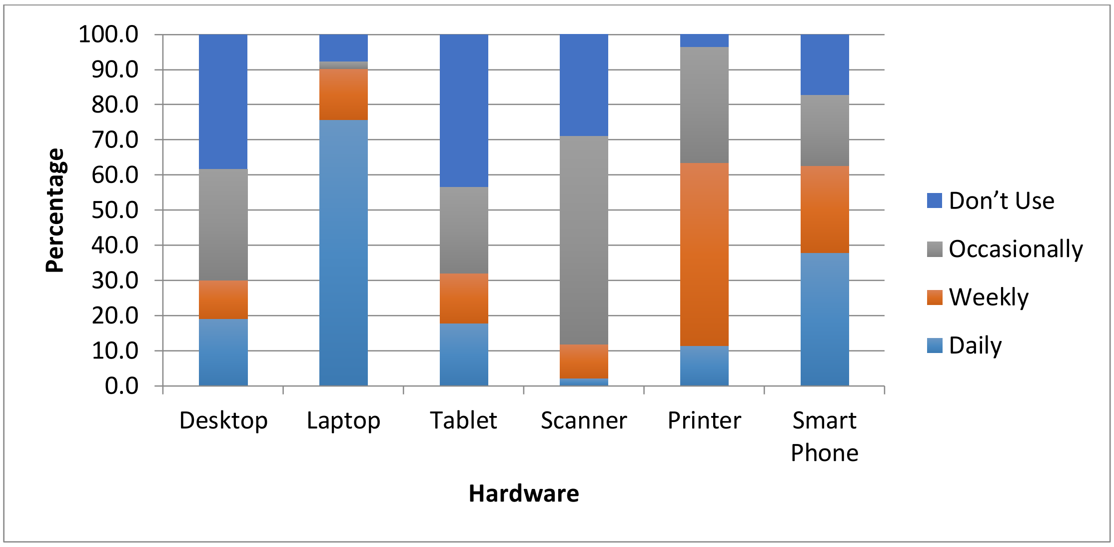


Figure 4: Student hardware frequency of use in study during semester

Figure 4 shows the frequency of use for each of the hardware types utilised for study purposes. Again the mobile devices (laptops and smart phones) are the most frequently used, followed by desktop PCs and tablets. It should be noted however that nearly 40% of students did not use desktop for their studies, while over 75% of students responding to the survey used a laptop at least daily in their studies. Tablets too were more frequently used in study, in comparison to previous years’ research, though there is still showing a high percentage (43%) who do not use tablets and this reflects in tablet ownership.

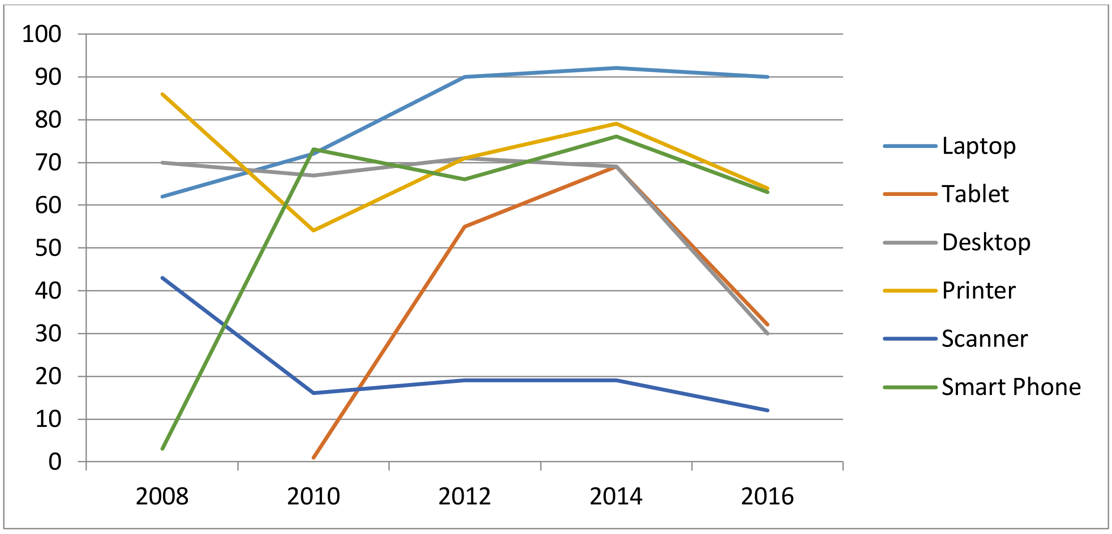


Figure 5: Trends in hardware frequency of use in study (at least weekly)

Hardware use in study at weekly and daily frequency from 2008 to 2016 is shown in Figure 5. Similar to the trends in hardware ownership, there were a rise in using laptop and a drop in using desktop for study purposes. Laptops are identified as the preferred device within this research setting. Additionally, more students used tablets and smart phones in their studies, which indicate that various types of digital technologies are being used for the purposes of study. While printer use has decreased over the period the upward trend evident since 2010 may be explained by the university’s zero paper policy, which in effect pushes printing back onto students who still believe they require a printed copy of some documents and learning materials.

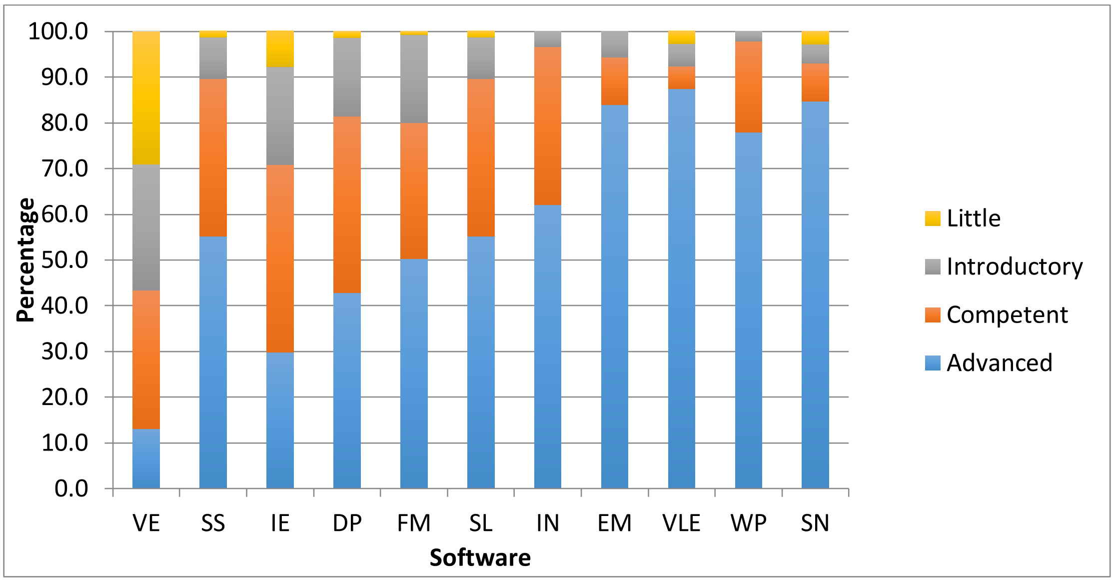
Students' software skills and frequency of use

An important part of the survey is collecting data on students' self-perceived skills with a variety of software. Table 1 illustrates two examples from the survey for Word processing and Spreadsheeting (e.g. Microsoft Excel).

Table 1: Sample from the survey where students indicated self-perceived skill level

Software	Little	Introductory	Competent	Advanced
Word processor	I can't do much	I can print a document, change fonts, spell check, insert a footer and page numbers.	I can insert images, create tables, change Page Setup, change margins.	I can use columns and sections, set up styles, use mail merge for labels or letters.
Spreadsheets (e.g. Excel)	I can't do much	I can enter data, use Sort, create charts [graphs] and modify them.	I can insert some calculations, format cells, insert and delete rows and columns.	I can use complex formulae, use absolute and relative cell references.

In addition to word processing and spreadsheeting skills, other nine software skills have been tested (See all the skills presented in Figure 6).



Notes: VE – Video Editing SS – Spreadsheeting IE – Image Editing DP – Digital Photography FM – File Management SL – Slideshows IN – Internet Browsing EM – Email VLE – Virtual Learning Environment WP – Word Processing SN – Social Networking

Figure 6: Student self-perceived skills with a variety of software

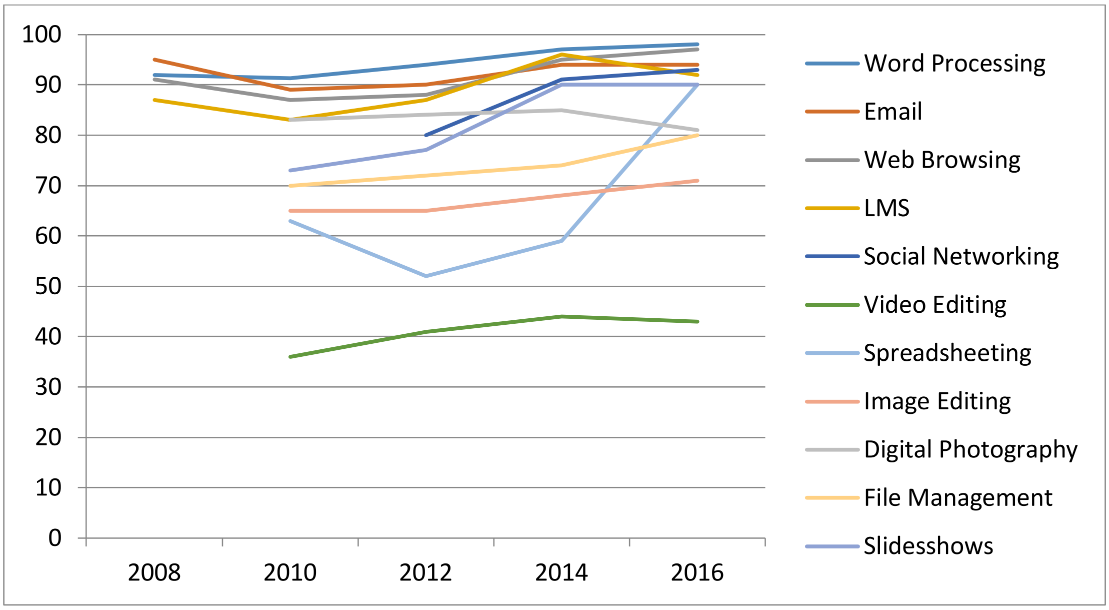
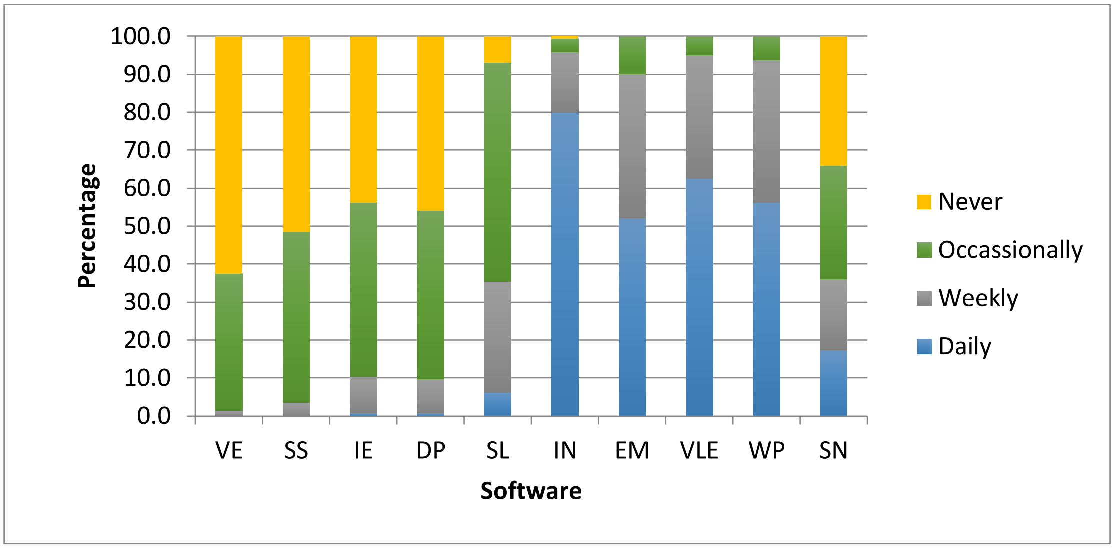


Figure 7: Trends in student software skills (at least at a competent level)

As a result of the survey, the students indicated some level of competency in all categories, with the exception of video editing (Figure 6). Less than 45% of students were competent in the use of video editing in 2016, reflective of the trends in the 2010 research (Figure 7). According to the findings presented in Figure 6, the greatest number of students who have the advanced self-perceived skill with software was in the virtual learning environment (Blackboard), followed by social networking, email, word processing and Internet browsing. No student reported knowing little about email and word processing, which indicates that the Education students at ECU had at least basic knowledge and skills of using email and word processing. This is consistent with the types of software they are most likely to be using in their Education course. However, it is surprising that comparing to previous years students were more competent in using spreadsheets in 2016, almost an increase of 30% since 2010 (Figure 7).



Notes: VE – Video Editing SS – Spreadsheeting IE – Image Editing DP – Digital Photography SL – Slideshows IN – Internet Browsing EM – Email VLE – Virtual Learning Environment WP – Word Processing SN – Social Networking

Figure 8: Software frequency of use

Figure 8 illustrates the frequency of use indicated by the students for the various software types. The software used on at least a daily basis by the majority of students was Internet browsing, virtual learning environment, word processing and email. No student reported using video editing on a daily basis in 2016. The frequency of student software use is consistent with their software competence, and may suggest that through more frequent use, students are likely to become more ICT competent.

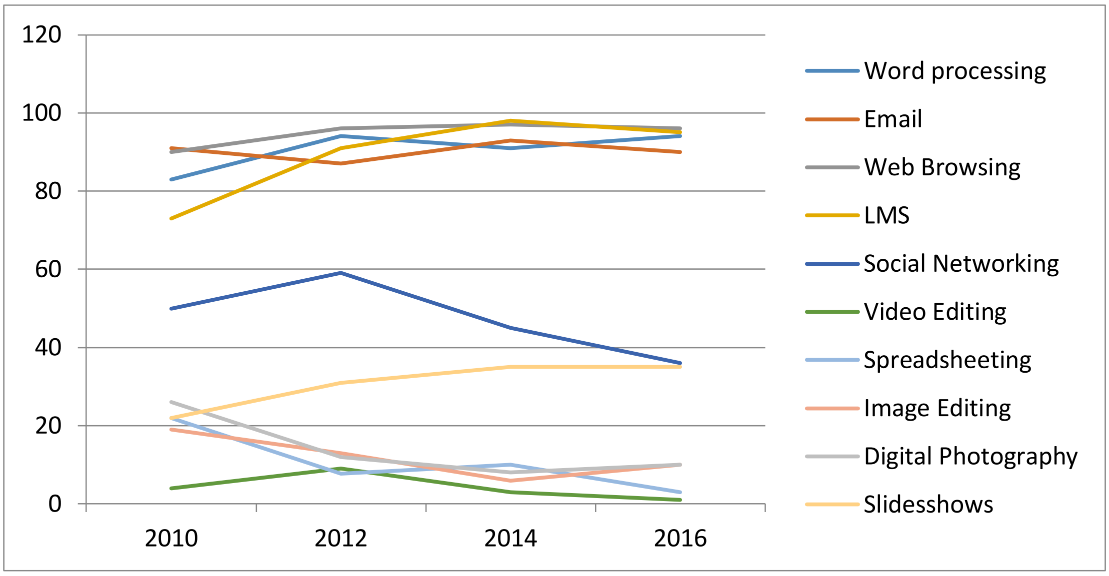


Figure 9: Trends in frequency of use of software in study (at least weekly)

This study has seen a slight rise in word processing use but a reduction in the use of the virtual learning environment in a weekly basis (Figure 9). An unexpected result is Social Networking, with a reduction from 59% in 2010 to around 35% of students indicating weekly use for study purposes during the semester. This indicates that less students are currently using social networking tools for study tasks. The authors believe that the drop of students using social networking for study maybe because they prefer to use the social networking function in Blackboard for their group studies.

Internet access

Figures 10 and 11 illustrate the ways that students have accessed the Internet chronologically, as identified in Figure 10 for 2016 and Figure 11 for 2008.

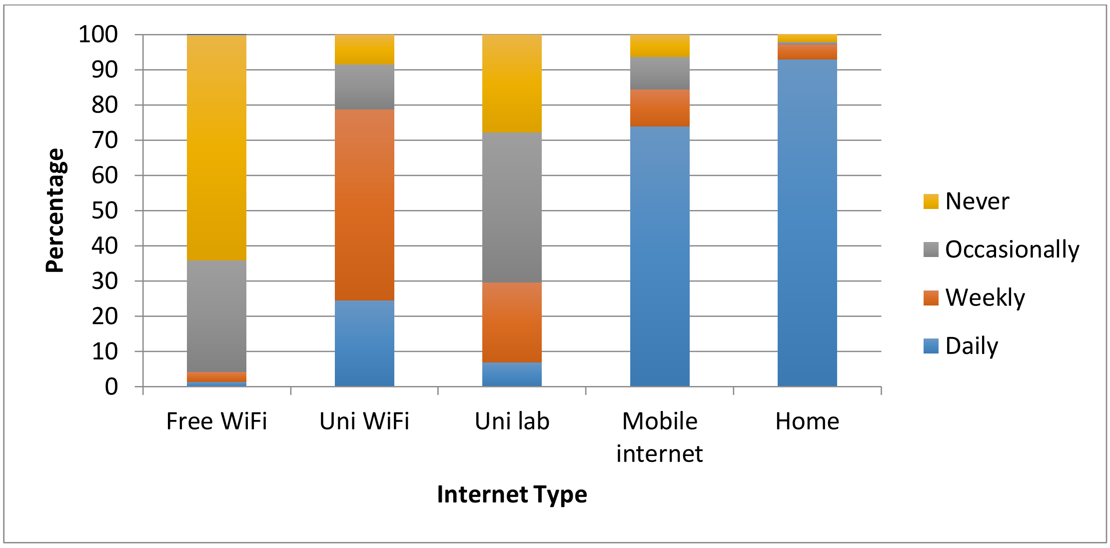


Figure 10: Student Internet use in their study (2016)

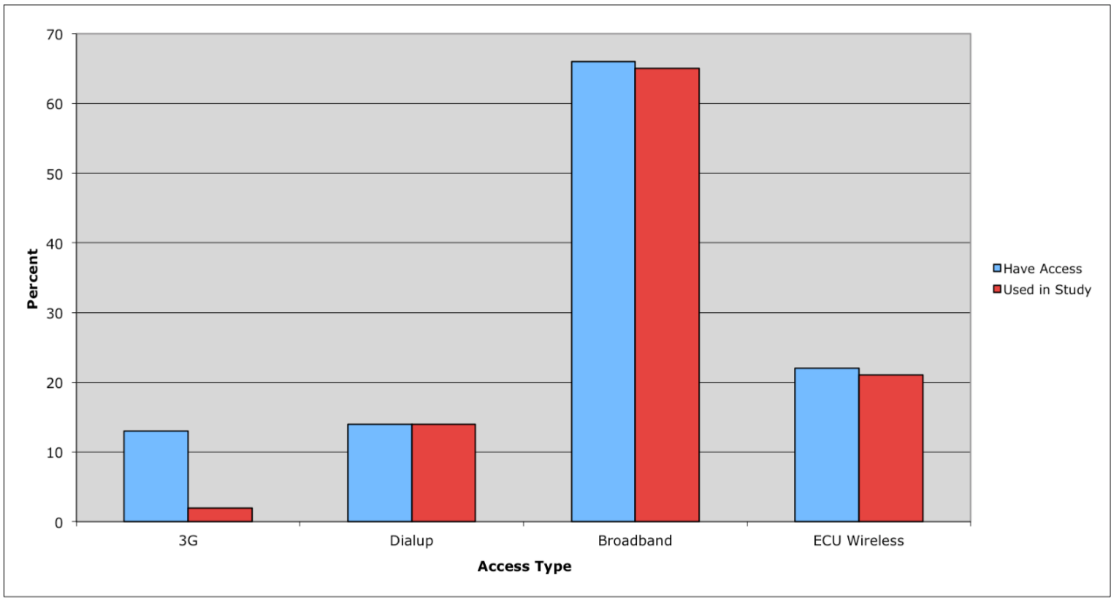


Figure 11: Student Internet use in their study (2008)

As might be expected with the advance in digital technologies, the pattern of accessing Internet is drastically different to the distribution from the 2008 survey with regard to both university wireless and 3G phone access to the internet. In 2008, just over 20% indicated using university wireless and just over 10% indicated using 3G devices to access the Internet. By 2016 this has changed to 91% accessing the Internet by using university wireless and over 95% indicating the use of 3G devices. Once again this indicates a huge shift toward mobile devices with built mobile Internet for student use.

Conclusions and implications

In summary, the outcomes from the 2016 survey are far more positive than those obtained in 2008. They continue the positive trends in applying digital technology in education evidenced in previous years studies. Increases in technology ownership by Education students have been quite dramatic particularly the ownership of laptop computers, smart phones and tablets. As could be anticipated, students are being required to use digital technology more often in their learning at University, indicative of a continued shift towards the use portable devices in tertiary education. The students have some level of competency in using most of the software skills, with the exception of video editing. The use of devices in the University setting has seen a move from the use of computer labs to personal devices and mobile Internet. The changes in the ownership of technology devices, student ICT skills and use, and Internet access reveals that students are taking more control of their using technology in learning, which may suggest the lecturers and unit coordinators to take consideration of designing courses on how to integrate portable devices into teaching and learning and the University to provide more technological trainings such as video editing for pre-service teachers. It also may suggest a bright future of university policies such as the BYODD policy to encourage students to bring their own digital devices.

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A Framework for Assessment of the Features of Technological Learning Activities in Elementary School Handicraft Education

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Abstract

The aim of this study is to propose a framework that features technology education components for assessing the characteristics of learning activities in elementary school handicraft education in Japan. We extracted the feature of technology education based on the concept of technological literacy in U.S. and National curriculum of Japan. Also, we carried out the survey on elementary school teacher et al about consciousness toward technology education. We then created a framework consisting of the following five components by comparing the result of the survey and extracted features: (1) understanding of technology; (2) creative activities using technology (purpose, design, idea, and exploration); (3) experience in using tools (scientific principle, usage, and safety); (4) experience in using materials (characteristics, selection, and processing); and (5) technology evaluation and management. It is considered important for future elementary school handicraft class to possess these components.

Keywords: Technological Learning Activities, Framework for Assessment of Learning Activities, Handicraft classes, Technology Education, Japan

Introduction

In many countries, technology education cultivates students' technological literacy using a systematic curriculum from kindergarten through grade 12 (K–12). However, several countries execute technology education in elementary school in the form of an integrated approach with other subjects, such as crafts, mathematics, and science education. Technology education is officially taught through junior high school technology and home economics classes, according to Japan's national curriculum. This curriculum also connects elementary school handicraft class with junior high school technology class (MEXT, Government of Japan, 2008a). As such, appropriate alignment between craft education in elementary school and technology education in junior high school is important in Japan. However, many elementary school teachers consider handicraft classes to be in the same category as junior high school art classes. From this, teaching with unified contents and methods, which is appropriate as technological literacy, are not practiced in the technology education in Japanese elementary schools. Therefore, in elementary school handicraft classes, teachers must correctly instruct students based on the technological characteristics of learning activities.

Many studies have investigated the relationship between elementary school handicraft classes and junior high school technology classes in Japan. For example, in Niigata Prefecture and Tokyo Metropolis, students actually made products in elementary school classes under conditions specified by the government of Japan, all with the aim of introducing technology education into elementary school (Moriyama 2009, Yaguchi Elementary School et al 2004-2006). Also, there was other example of practice to learn technology, students designed paper models in extra curriculum (T. Yamada & Y. Matsunaga 2015). Yata & Moriyama(2011) investigated elementary school teachers' awareness about technology education. They found that elementary school teachers positively answered students to design and make products, but had a negative attitude toward technology education in elementary school. However, these studies failed to reach any sufficient consensus on appropriate learning activities in elementary school handicraft classes.

To construct a framework for assessing learning activities in technology education, the present study compared the United States' and Japan's goals for technology education, in addition to investigating nursery school, kindergarten, and elementary school teachers' awareness about technology education. The obtained results were compared, and the necessary framework for assessing future technological learning activities in elementary school was constructed.

Examination of a framework for assessing learning activities

To construct a framework for assessing learning activities in technology education, the goal of technology education must be clearly comprehended. Therefore, the goals for technology education were compared between the United States and Japan, from which we extracted the learning content necessary for technology education.

Concept of technological literacy

According to the Standards for Technological Literacy proposed by ITEEA/ITEA in 2002, technological literacy among students of technology education refers to the students' ability to understand, use, evaluate, and manage technology.

This is based on that idea that a country's future technology is affected by the actions of its people. Although people generally depend on technology in their daily lives, people are barely interested in and have little knowledge of the basic characteristics of technology. Technological literacy is viewed as an ability to cope with such circumstances. The technological literacy curriculum describes in detail the technology content that students are to learn at each stage of development from kindergarten through the third grade of senior high school. In the United States, modules learning approach are primarily adopted in school lessons based on this concept of technological literacy.

Goal of technology education in Japan

In Japan, technology education is performed only in junior high school. According to the 2008 National Curriculum Standards for Junior High School, the goal of learning in technology class is to cultivate the students' ability and attitude to understand, evaluate, and use technology (MEXT, Government of Japan, 2008c). This curriculum provides the following three instruction items: (1) understanding technology used in daily lives and industries, (2) designing and making products, and (3) cultivating an attitude to appropriately evaluate and use technology. With regard to these instruction items, teachers must cultivate students' capacity for inventive ideas and their sense of ethics regarding technology.

Goal of elementary school handicraft classes in Japan

According to Japan's National Curriculum Standards for Elementary School, handicraft class aim to cultivate students' basic ability for imaginative and creative activities and to nurture students' aesthetic sensitivity (MEXT, Government of Japan, 2008d). This curriculum provides the following four instruction items: (1) enriching sensitivity through activities of expression and appreciation, (2) experiencing the joy of creation, (3) cultivating a basic ability for imaginative and creative activities, and (4) developing an aesthetic sensitivity. The creative activities are mainly activities where students select a material and devise the shape and color suitable for the material based on what they want to express.

Thus, Japan's elementary school handicraft class have been strongly connected to junior high school art classes. However, the 2008 Elementary School Teaching Guide for Japanese Course of Study: handicraft class and technology class highlighted this connection (MEXT, Government of Japan, 2008b).

Construction of a framework

The goal of Japan's technology education agrees well with the concept of technological literacy proposed by ITEEA/ITEA. Both elementary school handicraft classes and technology education consider experiential making activities important. In particular, making activities in handicraft classes include activities where students select a material, use a tool, and strive to create a product based on their free ideas, which contains important processes of learning design, processing, and materials in technology education.

In general, when teachers make students learn something, it is important for teachers to consider whether the subject matter is appropriate for the students at their current developmental stage.

Regarding this issue, Katsumoto and Moriyama (2013) investigated the appropriate time for students to learn how to design and make products (Figure 1). We found that consistently engaging in creative experiences was an important factor in ensuring that elementary and junior high school students are motivated by technological activities. For fifth- and sixth-grade elementary school students, experience in using various tools and materials was important, respectively. In elementary school handicraft classes, from the perspective of technology education, it was considered important to introduce learning activities using various tools and materials in the aforementioned creative activities.

As previously mentioned, to introduce technology education into Japan's elementary school handicraft classes, the following five components are considered necessary to include in the learning activities' framework:

(1) Help students understand technology that supports their daily lives and society
(2) Help students understand how to perform creative activities using technology
(3) Allow students to use various tools
(4) Allow students to use various materials
(5) Help students acquire the ability to evaluate and manage technology that supports their daily lives and society

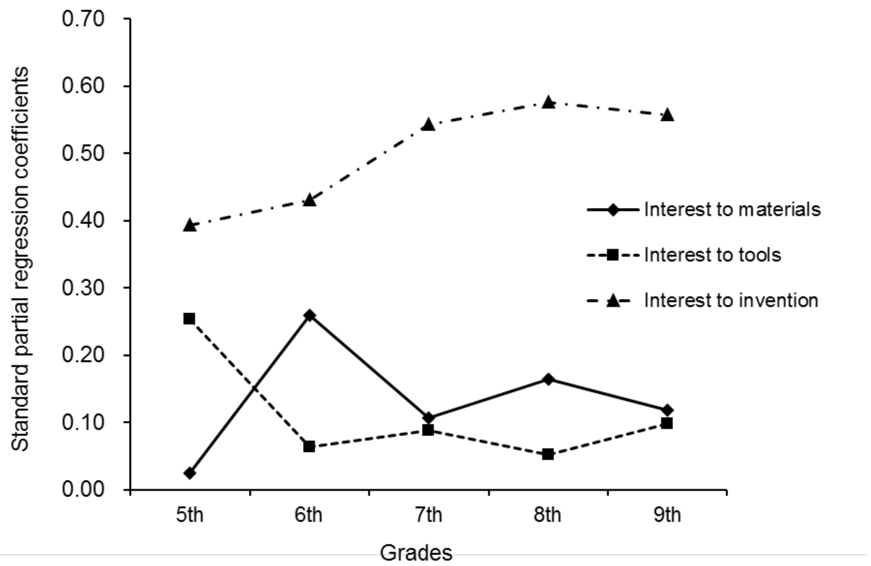

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Figure 1: Differences in the effects of consciousness on motivation for designing and making

Next, we investigated nursery school, kindergarten, and elementary school teachers' awareness about these components. Specifically, we investigated these teachers' awareness about creative activities, experience in using tools, and experience in using materials, which were considered important in both handicraft classes and technology classes.

Subjects

This study investigated 37 nursery school, kindergarten, and elementary school teachers in Hyogo prefecture, Japan.

Methods

The subjects were asked to respond to the following items in the form of free description: (1) the achievements of learning tools expected of students, (2) the achievements of learning materials expected of students, and (3) the achievements of creative activities expected of students.

Results

For each item, the obtained comments were collected and inductively classified into three categories, which are described below. Consequently, it was suggested that regarding the experience in using tools, nursery school, kindergarten, and elementary school teachers expected students to use tools safely after understanding the scientific principle of each tool. Through their experience with the materials, these teachers expected students to acquire knowledge on the characteristics of each material and to select and process them. Regarding creative learning activities, these teachers expected students to think about the purposes of their products and make efforts to designing and make products based on their free ideas and exploration.

The ways that students were expected to look at and think about tools:

Knowledge on the scientific principle of each tool (28 responses)

Typical comments included: "I want students to think about the reason for the shape of a tool," "I want students to understand the easy-to-use mechanism of a tool," and "I want students to be interested in the mechanism and history of a tool."

Skills for using tools safely (15 responses)

Typical comments included: "Since tools are convenient but sometimes dangerous, I want students to use tools carefully and quietly," "I want students to not get hurt when using tools," and "I want students to understand that lack of care may result in injury to themselves and others."

Skills for using tools correctly (14 responses)

Typical comments included: "I want students to understand that if they use tools correctly, they can design and make products beautifully and efficiently," "I want students to select tools correctly according to the purpose," and "I want students to become aware of the relationship between the usage of a tool and the result through experience."

The ways that students were expected to look at and think about materials:

Knowledge on the characteristics of each material (17 responses)

Typical comments included: “I want students to design and make products in which the characteristics of materials, such as wood and metals, are utilized,” “I want students to be always interested in the materials of daily necessities,” and “I want students to know the differences among materials, such as papers and plastics.”

Ability to select appropriate materials (12 responses)

Typical comments included: “I want students to think about the smell, touch, and preparation time of a material,” “I want students to have the ability to discriminate and classify materials,” “I want students to know the place of a material to be used,” “I want students to select a material suitable for their purpose,” “I want students to think about what are the type and usage of a material,” and “I want students to be aware that when the type of material is changed according to the purpose, the result is different.”

Ability to handle various materials (8 responses)

Typical comments included: “I want students to know that common discarded materials can be used as materials,” “I want students to design and make products using many types of materials,” and “I want students to know that there are many materials surrounding them.”

The ways that students were expected to look at and think about creation:

Ability to think freely (16 responses)

Typical comments included: “I want students to consider their idea important and to repeatedly address a matter,” “I want students to consider their personality important,” “I want students to making what they want after stretching their imagination of it,” “I want students to making a product without imitating others,” and “I want students to consider out-of-the-box thinking important.”

Spirit of inquiry (15 responses)

Typical comments included: “I want students to think of an easy-to-use and convenient product,” “I want students to think about something versatilely,” “I want students to imitate a product and then making a one-step-forward product,” “I want students to making a product while adopting various ideas and stimulating each other,” and “I want students to making a product through repeated trial and error.”

Ability to consider purpose (4 responses)

Typical comments included: “I want students to aim to making an easy-to-use and useful product,” “I want students to think about and making a product using empty boxes and wood, with which everybody can play,” and “I want students to always observe materials and consider the usage of them.”

Discussion

As we found from the investigation’s results, it is considered important to design and make versatile products through creative activities, as described in Section 2.4 (2). This is an important condition for students to understand the relationship between technology and society, as well as between technology and their daily lives. From this, students will also learn to recognize design's importance from the perspective of technology education. "Idea" and "exploration" can be added as subcategories below the corresponding framework category, as extracted from the investigation. Similarly, "scientific understanding of a tool's principle," "methods of using tools correctly," and "methods of using tools safely" can be added as subcategories of experience in the use of various tools described in Section 2.4 (3). Additionally, "understanding the characteristics of a material," "the ability to select appropriate materials," and "methods to process materials" can be added as subcategories of experience in the use of various materials described in Section 2.4 (4). Table 1 shows the framework we constructed based on these considerations. This table describes nursery school, kindergarten, and elementary school teachers' awareness about technology education while considering its goal. Therefore, it is expected that a consensus on the technological learning activities that should be performed in elementary school can be easily reached. However, contents of this framework reflected the consciousness of teachers at nurseries and elementary schools in Japan who are not familiar with technology education yet. Therefore, several things are different when the framework is compared with Standards for Technological Literacy. As an important difference, it can be pointed out that number of design related subcategories for learning creative thinking skills are limited. The reason for the subcategories of this category being only Idea and Exploration are thought to be because handicrafts classes at elementary schools are strongly influenced by the fine art education. It is feared that current teachers of nurseries and elementary schools in Japan do not recognize the importance of creative skills such as prototyping or brainstorming while designing. To deal with this issue, it is considered that constructing learning activities for elementary school teachers to teach technological designing process to their students in easy way is necessary.

Table 1: Framework for learning activities in elementary school handicraft education

Framework categories	Subcategories
(1) Help students understand technology that supports their daily lives and society	
(2) Help students understand how to perform creative activities using technology	Idea Exploration
(3) Allow students to use various tools	Scientific understanding of a tool's principle Methods of using tools correctly Methods of using tools safely
(4) Allow students to use various materials	Understanding the characteristics of a material The ability to select appropriate materials Methods to process materials
(5) Help students acquire the ability to evaluate and manage technology that supports their daily lives and society	

Conclusion and Future Tasks

By comparing the goal of technology education with teachers' awareness, this study has constructed a framework for assessing technological learning activities in elementary school handicraft classes. In the future, we must assess the existing learning activities in handicraft classes using this framework, and improve these activities from the perspective of technology education. However, in Japan, almost all elementary school teachers lack a teacher's certificate for technology education. Therefore, it is difficult to rapidly introduce technological learning activities into handicraft classes. It is possible that by implementing artistic and creative activities in stages, in such a way that introduces technological components and education on materials and tools prior to true technological learning activities, entry-level technological manufacturing activities can be introduced into elementary school handicraft classes.

In the future, it will be necessary to actually design these learning activities, experimentally practice them, and verify their effects.

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Meta-analysis on the Effect of Convergence Education (STEAM) based on Technology

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Abstract

Convergence education is synonymous with STEAM, which adds Art to STEM used worldwide. However, STEAM is more used than STEM in Korea. This study is to analyze the effect of convergence education based on technology in Korea (STEAM), using the meta-analysis. Thus, the literature reviews of 3 times have been conducted with the keywords of 'technology', 'practical arts', 'convergence education', 'STEAM', and 'T-STEAM' based on RISS, National Assembly Library, and Google Scholar service and as a result, a total of 30 papers, including 16 dissertations and 14 articles in journals were finally selected. the results of meta-analysis with random effects model showed that the overall effect size of convergence education based on technology was .628. Results of investigating the differences in effect in accordance with categorical variables are as follows. Firstly, the convergence education based on technology is found to have the largest effect size targeting the female students. Secondly, the convergence education based on technology is found to have a larger effect size in primary education than in secondary education. Thirdly, the convergence education based on technology is found to have a larger effect size in non-curriculum classes rather than in curriculum classes. Fourthly, the convergence education based on technology is found to have a larger effect size in developing the educational program based on STEAM model than in developing the educational program based on the pedagogy model. Fifthly, in case the effect of the convergence education based on technology is classified into 4C of core competence (Creativity, Communication, Convergence, and Consideration) of which the largest effect size is shown in the area of creativity. The results of analysis on the difference in effectiveness in accordance with the number of participants and the duration of treatment, which is a continuous variables, showed that the number of participants and the duration of treatment did not have a significant influence on the effect size.

Keywords : Convergence education, STEAM, STEM, Meta-analysis

Introduction

Now with the convergence of technologies, convergence of knowledge, and convergence of services, it is no exaggeration to call it the era of convergence as convergence is emphasized in various areas. Such flow is not unrelated to education; in 2010, Ministry of Education of Korea has suggested STEAM at the elementary/middle-school level, that is, reinforcement of convergence education, as a plan to foster world-class talents in science and technology. STEAM is a term first coined by Yakman of Virginia Tech in 2006, and according to Beak et al. (2011), the objective of convergence education is fostering talents that are capable of creative and integrative problem-solving. Here, creativity and problem-solving ability are also considered important in technology education, and as claimed by Liao (1998) that integrative approach to math, science, and engineering curriculum is essential in order to grow technological aptitude, the significance of convergence education with respect to technology education can be said to be enormous.

In case of technology education, not only the elements of STEAM, but also STS (Science Technology and Society), MST (Mathematics Science and Technology) and such integrative education have been persistently attempted, so the study on convergence education has been more active compared to other curriculum (Kim, 2014). Also, considering the intent and objective of convergence education, there are claims that technology curriculum should perform the key role in convergence education (Kim, 2014). In line with such circumstances, the technology-centered convergence education had seen various forms of studies such as model development, program and curricular material development, etc., and it has been revealed to be effective in various areas such as creativity, problem-solving ability, attitude, interest, etc. On the flip side, however, despite the same factors have been measured, each study show contrasting or contradicting results in the suggested effects, and there is no agreement on the variables influencing the education effect.

Based on the above discussion, there was the need to suggest consistent and objective study results through integrative analysis of each study result on technology-centered convergence education, and one of the analysis methods that can be used here is the meta-analysis method (Hwang, 2015; Kim et al, 2016). Accordingly, this study intends to conduct a meta-analysis on the overall effect size of technology-centered convergence education, and the effect of technology-centered convergence education according to additional various variables shall be examined so as to find the direction for future technology-centered convergence education. The study objectives to achieve such study purpose are as follows. First, the overall effect size of technology curriculum convergence education shall be analyzed. Second, the effect difference according to categorical variables of technology curriculum convergence education shall be analyzed, Third, the effect difference according to continuous variables of technology curriculum convergence education shall be analyzed.

Theoretical Background

Convergence education

Convergence education is synonymous with STEAM, which adds Art to STEM used worldwide. For a more detailed examination of the term of convergence education, the definition of convergence education proposed by Ministry of Education of Korea states that convergence education is the education which increases the level of interest and understanding for science technology, and grows science/technology-based convergent thinking and problem-solving ability. Convergence education of Korea is somewhat different from foreign cases in its purpose and direction; while U.S. executes convergence education from the perspective of learning such as academic achievement improvement, development of teacher expertise, and encouragement of advancement in science and engineering sector, Korea does so from the perspective of motivation for learning such as efficacy, confidence, and interest in science and technology along with the perspective of learning (Beak et al, 2011).

Beak et al. (2011) states that the objective of convergence education is to increase the interest and understanding on knowledge, process, and nature of science technology and engineering-related fields, and foster human talents that are creative and capable of integrative problem-solving, and proposes the 4C core competences of convergence education as in Table 1.

Table 1. Core competence and Factor of STEAM

Core competence	Meaning	Factor
Creativity	Promote creation & innovation	Creativity, problem-solving ability, problem-identifying ability, information-collecting ability, information-analysis ability, decision-making ability, evaluation ability
Communication	Communicative ability	Lingual communication, audio-visual communication, academic ability, global communication ability, communicating attitude, cooperating attitude

Convergence	Understand & utilize convergent knowledge	Understanding of various knowledge, understanding of connectivity and relationship among knowledge, creation of convergent knowledge of new value perspective, utilization of convergent knowledge
Caring	Practice concern & respect	Self-love, confidence, sense of self-identity, sense of self-efficacy, concern of others, respect for others, multicultural understanding, sensibility

Meta-analysis

The traditional study method currently in practice has various limitations such as the biased sample, descriptive explanation, opacity of method to reach conclusion, excessive dependence on statistical significance, etc. Also, it shows vulnerability to various errors such as publication, dissemination, confirmation, etc. Meta-analysis is an integrative analysis method which systematically and objectively analyzes various studies of the same subject in order to draw a comprehensive and objective conclusion beyond the limitations of the existing study method. That is, meta-analysis is a systematic method and means which integrates various results into one result by utilizing various empirical studies conducted beforehand, and through this, more insightful and analytic information on that subject can be provided. As such, meta-analysis is valuable in that it can estimate the parameter more accurately, and that the factors that can affect the results can be analyzed to minimize error and distortion (Hwang, 2015).

Beyne (2010) proposed 7 steps to conduct meta-analysis, where the researcher must be equipped with statistical knowledge for quantitative analysis and expert knowledge/experience in the research field. The first step is to select the study subject and contents, which is to propose the study purpose in detail like any other study. According to the study purpose proposed here, the related documentation, effect size type, and analysis methods shall vary. The second step is to search the related documentation suited to the study purpose, and one of the study selection criteria is PICOS proposed by Wood and Mayo-Wilson (2012). When selecting related documentation, one must be cautious of publication bias. In general, published studies are mainly composed of statistically significant studies, so insignificant studies may be overlooked. As such, the inclusion of only published studies in related documentation with significant values is called the publication bias, which is a factor threatening the internal validity of meta-analysis, so it is necessary to try to include unpublished studies. The third step is to execute qualitative verification of the related documentation selected in the previous step, and to code the study name, publication year and type, sample characteristics and type, measurement tools, effect size, etc. The fourth ~ sixth steps are to analyze the coded data, where the effect size of each study is calculated and then the average effect size, statistical significance, and error are verified, and then such result values are reported in the final seventh step.

When conducting meta-analysis, if data is reported to be heterogeneous, that is, if the population of target studies is not homogeneous, the analytic category should be materialized and the effect for study results should be analyzed. The method to materialize analytic category involve intuition of the researcher, theoretical considerations, and common variable extraction (Guzzo, Jackson, & Katzell, 1987). In this study, through theoretical considerations and common variable extraction, the categorical variables of gender, study subjects, education type, and education effect have been categorized. Also, through common variable extraction, continuous variables such as participant count and treatment period have been categorized.

Study Method

Data collection

In order to conduct meta-analysis, appropriate documentation review and accurate statistical analysis are necessary. Accordingly, this study collected data through documentation review over three phases by two researchers experienced in meta-analysis, and the coding and result interpretation have been conducted through discussion process later on.

For the data collection procedure, the first documentation review was conducted using National Assembly Library, RISS (Research Information Sharing Service), and Google Scholar Service with the keywords of 'technology,' 'practical course,' 'convergent human resource education,' 'STEAM,' and 'T-STEAM.' Then, with reference to the bibliography of the collected resources, the articles not discovered from the first documentation review were collected as the second phase. As the result of documentation review over two phases from June 10^{th} to July 1^{st}, 2016, 149 degree theses and 248 academic journal articles, with total of 397 articles were found. Afterwards, through third-phase documentation review, 8 articles published both as degree theses and academic journal articles, 36 articles without detailed information, 67 articles not centering on technology curriculum, and 256 articles that cannot be subjected to meta-analysis as effect size cannot be calculated were excluded, coming to the final selection of 16 degree theses and 14 academic journal articles, with total of 30 articles.

In this study, in order to check for publication bias, the funnel plot with effect size as x-axis and standard deviation as y-axis were proposed as in Figure 1. From the examination of Figure 1, while there are a few outliers, the left/right side of funnel is mostly symmetrical, thus it is difficult to say that there is a publication bias, but since the publication bias identification procedure should be conducted by a multilateral method, so fail-safe N was taken into consideration (Rothstein, Sutton, & Brenstein, 2006). First, as the result of examining fail-safe N of the traditional method, it was found that 9,885 studies should be added in order to nullify the entire effect size. This is a value exceeding 5k+10, which is the standard proposed by Rosenthal (1979), and thus this study result can be considered reliable. Next, as the result of examining fail-safe N of Orwin, when the omissible effect size is assumed to be 0.1, it was found that 103 studies were omitted. Here, considering that this study analyzed 30 results, it is hard to say that 265 studies have been omitted. In conclusion, as the result of analysis on error level using funnel plot and fail-safe N, it can be said that the publication bias of this study is not very large.

Effect size

Effect size refers to the statistical value about the direction and size where the discrepant or contradicting study results or study effects can be compared, and even if the studies of the same subject are analyzed, it is necessary to convert to the identical criteria such as effect size if the study method and criteria differ (Oh, 2002). The standardized mean change difference calculation method used in this study is as follows.

Study Result

Overall effect size

In this study, with the target of 30 articles in total, 73 effect sizes were found, and here, the violation of independence assumption should be noted. For example, from the examination of the articles utilized in this study, a single study suggested various results such as academic achievement, interest, creativity, and learning attitude as the effect of the convergence education. In such cases, multiple effect sizes are analyzed with the same sample, and this becomes a factor threatening internal validity. In order to resolve this, this study used Shifting unit of analysis method. This method uses each individual study as the analysis unit when calculating the entire effect size, so that only one effect size is calculated, and uses all individual groups as the analysis unit when calculating the effect size of subordinate groups, so that multiple effect sizes are calculated (Cooper, 2010).

In case of the articles utilized in the study, the study subjects and treatment methods vary, so the data utilized in this study were expected to be mutually independent, that is, heterogeneous.

Accordingly, homogeneity test was conducted, and as expected, the effect sizes were found to be mutually heterogeneous (Q=223.974, df=29, p=.000). Also, I^2 value was found to be 87.052, showing that the effect sizes of individual researches were heterogeneous at about 87% level. Generally, I^2 value of over 75% can be interpreted as very high heterogeneity, so the data utilized in this study was judged to have very high heterogeneity (Higgins & Green, 2011). Accordingly, meta-analysis was executed with random effect model, and as the result, the overall effect size of technology-centered convergence education was found to be .628. Here, in the 95% confidence interval, the minimum was found to be .500, and maximum to be .755. As such, since '0' is not included in the confidence interval, the overall effect size can be said to be statistically significant (Hwang, 2015). The details on this are as in Figure 2.

The overall effect size of .628 is moderate or higher, so the overall effect of technology-centered convergence education can be said to have a moderate or higher effect size (Cohen, 1988). The result simply that the overall effect size is moderate or higher, however, can pose difficulties for readers in interpreting articles. Accordingly, U3 for the overall effect size was examined, and as the result, the overall effect size .628 corresponds to 73.25 percentile, and this means that, as in Figure 3, when the average of the control group with general education is 50%, the average of the experiment group with technology-centered convergence education is about 73%, showing about 23% increase.

Effect difference according to categorical variables

In order to analyze the effect difference of technology-centered convergence education according to categorical variables (education effect, gender, school class, education type, development model), the sub-group analysis was conducted as follows.

Education Effect

As the result of analyzing the effect size difference per core competence according to the execution of technology-centered convergence education, technology-centered convergence education showed the highest effect in the creativity area, and the lowest effect in convergence area. Also, Q value was 16.232 (df=3. p<.001), showing significant differences in effect size between groups.

Gender

Technology-centered convergence education showed the highest effect when conducted on female students only, and the lowest effect when conducted on both male and female students. All showed moderate or higher effect size, however, and as the result of verification for differences between groups, Q value was .002 (df=2, p=.999), showing that the effect size between groups was not statistically significant.

School class

As the result of analyzing the effect size difference according to school class, the technology-centered convergence education, conducted in elementary-level education showed a higher effect size compared to middle-level education. Q value was also found to be .129 (df=1, p=.719), however, showing that the effect size between groups was not statistically significant.

Education type

As the result of analyzing effect difference divided into cases where technology-centered convergence education was conducted through curricular education and cases where it was conducted through creative experience activities or club operations and such non-curricular education, the technology-centered convergence education conducted through non-curricular education was found to have a higher effect size than that conducted through curricular education. The Q value for this, however, was also found to .530(df=1, p=.467), so the effect size between groups was not statistically significant.

Effect difference according to continuous variables

In order to analyze the effect difference of technology-centered convergence education according to continuous variables (participant count, treatment period), meta-regression analysis was conducted. The education period was from at least 3 classes to at most 34 classes, and the number of students was from at least 14 to at most 552. As the result of the analysis, the participant count and the treatment period were found to have no significant influence on the effect size.

Discussion and Proposal

First, as suggested in the study results, technology-centered convergence education is more effective when conducted in non-curricular hours than in curricular hours. Such differences were found to be greater for elementary level; the technology-centered convergence education through curricular hours in elementary-level education showed a low effect size of .384, while execution in non-curricular hours showed a high effect size of .702. Also, such results were statistically significant as well (Q=4.992, df=1, p=.025). From such aspect, it is necessary to develop various education programs so as to execute technology-centered convergence education during non-curricular hours such as after school or club/creative experience activity hours.

Second, from the perspective that one of the education objectives proposed by the curriculum of Korea is creativity education, and that the objective of convergence education is also to foster creative/convergent human resources, the effect size over 1 (85.54 percentile) in creativity area can be said to be a promising result. As such, the high effect size in creativity area can be speculated to be due to the fact that there is agreement not entirely but substantially, through continued interest and studies in creativity, and accordingly, the researcher conducting technology-centered convergence education is highly likely to have conducted the study after sufficient considerations on creativity. This presents us, however, with another implication. Currently, the convergence education of Korea is mostly studied centering on areas of creativity, convergence, and caring, and the studies on communication area are rather inadequate. The communication area as suggested in Choi et al (2013) includes communication ability, information processing ability, interpersonal relationship ability and such. Also, the personality area, emphasized along with creativity area in the current curriculum, includes not only the ability to care for others and self, but also the communication ability necessary for living as a member of the society. From such aspect, it is necessary to conduct studies on communication area actively in order to connect the technology-centered convergence education organically with curriculum and achieve more effective education.

Third, the meta-analysis method used in this study conducts analysis based on quantitative data, and thus has the advantage that it can draw objective and integrative conclusion, but has difficulties in suggesting qualitative discussion. That is, amongst various discourses suggested on the subject of technology-centered convergence education, this study attempted an agreement on the quantitative aspect, and in future, it is necessary to attempt to qualitative aspect through qualitative study methods.

Fourth, as suggested in the data collection method, 36 studies that cannot be subjected to meta-analysis due to the omission of substantial information had to be excluded from the analysis target when collecting data. Now that there are many cases where precedent studies are used not only for simply theoretical considerations, but also as direct study targets as in meta-analysis and systematic documentation review, so in future, the researchers should take more responsibility, and need to take efforts such as clearly describing study designs and study progression process, and describing the study results in detail without omissions.

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Proposal for Teaching Materials for Information Technology Education based on International Comparison of Students' Information Literacy

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Abstract

The purpose of this research is to propose the teaching materials about information technology (IT) education in Japan based on international comparison of students' information literacy.

We conducted a survey in junior and senior high schools in Japan, Korea, China and Indonesia to analyze various students' motivation for the acquisition of Information - the Utilizing Abilities and their knowledge level about IT. As a result, students in Japan would mainly like to use IT as hobbies and at home. In contrast, students in China and Indonesia would like to use it as part of their professional jobs. Also, Japanese and Indonesian junior and senior high school students' motivation were higher than in Korea and China. However, in Japan, scientific understanding of information was lower than other two viewpoints. And, all of the average scores about the knowledge of IT in Japan were lower than in junior and senior high schools of other countries.

From the results above, it was suggested that promoting scientific understandings of Information was very important for Japan's IT education. So, the teaching materials of logic circuit are proposed for it. It was expected that students could acquire logical thinking abilities through the learning activities by using proposed experimental device for a logic circuit.

Keywords: information technology(IT), logic circuit, motivation, knowledge, teaching materials

Introduction

The purpose of this research is to propose the teaching materials about information technology (IT) education *in Japan* based on international comparison of students' information literacy.

The subject of IT in Japan, called *Information Basic*, first appeared in 1989 as a part of technology education in junior high schools as a compulsory subject. In 1998, this subject was changed to *Information and Computer* and became compulsory subject for everyone, in the same year, the subject information was introduced as a compulsory subject in high school. In 2012, the government curriculum guidelines for junior high schools were revised and *Information and Computer* was changed to *Technology of Information Processing*. Also, government curriculum guidelines for senior high schools were revised in 2013 and the subject was changed to common subject *Information* (The Ministry of Education, Government of Japan, 2008ab). Recently, the Information-oriented progress in society is remarkable. It is also important to consider the system of IT education in this society.

One of the approaches to the problem is the method of grasping the situation of IT education from an international viewpoint. International comparison between two countries such as Japan and Thailand, Japan and China were conducted in the previous research. However, there have been no researches where three countries were taken into consideration. Moreover, these were conducted with the use of secondary documents of the education system and curriculum.

In this research, Korea, China and Indonesia which both have similar cultures to Japan were targeted and the places were visited directly and international comparison of information education was conducted from students' point of view (Masumoto, et.al. 2007, Hayashi, et.al. 2005, Motomura, et al. 2005).

The significance of this study is a survey by foreign countries in the similar cultural sphere having contents of the curriculum like Japan.

2. Outlines of IT education in Japan, Korea, China and Indonesia

Japan

IT has been a compulsory subject since 1998 in junior and senior high schools in Japan. However, this subject has been provided as a part of the technology subject in junior high schools.

Information and Telecommunications Network, *Design and Manufacture of Digital Work* and *Programming* constitute the main part of computer studies (MEXT, Japan 2003).

Korea

In Korea, the bulk of computer studies are constituted by *Human and Computer*, *Basis of Computer*, *Word Processing*, *Network Technology and the Internet* and *Multimedia* (Ministry of Education, Korea 2008 - 2015).

China

In China, *Computer Literacy*, *Network*, *Word Processing*, *Network Technology and Internet* and *Multimedia* are the main parts of computer studies (Ministry of Education, China 2008).

Indonesia

In Indonesia, *Computer Literacy*, *Network*, *Word Processing*, *Network Technology and Internet* and *Multimedia* are the main parts of computer studies (Ministry of Education, Indonesia 2013).

Japan **Korea** **China** **Indonesia**

Figure 1. Overview of Lessons in Senior High School

In this way, Information education of each country is a similar curriculum for junior and senior high schools.

Therefore we investigated using the contents of Japanese Information education curriculum.

Survey of international comparison

Method

The knowledge of students and their attitude towards education concerning information technology in Japan, Korea, China and Indonesia in junior and senior high schools were analyzed (Motomura, et.al. 2015). The survey was conducted at the last school year of junior and senior high schools.

After that, the teaching materials about logic circuit were developed.

Subjects

The survey was carried out from the years of 2013 to 2016. Subjects were selected from students who go to the ordinary public schools that are providing along with country's curriculum. The response rate was from 97.6 to 100%. The details of target students are represented in Table 1.

Table 1: Subjects of the Survey

Japan	Boys	Girls	Total
Junior High School Students	126	140	266
Senior High School Students	65	59	124
Total	191	199	390
Korea	Boys	Girls	Total
Junior High School Students	90	27	117
Senior High School Students	122	79	201
Total	207	111	318
China	Boys	Girls	Total
Junior High School Students	73	48	121
Senior High School Students	53	70	123
Total	126	118	244
Indonesia	Boys	Girls	Total
Junior High School Students	64	56	120
Senior High School Students	25	92	117
Total	89	148	237

Items

Items for evaluating students' awareness about IT.

The following question items were set up in order to acquire basic information about junior and senior high school students' awareness about IT. This question items were made with reference to Japan statistical yearbook 2011 - 2015 of Statistics Bureau, Ministry of Internal Affairs and Communications.

How would you like to apply your knowledge about computers in the future?

a) I would like to work in IT related business and use computers and networks professionally.

b) I would like to use computers and networks inside my company as a tool.

c) I would like to use computers and networks at home as a hobby.

d) I have no idea.

Items for evaluating students' motivation for the acquisition of Information - the Utilizing Abilities

We examined the enthusiasm of students for IT. The acquisition of *Information - the Utilizing Abilities* is based on information literacy, which is the objective of the Japanese government for IT education (4 point scale). The concept of the acquisition of *Information - the Utilizing Abilities* includes three viewpoints: *the practice activities of Information technology, scientific understanding of information*, and *the attitude which takes part in the Information society* (MEXT, Japan).

Item for grasping students' self-evaluation of their own knowledge level about IT

We examined the self-evaluation of students about the degree of recognition concerning IT (5 point scale). The compulsory phrases were extracted from textbooks that are used in Japan and it was classified into five categories. (Tables 2 and 3).

Table 2: Categories of Knowledge Items (Junior High School)

Categories of Knowledge items				
Information system	Practical operation	Network technology	Information society	Information ethics
OS	Icon	URL web page	Computer network	Computer virus
Server	CG	E-Mail	User name	Copyright
Software	Image scanner	Domain		Password
To digitalise	www & Internet	Network		User ID
Display	CD-ROM			
Hardware	Application software			

Hard disc	Keyboard
File	Data using Internet
Folder	CD
mouse	DVD
	Cell
	USB
	Database
	Draw type software
	To digitalise
	Spreadsheet software
	Use a printer
	Presentation software
	Programming
	Word processing

Table 3 Categories of Knowledge Items (Senior High School)

Categories of Knowledge Items				
Information system	Practical operation	Network technology	Information society	Information ethics & security
Binary, hexadecimal	CD-ROM	HTML, tag	Online shopping	Encryption
AND,OR,NOT	Jpeg, phg, gif	IP address	Media of communication	Computer virus
CPU	Animation	LAN	Media literacy	Intellectual property right
OS	Text file	POP server	Digital device	Industrial property
Compression, extraction	Draw type software	TPC/IP	Electronic commerce	Compliance (information ethics)
Analog, digital	Database	URL, web	ENIAC	Copyright, patent
Arithmetic & logic	How to use Powerpoint	Protocol	ETC	Credibility of information
Unit, storage unit	Multi-media	Compound conditions	IT	Network crime
Micro-processor	www		Car navigation system	Fire wall
Client Server System	Category search, keyword search		Techno stress	
Quantization	Search engine			

Charge Coupled Devices	
IC	
Pixel	
File format	

Results

Students' awareness of IT

Table 4 shows the summarized results of the connection between the students and IT in the future. The awareness of students between Japan, Korea, China and Indonesia in junior and senior high schools was obviously different.

The ratios of junior and senior high school students in China and Indonesia who want to become professional workers in the IT industry were higher than that of Japan. On the other hand, students in Japan would mainly like to use IT at home as hobbies.

Table 4 Students' Future Relationship with IT

Junior High School	Japan n=266		Korea n=117	China n=121		Indonesia n=120	
Working in IT related business and use computers and networks professionally	11 4.1%	* −	18 15.4%	46 38.0%	** +	34 28.3%	
Using computers and networks inside my company as a tool	67 25.2%	** −	36 30.8%	24 19.8%		28 23.3%	** +
Using computers and networks at home as a hobby	164 61.7%	** +	61 52.1%	48 39.7%		57 47.5%	** −
No idea	24 9.0%		2 1.7%	3 2.5%	* −	1 0.8%	

$\chi^2(6)=93.12$ $p<.01$

Senior High School	Japan n=124		Korea n=201	China n=123		Indonesia n=117	
Working in IT related business and use computers and networks professionally	12 9.7%	* −	24 11.9%	44 35.8%	** +	38 32.5%	
Using computers and networks inside my company as a tool	50 40.3%	** −	55 27.4%	35 28.5%		30 25.6%	** +
Using computers and networks at home as a hobby	51 41.1%	** +	98 48.8%	41 33.3%		47 40.2%	** −
No idea	11 8.9%		24 11.9%	3 2.4%	* −	2 1.7%	

$\chi^2(6)=55.33$ $p<.01$

The motivation for the acquisition of Information – the Utilizing Abilities

Table 5 shows the average scores of the questions about the motivation for the acquisition of *Information - the Utilizing Abilities*. In most of the question items, Indonesian junior and senior high school students' motivation was higher than in other countries.

Table 5: Motivation for the Acquisition of *Information - the Utilizing Abilities*

Junior High School		Japan n=266	Korea n=117	China n=121	Indonesia n=120	ANOVA
The practice activities	Ave.	3.23	2.03	1.92	3.69	F(3,620)=191.53**
of Information technology	S.D.	0.73	0.69	0.94	0.49	Indonesia>Japan>Korea>China
Scientific understanding	Ave.	2.59	2.62	1.81	3.18	F(3,620)=38.46**
of Informatiobn	S.D.	0.89	0.73	0.81	0.81	Indonesia>Japan>Korea>China
The attitude to take part in the	Ave.	2.94	2.21	1.83	3.34	F(3,620)=99.54**
Informatiobn society	S.D.	0.81	0.68	0.86	0.75	Indonesia>Japan>Korea>China

4 point scale **p<0.1 LSD method for Multiple comparison

Senior High School		Japan n=124	Korea n=201	China n=123	Indonesia n=117	ANOVA
The practice activities	Ave.	3.23	1.97	2.21	3.71	F(3,561)=187.21**
of Information technology	S.D.	0.67	0.71	0.85	0.61	Indonesia>Japan>Korea>China
Scientific understanding	Ave.	2.61	2.49	2.22	3.39	F(3,561)=46.29**
of Informatiobn	S.D.	0.84	0.75	0.88	0.82	Indonesia>Japan=Korea>China
The attitude to take part in the	Ave.	3.15	2.21	2.11	3.42	F(3,561)=98.82**
Informatiobn society	S.D.	0.78	0.72	0.89	0.69	Indonesia>Japan>Korea=China

4 point scale **p<0.1 LSD method for Multiple comparison

Self-evaluation of knowledge level about IT

Table 6 shows the average scores of the self-evaluation of the understanding of the knowledge about IT. All of the average scores in junior high schools in China were higher than other countries, and all of the average scores in Japan were lower than other countries in junior and senior high schools. However, *information ethics* was almost same level in four countries.

It can be deducted that junior and senior high school students in Japan has issues with understanding IT.

Table 6: Knowledge about IT in Junior and Senior High School

Junior High School		Japan n=266	Korea n=117	China n=121	Indonesia n=120	ANOVA
Information System	Ave.	3.03	3.43	4.25	3.86	F(3,620)=57.59 **
	S.D.	1.09	0.81	0.80	0.62	China＞Indonesia>Korea＞Japan
Practical Operation	Ave.	2.93	3.44	4.12	3.74	F(3,620)=62.83 **
	S.D.	0.97	0.81	0.75	0.66	China＞Indonesia>Korea＞Japan
Network Technology	Ave.	2.99	3.48	4.29	3.63	F(3,620)=53.23 **
	S.D.	1.12	0.78	0.86	0.78	China＞Indonesia>Korea＞Japan
Social Impact of ICT	Ave.	3.14	3.38	4.31	3.89	F(3,620)=44.39 **
	S.D.	1.20	0.73	0.83	0.86	China＞Indonesia>Korea＞Japan
Information Ethics	Ave.	3.19	3.21	3.28	3.27	F(3,620)=11.60
	S.D.	1.09	0.71	0.94	0.94	China=Indonesia=Korea=Japan

5 point scale **p<0.1 LSD method for Multiple com

Senior High School		Japan n=124	Korea n=201	China n=123	Indonesia n=117	ANOVA
Information System	Ave.	1.94	3.21	2.95	3.24	F(3,561)=104.71 **
	S.D.	0.69	0.61	0.82	0.67	Korea=Indonesia>China＞Japan
Practical Operation	Ave.	2.52	3.24	3.31	3.85	F(3,561)=66.90 **
	S.D.	0.87	0.58	0.79	0.74	Insonesia>China＞Korea＞Japan
Network Technology	Ave.	1.74	3.19	2.77	3.51	F(3,561)=143.02 **
	S.D.	0.67	0.65	0.90	0.71	Korea＞Indonesia>China＞Japan
Social Impact of ICT	Ave.	2.59	3.11	3.02	3.31	F(3,561)=21.07 **
	S.D.	0.89	0.59	0.76	0.74	Insonesia>Korea＞China＞Japan
Information Ethics	Ave.	2.79	3.26	3.56	3.23	F(3,561)=19.56 **
	S.D.	1.03	0.58	0.78	0.79	China＞Korea=Indonesia>Japan

5 point scale **p<0.1 LSD method for Multiple com

Discussion

From the results stated above, there are currently two main concerns regarding IT education in Japan.

Firstly, in Japan, the time of IT education should be devoted more than ever. The subject of IT has been a compulsory subject at junior and senior high schools. However, it is a part of the technology subject of junior high school, and there is not enough time devoted to it. In Korea, China and Indonesia, the information-related contents are learned in a curriculum from the beginning of primary school. Consequently, all of the average scores about the knowledge of IT in Japan were lower than other countries in Junior and Senior high schools. The shortage of time for learning IT in Japan is likely to have caused the lack of recognition of the importance of IT.

Secondly, there is high motivation among students to learn about IT. In most of the question items about the motivation for the acquisition of Information - the Utilizing Abilities, Japanese junior and senior high school students' motivation is almost always higher than that of Korea and China. However, that motivation is not a direct indicator of the students' knowledge. Almost all average scores about the knowledge of IT in Japan were lower than in other countries. Moreover, Japanese students' motivation for acquisition of scientific understanding of IT and that of Korea were similar, and that motivation was not high. That's the problem in Japan and that's we have to think about.

Considering all of the things stated above, we think that promoting the scientific understanding of IT is very important for Japan's IT education in the future. Therefore, we would like to propose the teaching materials of logic circuit to promote the scientific understanding of IT.

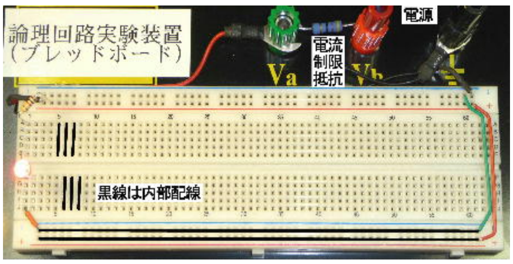
Proposal for teaching materials for promoting scientific understanding of IT

Importance of teaching logic circuit

According to the New National Curriculum Standards, learning programming will become a compulsory in primary school. However, only learning about programming should be not enough to promote students scientific understandings of IT. It is important for students to learn logic to process information. In order to make students understand the logic of processing information, it is necessary to teach them about logic circuits. It is expected that, by learning both programming and logic circuit, students acquire logical thinking abilities. There are various great teaching materials for programming education like Scratch, however good teaching materials for teaching logic circuit is not enough. So, we developed experimental device for a teaching logic circuit.

Developed teaching materials for logic circuit learning

Figure 2 shows the experimental device for a logic circuit. In this device, a current limiting resistor is arranged in the power supply circuit. In actual practice, students will create various types of circuits. When a short circuit accident occurs due to incorrect wiring, the current is restricted, and the power indicator is extinguished. Therefore, students become aware of incorrect wiring (Kudo, et.al. 2016).



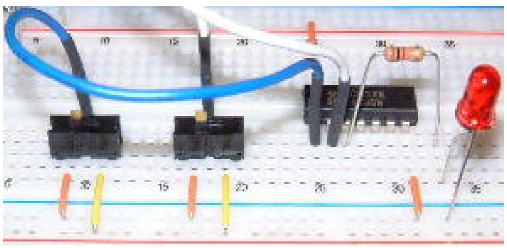


Figure 2. The experimental device
Figure 3. Practical wiring diagram

for the logic circuit   of the AND circuit

The configuration of the logic circuit was prepared with reference to *Basic Industrial Technology*, a junior high school textbook, and based on the readiness of each student.

A teaching plan to be practiced in junior high schools is described below:

(1) Content of the instruction

• AND, OR, and NOT circuits: The wiring of the basic logic circuit and the creation of a truth table. Figure 3 shows the practical wiring diagram of the AND circuit.

• NAND circuits and various types of logic circuits: The creation of the basic logic circuit, in which NAND circuits are combined. Boolean algebra and logic, De Morgan's laws, and basics of circuit design.

(2) Experimental procedure

Students wire each item's circuit while referring to the practical wiring diagram and the circuit diagram. Students manipulate the switch following the truth table's input field, read the experimental results based on the lighting state of the light emitting diode bulb, and enter the results into the truth table's output field.

(3) Boolean algebra

Through the experiment, students confirm Boolean algebra theorems and become aware that De Morgan's laws are used for the equivalent exchange in the circuit diagram, such as the conversion between AND and OR circuits.

(4) Wiring methods

Teacher ensure that senior high school students understand that although the practical wiring diagram differs from the circuit diagram, no problems arise when the former is replaced with the latter, so both diagrams are logically equivalent. Teacher help junior high school students to understand the importance of paying attention to wires' color coding and to use the same color for each wiring system, all while considering students' acquisition of problem-solving abilities. teacher ensure that students understand the idea of circuit design in (3) Boolean algebra.

Various types of teaching materials for teaching logic circuits

Since the above-mentioned teaching materials use actual ICs, some junior high school students might find it difficult to perform the activity. Therefore, we propose two alternative ideas: (1) the first idea is to use Minecraft (Figure 4), which is a sandbox-type manufacturing game; and (2) the second idea is to use littleBits (Figure 5), which is an electronic kit that compliments students' learning through virtual reality, improving their learning efficiency. By combining these three ideas, students can deepen their understanding of logic circuits through experience.

Figure 4. NOR circuit created using Minecraft

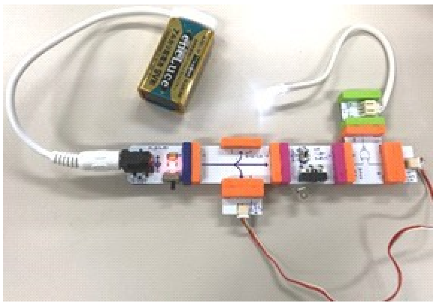


Figure 5. Example of a NAND circuit in littleBits

Effects of Teaching

We carried out lessons in junior high school using these teaching materials. As a result, comments such as "I understood that CPU have hardware including logical circuits, and program are running in it in order to process data" were obtained after the teaching. Also, teacher asked students a question about examples of logical circuit around us in daily life. As a result, for example, answers such as "I think the OR circuit is used in the stop sign system in bus, because the stop sign turn on if someone presses the switch" was obtained.

From these students' reactions, it was suggested that learning the logic circuit is suitable for not only learning about hardware but also learning about logic of information processing through real experiment.

Conclusions

In this research, we examined the awareness of students about IT education in junior and senior high schools in Japan, Korea, China, and Indonesia. As the results, the problem about *scientific understanding of information* was made clear in Japan. Therefore, we developed teaching materials about logic circuit based on the viewpoint of *scientific understanding of information*. It will lead to Japanese IT education in the future.

The results of this study can be summarized as follows:

1) Students in Japan would mainly like to use IT as hobbies and at home. In contrast, students in China and Indonesia would like to use it as part of their professional jobs.

2) Japanese and Indonesian junior and senior high school students' motivation were higher than in Korea and China. However, in Japan, *scientific understanding of information* was lower than other two viewpoints.
3) All of the average scores about the knowledge of IT in Japan were lower than in junior and senior high schools of other countries.
4) The teaching materials of logic circuit are beneficial for developing *scientific understanding of information*.

Acknowledgment

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Cultural Movement toward Technology Education in South Korea: In-service Technology Teachers' Movement

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Abstract

This study aimed to explore in-service technology teachers' efforts to build a sound technology education culture in South Korea. This study employs a case study approach to explore the technology teachers' movement. To accomplish the purpose of this study, we have concentrated on the Korean Technology Teachers' Association (KTTA). We first visited an in-service technology teachers' monthly workshop or seminar sessions in three regions. Three regional technology teachers' organizations were selected for this case study. Data were collected through in-depth interviews with leaders of the technology teachers' organization, related documents on their workshop or seminar, and interviews with the participants. Second, we participated in 2015/2016 technology festivals (Korean Convergence Technology Festival for Youth) operated by leading in-service technology teachers. Data were collected based upon the verbal or written consensus of all the participants and analyzed by content analysis. The KTTA was originally motivated by teachers' challenges or problems that they had faced during their teaching experience. This was a suitable place for sharing their challenges or problems. Moreover, they have made various efforts to improve the public's misconception regarding technology education. Through a monthly onsite workshop and online community activity, they have built an organized learning community for technology teachers. Additionally, they have planned and operated an annual technology festival to promote the benefits of technology education to the public. This has been a perfect opportunity to direct the public's attention toward technology education. The festival has targeted everybody, including students, parents, and educators. The findings derived from the data in this study indicate that Korean in-service technology teachers have built a sound technology education culture.

Keywords: technology education, culture, teachers, movement, South Korea

Introduction

Technology education was introduced in the second revision of the national curriculum in South Korea and first offered to secondary school students as an independent subject in 1970. However, technology education in South Korea has undergone continuous innovations and challenges in terms of the curriculum, instructional approach, and teacher education (Yi & Kwon, 2008). Among the challenges faced by the South Korean technology education community, insufficient implementation of technology education by non-qualified technology teachers has been considered a huge challenge.

The education system in South Korea is based on a strong national curriculum. All educational activities, including technology education, have been implemented under the national curriculum. Elementary school teachers largely teach all the school subjects regardless of their undergraduate concentration but secondary school teachers largely teach their own licensed subject. However, secondary school-level technology education has suffered from students' low learning motivation toward technology.

This insufficient student motivation was based on technology teachers' lecture-based teaching style and incorrect perceptions regarding technology education (Kwon & Mo, 2014). In other words, it was a challenge for the identity of technology education in South Korea to face frequent transitions of the technology education curriculum without a theoretical background. This has caused low motivation and biased perceptions regarding technology and technology education for the public. In this environment, technology teachers have started to work together to change the undesirable technology and technology education culture. They have organized many in-service technology teachers' learning communities and launched a technology teachers' movement.

This study focuses on the in-service technology teachers' movement and their achievements regarding Korean technology education. The purpose of this study was to explore in-service teachers' efforts to build a sound technology education culture in South Korea.

Theoretical Background

Teachers' learning community

A teachers' community has been proposed as one of the most effective ways to improve teachers' learning and professional development (Chang & Hsu, 2017; Ham et al., 2014). A teachers' learning community can be defined in diverse ways but key ideas commonly included in many definitions are sharing the values, knowledge, and experience of the members, creating a new culture with learning and interaction, and collaborating with other members with clear goals and practices (Han, 2001; Seo, 2008).

The Korean technology teachers' learning community has been developed with several motivations: to share ideas and practices for exemplary technology teaching, develop technology teachers' teaching competencies, and innovate technology classrooms (Ham et al., 2014). In particular, it can be a perfect chance to improve teaching competencies to enable first-year technology teachers to participate in learning communities (Lim & Na, 2011). Due to the recently revised curriculum and educational settings, South Korean technology teachers have suffered from low motivation to teach technology. Many unqualified technology teachers have taught technology, which has resulted in students' low motivation to study technology. Technology teachers' learning communities can be a solution to solve these problems in South Korea.

Initially, several regional learning communities for technology teachers were organized to solve the problems that they had faced. They focused on improving technology teachers' teaching competencies or laboratory skills for their technology classrooms. Moreover, the Korean Technology Teachers' Association (KTTA) was created to tackle a significant task called the "Technology Teachers' Movement." Recently, the KTTA has played a significant role in creating a sound culture toward technology and technology education. They have made efforts to share the true values and benefits of technology and technology education with all Koreans over eighteen years.

Rogers' diffusion theory

The theory on the diffusion of new innovation has been studied for approximately four decades, and one of most popular theories is Rogers' diffusion of innovation theory (2003). Many educational researchers and practitioners have used the Rogers' theory as a very effective way to examine the adoption of new innovation by educators in different areas (Sahin, 2006; Yates, 2001). Diffusion was defined by Rogers(2003) as "the process in which an innovation is communicated through certain channels over time among the members of a social system" (p. 5). Rogers (2003) also defined the innovation-decision process as:

> the process through which an individual (or other decision making unit) passes from gaining initial knowledge of an innovation, to forming an attitude toward the innovation, to making a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision. (p. 168)

Rogers (2003) described the five basic stages of this decision process as follows: knowledge, persuasion, decision, implementation, and confirmation, as presented in Figure 1. Learning communities have helped technology teachers in need by sharing exemplary technology classrooms and practices and finally implementing members' instructional designs and practices.

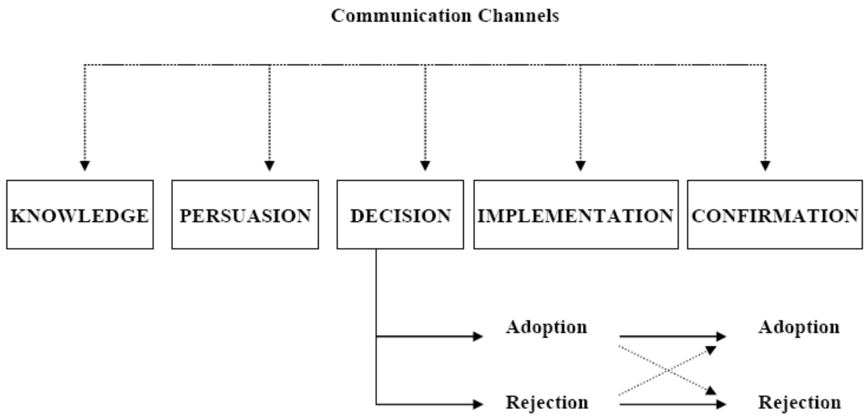

Figure 1. Model of five stages in the innovation-decision process (Rogers, 2003)

The factors that Rogers suggested for determining the rate at which adopters moved from one stage to a higher one were awareness, interest, evaluation, trial, and adoption. Furthermore, the perceived attributes of innovations in Rogers' diffusion of innovation were relative advantages, compatibility, complexity, trialability, and observability. Rogers (2003) presented potential adopters of an innovation in five categories: innovations, early adopters, early majority, late majority, and laggards (Figure 2).

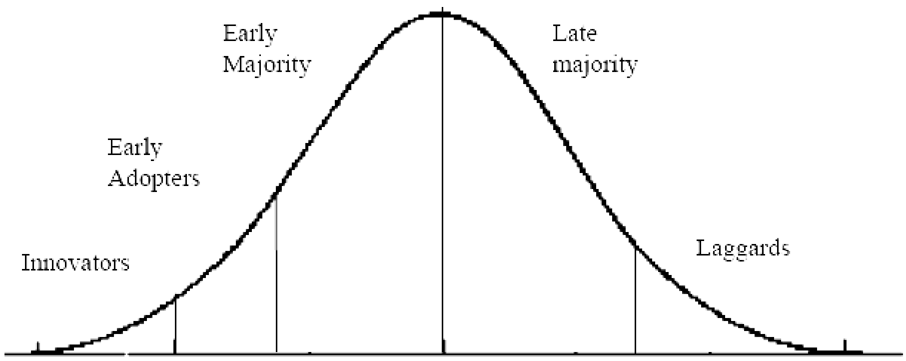

Figure 2. Adopter categorization on the basis of innovativeness (Rogers, 2003)

Method

The purpose of this study was to investigate in-service technology teachers' efforts to build a sound technology education culture in South Korea. To accomplish the purpose of this study, we have concentrated on the KTTA and several learning communities. The participants in this study were nine technology teachers who were leading members for the KTTA or other regional learning communities.

We first visited in-service technology teachers' monthly workshop or seminar sessions in three regions. Three regional technology teachers' organizations were selected for this case study. Data were collected through in-depth interviews with leaders of the technology teachers' organization and related documents on their workshop or seminar were collected and analyzed. Second, we participated in 2015/2016 technology festivals (Korean Convergence Technology Festival for Youth) operated by leading in-service technology teachers. Data were collected based upon the verbal or written consensus of all the participants and analyzed by content analysis. The participants' names presented in this paper were all pseudonyms.

Findings

Korean Technology Teachers' Association (KTTA)

The KTTA was initially organized to take systemic actions regarding the seventh revised national curriculum as a teachers' organization in 1999. The seventh revised curriculum had merged subjects such as technology and home economics, which caused a huge problem for Korean technology teachers. This resulted in a crisis and chaos in terms of the identity of technology education in South Korea. The KTTA played a significant role in solving the potential problems that Korean technology teachers faced due to the seventh revised national curriculum.

> Kim: It was shocking for all the in-service technology teachers to learn merged subjects like technology and home-economics from the announcement of the seventh revised national curriculum. As a technology teacher, I did not know what to do at this point. Frankly speaking, I was just disappointed with all the situations that technology teachers had experienced.

> Choi: The transition to the seventh revised curriculum was a huge shock to us. However, it was a good starting point for technology teachers to create a technology teachers' organization. We had had several regional organizations for technology teachers before the initiation of the KTTA. The regional organizations were motivated to work together and finally, we could have a wonderful opportunity to amplify the voices of technology teachers.

The philosophy of the KTTA started to diffuse among technology education practitioners. Many in-service technology teachers have joined the KTTA since it launched summer professional development (PD) sessions and a publication for technology teachers in 2002. The PD was a perfect opportunity for technology teachers to share their experiences and obstacles in teaching technology.

> Park: I remember joining the KTTA when I attended the first summer PD in 2002. It was really good to meet other technology teachers from all around the nation. The network of technology teachers from the PD was so valuable.

Song: During the KTTA PD session, I could solve problems that I had experienced in my previous teaching. There were many experts or teachers who had solved the problems associated with technology education classrooms. This was really helpful and meaningful because I could gain the confidence to teach technology.

Learning Community for Technology Teachers

The KTTA has played a critical role as a learning community for in-service technology teachers. The KTTA's summer PD session is valuable for in-service technology teachers because it provides a good opportunity for technology teachers' learning and reflection. The key topics of the PD sessions are presented in Table 1.

The topics have been decided by in-service technology teachers' needs. Additionally, the KTTA has an on-line community through which technology teachers can share their experiences and teaching materials, search for relevant resources for technology education, and provide productive feedback and outcomes. This is a good channel for technology teachers' communication.

Baek: I anticipated participating in the KTTA summer PD because it is a perfect chance to learn through diverse hands-on activities. I had been having a tough time due to the insufficient implementation of technology classrooms. As you know, lecturing was a simple choice for a novice teacher. However, the PD provided diverse experiences using hands-on technological activities.

Shin: There was simple logic for my problem with teaching technology. I could not manage student-based hands-on activities because I did not have any experience of students' hands-on activities. But, the KTTA summer PD was a wonderful place to learn how to manage hands-on technological lessons.

Table 1: Themes of the KTTA Summer PD

Year	Themes	Year	Themes
2002-3	Summer PD for Technology Teachers	2010	Hands-on Activities for Manufacturing, Transportation, Communication
2004	Basic Electrical & Electronics	2011	Hands-on Activities for Construction, Electricity & Electronics, Biotechnology
2005-6	Summer PD for Technology Teachers	2012-3	Integrative Strategy for Technology Education

2007	Invention and Mechatronics	2014	Strategies for Free Semester
2008	Invention Education for Technology Teachers	2015	We are Makers!!
2009	Preparing for New 2007 Curriculum	2016	PD for Creative Human Resources

Diffusion of technology education culture

The KTTA started a cultural movement to create a sound culture for technology education. Insufficient research and unqualified teachers have been huge obstacles for the sound implementation of technology education. To overcome the existing problems, the KTTA chose to establish the "technology teachers' cultural movement." The KTTA has participated in several funded research projects related to the implementation of technology education practices. In addition, it has provided support for constructing and operating regional technology teachers' learning communities. The KTTA has focused on the word of 'diffusion' of technology and technology education in all their tasks. Recently, the KTTA has played a significant role in operating "The Korea Convergence Technology Festival for Youth," an exemplary cultural movement for technology and technology education. Key tasks conducted by the KTTA are presented in Table 2.

Table 2: Key tasks conducted by the KTTA

Year	Key Tasks or Projects
2003	Department of Education Project (PBL Hands-on Activities Model and others)
2006-9	Foundation of Industrial Technology (Tech Road, Homo Faber, Tech-mania)
2007	Educational Fair : Experiencing "Technological Hands-on Activities"
2008-9	Tech-mania Festival : "War-game using Catapult"
2010	"Technological World" Publication for Youth funded by KIAT
2012	Korean Convergence Technology Festival for Youth (4^{th} National Festival)
2015	Educational Service (Cambodia) – Dream Class with Technology Teachers

Conclusion

In South Korea, technology education has been offered since 1970 and its contributions to society have been significant. However, technology education suffered from insufficient practices and unqualified teachers. Unqualified technology teachers struggled to implement hands-on technological activities in their classrooms. The KTTA was initiated by leading technology teachers to overcome the existing problems that Korean technology education faced.

The KTTA started a learning community for in-service technology teachers. Additionally, it has made efforts in several cultural movements to improve the public's perceptions regarding technology and technology education. Initially, the KTTA as a learning community launched annual PD programs for in-service technology teachers. This was a perfect opportunity to demonstrate the exemplary implementation of technology education to other technology teachers. Furthermore, the summer PD programs have provided wonderful places to share technology teachers' experiences regarding the implementation of hands-on technological activities with diverse learning themes. The KTTA participated in the process of publishing "Technological Worlds" books for youth to advertise technological literacy and its value to the young people. They also launched a huge national festival named the "Korea Convergence Technology Festival for Youth" and operated the whole process of the event for diffuse exciting hands-on technological activities to the public, including students, parents, and pre-service teachers.

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Students' Perception of Technology in Korean High School

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Abstract

The purpose of this study is to investigate the differences in perceptions of technology in relation to variables associated with high school students' gender, parental occupation, and choice program for the technology curriculum. To accomplish the purpose of this study, it was conducted with literature and survey studies. The questionnaire consisted of 14 items and the reliability test showed that the Cronbach-α value was 0.95. As a result of this sampling, 450 questionnaires were collected from 16 schools and the recovery rate of questionnaires was 93.8%. Based on the results, the conclusions are as follows. First, according to gender, male students' perception of technology was significantly higher than female students. Second, there was no significant difference in perception of technology among high school students according to their parents' technical occupations. These results may be evidence that parents do not have deep conversations with their children in relation to their occupations, or that their children do not care about what their work is. Third, students who attended technical subjects were highly aware of the technology, and showed a high awareness of the importance of technology, usefulness, and prospects of technology-related occupations. Finally, in the high school students' perception of technology, there was a low perception in concept differences between technology and engineering. In other words, it showed low perception compared with other factors of technology recognition, which means that they did not know the conceptual difference of technology and engineering and that they answered that both concepts were almost similar.

***Keywords**:* student perception, high school students' perception, students' recognition

Introduction

Perception is related to learning motivation, which is a desire for knowledge, and in particular, it has an influence on intrinsic motivation of learners and thus improves learning desires. In addition, perception is a concept that is related to practice beyond the level of enlightenment, knowledge, and understanding. A high awareness of technology can be seen as a way to improve students' learning desires for technology. In research on attitudes of technology, attitudes toward technology are closely related to the perception of the concept of technology. In other words, the degree of recognition of the concept of technology influences students' attitudes toward technology (Lee, 2009). However, the nature of technical education emphasizes practical activities through a kind of experience by dealing with tools and materials through work and using them to complete the project. Research on attitudes toward technology has been conducted for elementary school students, junior high school students, and high school students, but there have been few studies on the perception of technology. Internationally, the perception of technology has been studied mainly in the United States, Taiwan, Hong Kong, and Korea (Rose & Dugger, 2002; Rose, Gallup, Dugger & Starkweather, 2004; Lee, 2009), and Korea has studied partly on elementary and junior high school students (Shim & Lee, 2014; Lee, 2015). By examining how technology education is perceived by students in elementary, middle and high schools, we can infer the results of technology education taught in schools. In addition, the result of this study is very necessary because it can provide important basic data and suggestions for technology education.

The purpose of this study is to investigate the differences in perceptions of technology depending on the variables related to high school students (gender, parental occupation, and technology classes), and the details of the study are as follows. First, investigate the differences in perception of technology according to gender of high school students. Second, investigate the differences in perceptions of technology among high school students depending on their parents' technological occupation. Third, survey the differences in the perception of technology depending on whether high school students take technology courses.

Method

Questionnaire

The questionnaire in this study was made in reference to the previous study (Lee, 2009; Fang, et al, 2007; Rose, et al, 2002). To improve the validity of the questionnaire, six evaluators (three professors, three teachers) verified the facial validity and revised the questionnaire to reflect the results. A preliminary questionnaire was constructed based on questionnaires on the perception of technology in literature. The preliminary question was composed of 16 items and the 5 point Likert scale was used. To verify the reliability of the questionnaire, the preliminary survey questionnaires were distributed to 95 students, and 90 pieces were used for analysis except 5 fraudulent responses. The preliminary questions consisted of 16 items in total, with 4 items each in terms of importance of technology, usefulness of technical education content, prospect of technology related occupation, and difference of technology and engineering. In order to obtain the reliability of the item internal consistency of the questionnaire, the Cronbach-α value was 0.89, and the two items with low reliability were deleted. The final questionnaire consisted of 14 items. The reliability test showed that the Cronbach-α value was 0.95, which was very high. A questionnaire on 'recognition of technology' is as follows. The 'importance of technology' consists of four items; interest in technology, learning advanced technology, interest in the field of technology, and importance of technology. The 'usefulness of contents of technical education' was composed of 4 items; Usefulness of technology education, aspiration of technology lesson, knowledge of mathematics and science, and solution of technological problem in daily life. 'Prospects for technology-related jobs' consist of three items; Future technology-related career choices, the prospect of the technology profession, and the search for a technical job. The difference between 'technology and engineering' consists of three items; Concepts of technology and engineering difference, role, and occupation.

Sampling Respondents

The population of this study is male and female high school students in Korea. As of November, 2016, there are 210,302 male and 208,400 female students in the second year of high school in Korea, and the total number of students is 418,702 (http://cesi.kedi.re.kr, 2016). Using the survey system (http://www.surveysystem.com), the size of the sample was found to be 5% for the significance level and 95% for the confidence interval, and 384 individuals were able to represent 418,702 populations. In addition, when the population size is more than 500,000, the appropriate sampling number is 384, so 480 people are considered to represent the population considering the average recovery rate. In this study, a modified cluster sampling method was used in consideration of local characteristics. That is, in the first stage, one school was selected for each of 16 provinces. In the second stage, one class was selected for each school. As a result of this sampling, 450 questionnaires were collected from 16 schools, and the recovery rate of questionnaires was 93.8%. A total of 434 questionnaires were used for statistical analysis and 16 were not used due to unfair responses.

Statistical analysis was done using SPSS WIN 22.0 statistical program. In this study, reliability and t-tests were performed. The significance level required for statistical testing was set at 5% ($p < 0.05$).

Results and Interpretation

General characteristics of respondents

Among the students who responded to the questionnaire, 50.5% of male students and 49.5% of female students were found to be uniformly sampled according to gender. The rate of parents' job related to technology was 65.4%. Among the respondents, 83.2% of students took technology courses. Four sub-factors were examined for the perception of technology among high school students. Overall, high school students were highly aware of the importance of technology, the usefulness of technology content, and the prospects of technology-related jobs. Also, high school students were not aware of the conceptual differences between technology and engineering. In other words, it means that students recognize technology and engineering as the same concept. As a result of survey on ‘the importance of technology in everyday life for adults, Americans responded that 99% in 2001 and 98% in 2004 were important, and Taiwanese 92% thought it was important (Fang, Teng & Chen, 2007).

Analysis of perception of technology by gender

The first research content was to examine whether the perception of technology in high school students differed by gender. The results of the t-test between the two groups are shown in Table 1. Overall, high school students' perception of technology was higher for boys (average 3.9) than girls (average 3.7).

Table 1. Overall awareness of technology by gender

Gender	Number of cases	Mean	Standard Deviation	*t*	df	*p*
Male	219	3.938	.395	6.950	432	.000**
Female	215	3.659	.442			

Notes: $^{*}p<0.05$, $^{**}p<0.01$

Table 2 shows the results of t-test for recognition of technology by sub-factors. The perception of 'importance of technology' was higher in male students (average 4.28) than female students (average 3.97). There was a significant difference between male students (average 4.33) and female students (average 4.02) in 'usefulness of technology contents', and both groups showed high recognition. In the "Prospect of Technology-Related Jobs," male students (average 4.14) answered that they had more prospects than female students (average 3.87). In the ‘concept difference between technology and engineering’, there is a significant difference in the scores of boys (mean 3.01) and female students (average 2.79), but it means that they do not clearly understand the difference between technology and engineering.

Table 2. Results of the t-test for recognition of technology by gender

Items	Gender	N	M	SD	*t*	df	*p*
Importance of Technology	Male	219	4.275	.561			
	Female	215	3.969	.602	5.490	432	.000**
	Total	434	4.123	.601			
Usefulness of technology education contents	Male	219	4.327	.311			
	Female	215	4.015	.369	9.517	432	.000**
	Total	434	4.172	.374			
Prospect of technology-related occupation	Male	219	4.143	.459			
	Female	215	3.867	.510	5.934	432	.000**
	Total	434	4.006	.504			

Difference between technology and engineering	Male	219	3.008	.841			
	Female	215	2.785	.853	2.745	432	.006**
	Total	434	2.897	.853			

Notes: *$p<0.05$, **$p<0.01$

Analysis of perception of technology by parents' occupation

Research content 2 was to investigate how students perceive technology differently depending on their parents' technical profession. In order to analyze this, t-test was conducted between the two groups, and the results are shown in Table 3.

Table 3. Overall perception of students' according to their parents' occupations

Occupation of Parent	N	M	SD	*t*	df	*p*
Technical related occupation	284	3.8115	.44505	.766	432	.444 *N.S.*
Non-technical occupation	150	3.7774	.43372			

Note: N.S.: Not Significant

In other words, there was no significant difference between the two groups (the mean perception of students related to technology was 3.81, and the average perception of students not related to technology was 3.78). These results indicate that student skills perceptions are not high and are usually moderate, depending on the profession of their parents. However, analysis of the perception of technology by sub-factors showed significant difference only in 'usefulness of technology' as shown in Table 4. In other words, students who responded that their parents' job was related to technology (average 4.20) recognized the utility of technology more than those who did not (average 4.12). There was a high perception of 'importance of technology' (average 4.12) and 'prospect of technology related occupation' (average 4.00), but there was no significant difference between the two groups. Students' perceptions of the factors of 'conceptual difference between technology and engineering' (average 2.90) were low and they did not distinguish between the concepts of technology and engineering.

Table 4. t-test results of the perception of technology by parents' occupation

Items	Occupation of Parent	N	M	SD	*t*	df	*p*
Importance of Technology	Related	284	4.109	.594	-.673	432	.501 *N.S.*
	Non-related	150	4.150	.615			
	Total	434	4.123	.601			
	Related	284	4.199	.374	2.053	432	.041*

Usefulness of technology education contents	Non-related	150	4.122	.372			
	Total	434	4.172	.374			
Prospect of technology-related occupation	Related	284	4.022	.501	.919	432	.359 *N.S.*
	Non-related	150	3.976	.509			
	Total	434	4.006	.503			
Difference between technology and engineering	Related	284	2.916	.833	.618	432	.537 *N.S.*
	Non-related	150	2.862	.890			
	Total	434	2.897	.852			

Notes: $^{*}p<0.05$, $^{**}p<0.01$, *N.S. : Not Significant*

As shown in Table 4, high school students' perception of technology is not related to parents' jobs. These results are consistent with the results of Lee (2009) on elementary school students.

Analysis of recognition of technology by taking courses in technology subject

Research content 3 was to investigate whether there is a difference in perception of technology among high school students depending on whether or not they have taken the technology course. There was a significant difference at the 5% level as shown in Table 5 as a result of the t-test between the two groups after classifying the technical subjects into the selected group and non-selected group in the first year of high school. In other words, the perception of students who learned technology (average 3.82) was higher than those who did not learn (average 3.67), and overall students' perception of technology was common. However, when analyzed by sub-factors, there were significant differences among the factors as shown in Table 6.

Table 5. Overall perception of technology students' by taking technology subject

Selection of technology subject	N	M	SD	*t*	df	*p*
Take course	362	3.8217	.42775	2.345	432	.019*
Non- take course	72	3.6889	.49055			

Notes: $^{*}p<0.05$

According to the factor analysis and whether or not they took the technology course, the recognition of the student who completed the technology course in the 'importance of technology' factor was higher than that of the student who did not complete it. In the 'usefulness of technology' factor, students' perception of technology subjects was higher than that of students who did not. In the factor of 'technology-related career prospects', students who took technology courses (average 4.05) showed higher recognition than students who did not attend (average 3.79). However, there was no difference in the recognition score according to the 'technology and engineering concept' factors, and the students did not know the difference between the two concepts.

Table 6. Result of the perception according to the attendance of technology subject

Items	Selection of technology subject	N	M	SD	*t*	df	*p*
Importance of Technology	Take	362	4.1492	.59649	2.021	432	.044*
	Non-take	72	3.9931	.60945			
	Total	434	4.1233	.60077			
Usefulness of technology education contents	Take	362	4.1892	.35760	2.129	432	.034*
	Non-take	72	4.0868	.44238			
	Total	434	4.1722	.37438			
Prospect of technology-related occupation	Take	362	4.0488	.48086	4.023	432	.000**
	Non-take	72	3.7917	.56346			
	Total	434	4.0061	.50399			
Difference between technology and engineering	Take	362	2.8996	.84724	.140	432	.889 N.S.
	Non-take	72	2.8843	.88662			
	Total	434	2.8971	.85287			

Notes: *$p<0.05$, **$p<0.01$, N.S.: Not Significant

Implications

Based on the results of high school students' perception of technology, the discussion and implications are as follows. First, according to gender, perception of technology was higher in male students than in female students. In general, male students are empirically observed to be actively involved and interested in activity-based practice in elementary, middle, and high school technology classes, so this can be deduced to some extent. It is confirmed in the results of a study that male students actively participated in the practical activities of technical classes. This is supported by research results (Lee, 2009) and middle school students' research findings on technology perception (Lee, 2015). Therefore, when performing various activities in technical classes, it is necessary to provide opportunities for female students to participate actively by providing friendly projects.

Second, high school students are unaware of the conceptual difference between technology and engineering, which is a result not mentioned in elementary, middle, and high school technology education. Although the traditional concept of technology and its social influence are presented in technology education, it is a result of not presenting the concept and relationship of engineering and technology. Although 'Engineering Technology' courses are organized into elective courses in humanities high schools, but only 10% of the students are selected, so their influence is insignificant. The concept of technology is taught in the middle and high school technology textbooks as 'activities to make products or structures using resources, tools, techniques and knowledge to meet human needs and desires (Lee, et al., 2015). In addition, the concept of engineering in engineering textbooks is defined as 'a science that utilizes and applies knowledge and theories such as mathematics, science, technology and art to solve problems' (Choi, et al, 2015; Gang, et al, 2013). Dev (2017) also explained the hierarchical differences of science, engineering and technology. In other words, science is knowledge of general truths and laws through natural phenomena. Engineering is the application and solving of scientific knowledge to make and design things, and technology is the sum of engineering tools, devices, and processes. Therefore, this result reveals the situation of students who have not learned the difference between technology and engineering. In addition, according to a research on the technology of Koreans (Lee, 2009), it has been reported that Korean people cannot clearly distinguish the concept of technology from science.

Third, according to the occupation of parents related to technology, there is no difference in students 'perception of technology, and it can be interpreted that parents' jobs does not affect students' perception of technology, but it affects the perception of technology according to whether they have learned technology. The perception of students who took technology courses was relatively higher than those who did not. Students who were taught technology subjects were influenced by increasing cognition of the importance of technology, its usefulness, and the prospects of technology-related jobs. However, it does not affect the conceptual difference between technology and engineering, so it is necessary to discuss engineering in a technology class.

Finally, in high school, 'Technology & Home economics' courses are organized as elective courses in the first year, but until the last curriculum, the courses were organized as compulsory courses. In this study, 16.8% of respondents were not able to take technology classes, and this phenomenon is highly dependent on the supply and demand of technology teachers. In high school, elective courses are not given to students wholly, but are largely influenced by the level of teacher supply. As a result, students may not be able to take elective courses.

Conclusion

The aim of this study is to investigate the difference in perception of technology according to gender, parents' occupation, and technology subjects related to high school students. The questionnaire survey was conducted for 480 second grade high school students. Based on the results of the data analysis, the conclusions are as follows. First, according to gender, male students' perception of technology was significantly higher than female students. Second, there was no significant difference in perception of technology among high school students according to their parents' technical occupations. These results may be evidence that parents do not have deep conversations with their children in relation to their occupations, or that their children do not care about what their work is. Third, students who have attended technical subjects were highly aware of the technology, and showed a high awareness of the importance of technology, usefulness, and prospects of technology-related occupations. Finally, in high school students' perception of technology, there was a low perception in concept differences between technology and engineering.

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In order to know where you are going you need to know where you are: A Large Sample Case Study, investigating Initial Teacher Education Students' Understandings of Technology and Technology Education

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Abstract

Technology education has been a compulsory curriculum subject in New Zealand for twenty years. Is it safe to assume however, that the majority of people now entering teacher education courses understand what the subject entails?

In 2013 a national research project began, involving all leading New Zealand universities, to investigate Initial Teacher Education (ITE) formerly pre-service student understandings of Technology Education. This paper reports one region's findings, including whether these understandings varied depending on student age, gender, sector, their National Certificate of Achievement (NCEA) senior schooling pass rates or credits and further tertiary training and vocational pathways.

This interpretivist large-sample case study involved gathering data from 906 participants over a three year period. On the first day of their Technology Education course, ITE students were invited to complete a questionnaire that investigated their understandings of technology and Technology Education.

Data analysis techniques involved Mann-Whitney U tests, Kruskal-Wallis tests and effect size estimates. Generally students had a positive view of technology, although the strength of this attitude significantly varied with age, whilst the role and importance placed on key aspects of technology varied between sectors. Societal aspects were important especially to those who were older, had a low NCEA credits and lower qualifications. Most students understood the differences between science, engineering and technology. Creativity was seen as an integral part of technology but this view also varied significantly with training and vocational pathways, age and gender.

These findings provide an insight into ITE student understandings and values. They will inform future course content and emphasise areas to be reconsidered to ensure students' needs are fully met.

Keywords: Technology education, pre-service, initial teacher education, personal construct, perceptions, teacher education

Introduction

In many parts of the world, Technology Education has existed as a subject for over two decades. Unlike traditional subjects such as science and mathematics with their well-established disciplines, each country has interpreted the discipline of Technology Education in their own way. Some have focussed on life skills, design and creativity, traditional subjects such as cooking, sewing, woodwork and metalwork, whilst others have included industrial arts or arts and crafts (Courtney, Lee, McGlashan, Toso, & Neveldsen, 2017; Ferguson, 2009; Granshaw, 2015). Generally however most people feel technology education is an important part of the school curriculum (Amirshokoohi, 2016; Brown & Brown, 2010).

In the last two decades the New Zealand curriculum has undergone two major iterations (Granshaw, 2015). The 1995 curriculum included a new learning area called Technology Education (Ministry of Education, 1995), whilst the 2007 curriculum brought major changes and new emphases of content within the Technology Education learning area (Ministry of Education, 2007). In 1995 the New Zealand curriculum defined Technology Education as "a creative, purposeful activity aimed at meeting needs and opportunities through the development of products, systems or environments" (Ministry of Education, 1995, p.6). Whilst the 2007 New Zealand curriculum defined Technology Education as "intervention by design: the use of practical and intellectual resources to develop products and systems (technological outcomes) that expand human possibilities by addressing needs and realising opportunities" (Ministry of Education, 2007, p.32).

Initially few people fully understood what was involved in the discipline and many misconceptions existed (Compton, 2011; Compton & France, 2006; Moreland & Jones, 2000; Williams, 2011). Technology Education in the 2007 curriculum placed a heavy emphasis on 'adaptation and innovation'…'graphics and other forms of visual representation'… 'the socially embedded nature of technology' as well as including learning about 'technological practice', 'technological knowledge' and the 'nature of technology' (Ministry of Education, 2007, p.32).

In order to teach Technology Education effectively it is important teachers have a well-developed understanding of the discipline itself and all its multi-facets (de Vries, 2012). This enables the establishment of clear goals, classroom activities and authentic contexts (Brown & Brown, 2010). Teacher knowledge is critical (Elton, 2006) as are student and teacher values as these have been shown to influence and impact upon technological literacy (Ardies, De Maeyer & Gijbels, 2013). Teacher Education plays a pivotal role in developing this understanding (Many, Howard & Hoge, 2002). For this reason a great deal of time within Technology Education ITE courses is devoted to explaining the discipline and why it is needed to prepare students for lives in the 21st century.

Research in the late 1990’s investigated people’s understandings of technology and Technology Education. However few have investigated whether these understandings and/or misconceptions still exist twenty years after the introduction of the Technology Education curriculum into New Zealand schools. This study investigated the understandings held by students entering ITE) of the nature of technology and Technology Education from their own ‘feed-in’ perspectives. The research questions are listed:

RQ1. What are ITE students’ views on technology and Technology Education?

- RQ1a. What is the students’ strength of belief about humans developing new technologies to improve upon previous technologies
- RQ1b. What do ITE students’ think the subject/learning area called Technology is mostly about?
- RQ 2. How do ITE students’ views on Technology differ by age-group?
- RQ 3. How do ITE students’ views on Technology differ by sector?
- RQ 4. How do ITE students’ views on Technology differ if they have obtained NCEA credits (school qualifications) in the subject?

Methods

The research team used survey methods and a descriptive and comparative research design to investigate ITE student views on technology and Technology Education and how these views differed by age-group and educational sector. After gaining ethics approval, the researchers piloted the questionnaire with one cohort of Technology ITE students (July 2013). Over the following two years all Technology ITE students were invited to participate in the research (cohorts in February/March and July 2014 as well as February/March and July 2015). Therefore, several waves of convenience sampling were used for this study.

Prior to any instruction on the first day of class, ITE research participants were invited to complete an anonymous questionnaire about their perceptions of technology and Technology Education, their attitudes towards technology, and experiences that shaped their perceptions of technology education.

The participating initial ITE programmes were the Bachelor of Teaching, and the Graduate Diploma in early childhood education (ECE, up to 5 years of age), primary (aged 5 to 12 years), and secondary education (aged 13 – 17 years. This process was replicated at the six leading universities throughout New Zealand, with the intent of combining the data to give a national overview at a later stage

Participants

A total 906 participants were involved in the research. The majority (83.2%) of these participants were female, whilst 64.6% were aged 17-to-24. As the New Zealand curriculum was first introduced in 1995 (Ministry of Education, 1995), the 17-to-24-year-old cohort have probably only experienced a schooling system that contained Technology Education. Most of the participants (76.4%) were from the primary education sector, whilst 21% were from early childhood education (ECE) and 3% from the secondary sector. Of the total 906 participants, 865 answered the question concerning whether or not they had achieved national NCEA senior assessment credits in Technology Education. Of these 865, 236 respondents (27.3%) stated that they had achieved such credits, and the majority of these, n = 199 (84.3%), were under the age of 25.

Instruments

In 2010 Technology Education lecturers from the six main ITE providers within New Zealand (Auckland, Canterbury, Massey, Otago, Victoria, and Waikato universities) initiated the NZ Association of Academics in Technology Education (NZAATE). This forum agreed to participate in joint research to investigate the personal beliefs and conceptions of their students (Forret et al., 2013). Each institution contributed to the development of a questionnaire which was subsequently used to gather data about students upon entry. This information was used initially to inform practice at each university and remains the primary instrument in the current investigation. This research is based on data gathered from one of these universities.

Data preparation and analysis

Data were screened, cleaned and adjusted for anomalies (Pallant, 2011). Respondents with more than 10% missing responses were removed from the data set in accordance with Bennett (2001). It must be noted that the number of participant responses (n) varies slightly between questions as some participants did not answer every question.

Statistical Package for the Social Sciences (SPSS) 22 was used for the majority of data analysis, whilst effect sizes were carried out with the assistance of the R statistical package (R Core Team, 2015). To gauge the general magnitude with which participants responded to the ordinal questions, means (*Ms*) and standard deviations are presented.

Due to the categorical and ordinal nature of this data, nonparametric statistical analyses were undertaken. Where comparisons were made between two cohorts (e.g., younger vs. older age-groups), Mann-Whitney U tests were performed. Where comparisons were made between three cohorts (e.g., ECE vs. Primary vs. Secondary), initial Kruskal-Wallis tests were followed up by paired post-hoc Mann-Whitney U tests and effect size estimates. Where the effect of age-group and sector were assessed, meaningful results are those which met at least a small effect size ($|0.15| \leq \delta \geq |0.32|$), and also met the Bonferroni adjusted level for statistical significance (for sets of questions).

Findings

Overall understandings

Research Questions:

1. What are ITE students' views on technology and Technology Education?
2. How do ITE students' views on Technology differ by age-group?
3. How do ITE students' views on Technology differ by sector?

Participants viewed technology positively, however this varied with participant age. Results revealed that students over 24 years old considered technology slightly more important to New Zealand than those under 24 years of age ($\delta = 0.23$, $p < .001$); and, the older group thought that problem solving ($\delta = 0.15$, $p < .001$) was more relevant to technology than the younger group.

Most students understood the role and importance of key aspects of technology however this varied between sectors. Where ECE responses were compared to the primary cohort responses, the primary cohort thought that technology was less important to New Zealand than the ECE cohort ($\delta = -0.16$, $p = .001$); technology was less focused on learning about new inventions ($\delta = -0.17$, $p < .001$); and, that technology was less concerned with learning about technology over time, place and cultures ($\delta = -0.15$, $p = .003$). When the primary cohort's responses were compared with the secondary cohort's responses, the secondary cohort was more inclined to believe that design was a process to turn ideas into products ($\delta = 0.46$, $p < .001$), and that technology was more important to New Zealand than the primary cohort ($\delta = 0.32$, $p = .012$). Where the ECE cohort's responses were compared with the secondary cohort's responses, the secondary cohort was more inclined to believe that design was a process to turn ideas into products ($\delta = 0.37$, $p < .004$).

Society

Research Questions:

1a. What is the students' strength of belief about humans developing new technologies to improve upon previous technologies

1b. What do ITE students' think the subject/learning area called Technology is mostly about?

2. How do ITE students' views on Technology differ by age-group?

3. How do ITE students' views on Technology differ by sector?

4. How do ITE students' views on Technology differ if they have obtained NCEA credits (school qualifications) in the subject?

The entire sample was in quite strong agreement with the notion that 'Humans often develop new technologies to improve upon previous technologies' and these results were not affected by student demographics, cohort or NCEA credits. Students agreed with the notion that the subject Technology mostly involved learning about technology and its part over time, place, and cultures. Although the student demographic had no effect on views, students who have attained NCEA credits were less likely to agree with the notion compared to those who had not. Students in the graduate diploma in primary programme placed significantly less emphasis on learning about the subject over time and place and cultures (β = -0.27, $p < .001$). Participants thought that the subject of Technology had some focus on what experts in the community do in their job.

Student age had a significant effect on these views, with older students (over 37 years old) being more inclined to believe that Technology was mostly about what experts in the community do in their jobs compared with younger students (δ = 0.24, $p < .001$).

STEM

Research Questions:

1b. What do ITE students' think the subject/learning area called Technology is mostly about?

3. How do ITE students' views on Technology differ by sector?

Results indicated that all student demographic groups were consistent in their view that experiments were part of the subject, science; and that Technology Education was mostly about creativity, design and showing others your ideas. On the other hand, results revealed that students in the Pasifika degree-track were more inclined to believe that Engineering and Technology were one and the same thing; and were much more inclined to believe that Science and Technology were one and the same thing.

Discussion

Students in this study were positive about Technology as they believed it was important to New Zealand. These positive findings support those of the USA (Knezek, Christensen, & Tyler-Wood, 2011) the Netherlands (de Klerk Wolters, 1989), Germany, Turkey and Malta (Sjøberg & Schreiner, 2010). This positive attitude towards Technology has been shown to be a prerequisite to effective teaching about technology (Bame, Dugger, de Vries, & McBee, 1993) as it influences students' understandings and views (Dakers, 2005; Hathaway & Norton, 2016; Head & Dakers, 2005; Knezek et al., 2011; Rohaan, Taconis, & Jochems, 2010). Data suggested that many participants were aware that traditional woodwork, metalwork, sewing and cooking were no longer a key focus of Technology Education. If students entering teacher education had this understanding, less time would be need to be devoted to clarifying the distinction between the traditional and current subject focus. A key aspect for ITE is that if a learner does not have the understanding and desire to become involved they are unable to participate fully in Technology (Ankiewicz, van Rensburg, & Myburgh, 2001; Reddy, Ankiewicz, de Swardt, & Gross, 2003).

Participants believed that design applied more to Technology than science subjects. Results suggest that participants were aware that Technology Education included design, thinking about the impact of technology, planning, making and problem-solving. *D*esign is a key *component* of Technology Education (Compton & Harwood, 2006; Jones, Buntting, & de Vries, 2011; Ministry of Education, 2001; Pavlova, 2005) and if students are entering ITE education with this premise firmly established, curricular can be more swiftly covered and attention can be redirected to assisting students in integrating design into classroom practice.

Implications

Findings from this study provide a solid basis for a longitudinal national study to investigate whether and how attitudes evolve over time as a more informed ITE student cohort complete their ITE programmes, teach, gain registration and become experienced members of the teaching profession (Ardies, De Maeyer, & Gijbels, 2013).

Furthermore it is important to acknowledge the differences between the ECE, primary and secondary sectors to ensure they key components relevant to each sector underpin contemporary pedagogy changing beliefs and attitudes is problematic, differing amounts of time will be needed to inform each sector accordingly (Amirshokoohi, 2016). Lecturers who teach across multiple sectors need to ensure they are familiar with the findings that identify ITE student perceptions and misconceptions prior to developing course material for each semester.

Findings from this study suggest that students hold a sound understanding of the synergies between technology and society. However the cultural and historical aspects appeared to be less valued by students with increased qualifications, and for this reason targeted teaching may be beneficial for graduate diploma and secondary courses.

Older students are more inclined to believe that Technology Education is about what experts in the community do in their jobs compared with younger students. Further research is needed to explore whether these groups have interpreted the question to be about career planning or communities of practice.

Findings from this study highlight the need to work with other learning areas to address misconceptions about Technology Education and other subject disciplines/learning areas. These findings also highlight the need to provide curricula that imparts ITE students with an understanding that domain-specific knowledge is essential to success (Rowlands, 2011). ECE and primary ITE educators are encouraged to ensure students consider trialling and implementing programs that offer extended opportunities for project work over longer periods of time that demand student commitment and ownership (Kind & Kind, 2007).

Conclusion

Knowledge that students are entering ITE placing a high value on Technology and with an adequate basic understanding of the discipline, enables a change in emphasis in Technology Education's programmes. This knowledge will enable the limited time available in ITE programmes to be devoted to developing and extending existing notions to develop strategies for successful implementation of the curriculum.

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STEMaker: From Maker to Innovative and Entrepreneurial Talent, anthropocentric vision and beyond

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Abstract

This paper discusses the qualities that a STEMaker should have and how schools can implement STEMaker Education by making reference to the "4D curriculum planning tool", and to plan "STEMaker Projects" to develop students to be active players in the "Small Innovative Enterprises (SIEs)".

Amid the purpose held by the central agency that TE and STEM education have to contribute to the economic competitiveness of the future generation, the HKTEA believes that the intrinsic value of TE and STEMaker education should not be crowded out by the instrumental concern. Therefore the HKTEA also advocates the "anthropocentric perspective" as one of the characteristics of STEMakers to state the importance of arousing students' awareness in how to make changes in the made-world responsibly to uphold the well-being of the human, the society and the environment.

With the goal "to unleash students' potential and develop their capacity to innovate", the Education Bureau of the HK Special Administrative Region Government (EDB) published the "Report on STEM Education" (CDI 2016). Two approaches have been recommended by the EDB to implement STEM in Hong Kong schools. The Hong Kong Technology Education Association (HKTEA) recognised the second of these, an integrated project based approach as more promising in realising the purpose of "unleashing students' innovation". The HKTEA advocated the notion of "STEMaker" to conceptualise the vision and the strategy to make STEM education happen in Hong Kong, which makes reference to the "Maker culture/movement", recognising that students are involved in manipulating materials, resources & equipment to bring about changes respectively in the made-world. The vision of STEMaker education is "to develop students into STEMakers who bear the three inter-related qualities: STEM literacy, Entrepreneur mindset and Anthropocentric perspective, so that they will participate actively in the '*Small Innovative Enterprises (SIEs)'* to contribute to HK's economic growth."

What STEM is

The acronym STEM was first promulgated in the 1990s in the USA at the National Science Foundation (NSF). It represents the four related learning areas of Science, Technology, Engineering and Mathematics. Its aim is to train sufficient workers in STEM fields in the workforce to maintain a competitive edge for the long term economic development of the country.

In Hong Kong and elsewhere, the meaning of STEM has been open to interpretation by stakeholders. Williams (2015) points out that educators in different stages of schooling, namely tertiary, secondary and primary, tend to regard it as one or two subjects that are represented by the different "letters" in the S-T-E-M acronym. This observation is shared by Sanders (2009) in suggesting that teachers define it in ways that are more related or beneficial to their subjects, thus adding to the ambiguity. The equivocality is not limited to the "what is" discussion. It extends to the way how it is implemented in school, i.e. whether it is a subject in the formal curriculum or a set of informal learning experiences. It should be mentioned that there have been attempts to equate it with out-sourced courses and products.

Despite the uncertainties in definition, the instrumental purpose of STEM in training workers and maintaining a competitive edge for economic development is commonly shared by governments and educators around the world. Therefore STEM is used "in conjunction with workforce planning to ensure there are enough engineers and scientists graduating from university to satisfy the economy's needs" (Williams 2005), so as to "promote[s] interest in STEM careers as STEM-Education workforce is needed to help our country stay competitive" (Reeve, 2015b)

STEM Education in HK: What is the purpose and what it has promised

In Hong Kong, there have been very robust science and mathematics programmes in schools. Students have performed extraordinarily in the past in international assessments such as the PISA survey administered by the OECD. However, STEM education has not gotten much attention in the education community in the past decades and no official attempt has been made to integrate these learning areas, apart from some sporadic school-based trials.

<u>Purpose of STEM Education in Hong Kong</u>

In two consecutive Policy Addresses the Chief Executive of Hong Kong made STEM an imperative to equip the future generations for the keen global competition ahead (GHKSAR 2015 para.152 & 2016 para.89). With this goal in mind, the EDB launched respective curriculum review consultation and published the “Promotion of STEM Education, Unleashing Potential in Innovation—Overview” (CDC 2015, hereafter referred as “Overview”) and the “STEM Education Report” (CDC 2065, hereafter referred as “Report”).

Promise of STEM Education in Hong Kong

Reading through the paragraphs of the “Overview”, it is unequivocally clear that the promise of STEM education is its provision to Hong Kong’s economic growth. Nevertheless, the authors also identify two main messages that constitute a more important promise in the STEM education endeavour.

First is the confirmation of the status of STEM education as an entitlement for all primary and secondary students. The “Overview” states that “[A]ll students have the ability to learn, and they should be provided with STEM-related learning opportunities which form part of the essential learning experiences….” (ibid. para.7-ii). It does clearly pronounce that STEM related experiences will no longer be limited to the talent or gifted few who achieve outstanding results in local and international competitions including the Science Fair, the Science and Mathematics Olympiads, the Intel International Science and Engineering Fair and the likes; it is going to be a common learning experience for ALL!

Secondly, for the very first time the Design &Technology/Technology Education type of hands-on, problem solving learning comes to centre stage of the Hong Kong education scene. On reflecting on the previous low-status of hands-on learning, the “Overview” voices out that “[W]hile Hong Kong students perform well in science, technology and mathematics, they may focus on disciplinary studies and may not evenly participate in hands-on activities in schools. Therefore, it is necessary to strengthen the ability of students to integrate and apply their knowledge and skills across different subject disciplines through solving daily life problems with practical solutions and innovative designs. (ibid. para.6) Furthermore, the seminal message of “*Strengthening the ability to integrate and apply*” gives rise to the role of “big integrator” of authentic, purposeful problem solving learning activities, in which students will draw upon the concept and understanding of STEM subject, and utilise resources and materials to bring forth innovation in addressing needs with tangible outcomes. This is in line with the “purposeful design and inquiry” of “Integrative STEM education” put forwarded by Sanders (2009) which combines the “modus operandi” of Technology and Science Education in a holistic manner.

In summary, the hands-on, design-and-make learning for all students is regarded as the promise of the upcoming STEM education which is in view of its potential and extent to enable the next generation to contribute to the prosperity of Hong Kong.

What has been recommended to realise these promises

The "Overview" stipulates two approaches to implement hands-on STEM education in Hong Kong schools that enable the integration and application of knowledge and skills across the disciplines of Science, Technology and Mathematics Education KLAs. They are:

> Approach One
>
> Learning activities based on topics of a KLA for students to integrate relevant learning elements from other KLAs
>
> Approach Two
>
> Projects for students to integrate relevant learning elements from different KLAs (ibid).

The example employed by the central agency to illustrate Approach One is the "making of a DNA model" in Biology subject, in that students will make use of tools and materials to produce a DNA model to supplement their learning in the topic. As the outcome of the learning activity will be more focused on the acquisition of subject-based concepts and knowledge, it can be coined "*STEM education for understanding*".

On the other hand the example used for illustrating Approach Two is "Design and make an environmentally friendly greenhouse". It is a D&T type of problem-solving project that integrates learning elements across Science, Technology and Mathematics. As the outcome of learning will bring about the creation of products to serve a client's need, it can be coined "*STEM education for innovation*".

Along with the stipulation of approaches for organising learning activities, the following "Strategies for Promoting STEM education" are suggested: "Renew the curricula of Science, Technology and Mathematics Education KLAs", "Enrich learning activities for students", "Provide learning and teaching resources", "Enhance professional development of schools and teachers", "Strengthen partnerships with community key stakeholders", and "Conduct review and disseminate good practices". (ibid.)

Despite the well-concerted and meticulously derived recommendations in the "Overview", the fact is that the definition and denotation of STEM are open to interpretation as mentioned previously. This has been resulted in a multitude of explorations and endeavours by stakeholders (e.g. schools, professional associations, vendors, service-providers etc.) in realising the promise of STEM education.

Up to this moment, there has not been any robust survey or study undertaken to probe into the ways these products and services are incorporated in schools curricula on the extent of impact on students' learning. It is fair to say that the effectiveness of the "readied solution" approach is yet to be determined and it would be hard to tell whether it could achieve the promise of STEM education or not.

What the HKTEA suggests to realise the STEM Education promise

Amidst the multitude of explorations and endeavours by schools and stakeholders, the HKTEA put forward the notion of "STEMaker" to conceptualise the vision and the strategy to make STEM education happen in Hong Kong to the audience.

The vision of STEMaker education is "to develop students into STEMakers to participate actively in the "*Small Innovative Enterprises (SIEs)* [1]" to contribute to HK's economic growth." The deliberation of the STEMaker vision and related concepts originate from:

- the accountability to the call of the government to develop students to meet the challenges of the 21st Century;
- the imperative that STEM education has to be for all students;
- the foreign lessons in implementing STEM education (e.g. Sanders 2009; Kimbell 2011, de Vries 2015, Reeve 2015a & 2015b, and Williams 2015); and
- the reference of hands-on activities to the Make Culture/Movement.

<u>The desirable qualities in STEMakers</u>

With reference to literature on the outcome of STEM education (e.g. STEM Competencies in Bybee, 2010) and the considerations mentioned above, STEMaker will have three inter-related qualities: STEM literacy, Entrepreneur mindset and Anthropocentric perspective, as the goals of STEMaker education.

STEM literacy implies

- the knowledge, skills and capabilities in science, technology, engineering & mathematics; and
- the capabilities in innovation & making changes, problem solving, making tangible solution and the likes.

Entrepreneur mindset consists of the competence and understanding in:

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[1] Small innovative enterprises are normally comprised of several young entrepreneurs that

- focus on the design and development of client-oriented products involving a range of technologies and related sciences and Maths concepts and understandings.
- raise capital through cloud-funding
- depend on collaboration and effective communication among members to operate and flourish
- are flexible in making timely adjustment to cope with the challenges and fluidity of global markets

- Project management, accounting, financing, marketing, team work, collaboration, presentation, communication

Anthropocentric perspective highlights:

- the importance of peculiar human qualities including *Intuition, imagination, insight, perseverance, intentionality* and the likes (Capel, 1992)
- the awareness, the understanding and the ability to be a self-determining citizen who is able to cope with the challenges of the future, and to make technologically informed decisions in pursuing the well-being of oneself and others through technological actions.
- the values and attitudes of caring & respectfulness to:
  - Others– i.e. user's need/ preference/ cultural background oriented design, universal design
  - The environment—i.e. responsible use of technology in innovation & problem-solving , sustainable design, up-cycling

The STEMaker Project and "4D Curriculum Planning Tool"

The suggested strategy is to develop students to be STEMakers with the 3 desirable qualities through the planning and implementation of STEMaker projects in schools by making reference to the "4D Curriculum Planning Tool".

Following a D&T tradition, the STEMaker project is the hands-on and minds-on authentic learning activities that can serve as the platform for the integration of relevant subject knowledge and understanding. It is the appropriate manifestation of the learning activities of Approach Two in the "Overview", as it aims at the creation of novel artefacts and systems to serve users' needs, i.e. "*STEM Education for innovation*". The characteristics of STEMaker project are as follows

- Purposeful problem solving and inquiry that brings about changes in the made-world.
- Students manipulate materials, resources and equipment to create tangible outcomes
- Flexible construction and application of STEM knowledge, skills & values/attitude
- Varying and authentic problem situations to provide quasi-real life learning experiences that entail the development of generic skills, such as coping with complex and uncertain ill-defined problems, working collaboratively with others as a team with effective communications[2]
- Good quality and presentable products as learning outcomes
- Awareness of users' needs and preferences and Conscious appraisal of own products as well as the human's impact to the society and environment

[2] Some of the characteristics are adopted from Kimbell and Perry (2001)

The "4D Curriculum Planning Tool" shown in **Figure 1** serves as advance-organiser. The S, T and M dimensions [3]help teachers in identifying and determining the learning elements to be incorporated in STEMaker projects, whilst the "Variation of Delivery" dimension will probe teachers to consider school administrative planning matters in terms of curriculum allocation, different modes of delivery (from formal Technology Education lessons, project-learning month and weeks to one-off activity days). Moreover, the Model can facilitate cross-disciplinary collaboration among subject panels to look for appropriate planning of learning elements that are beneficial to students' learning.

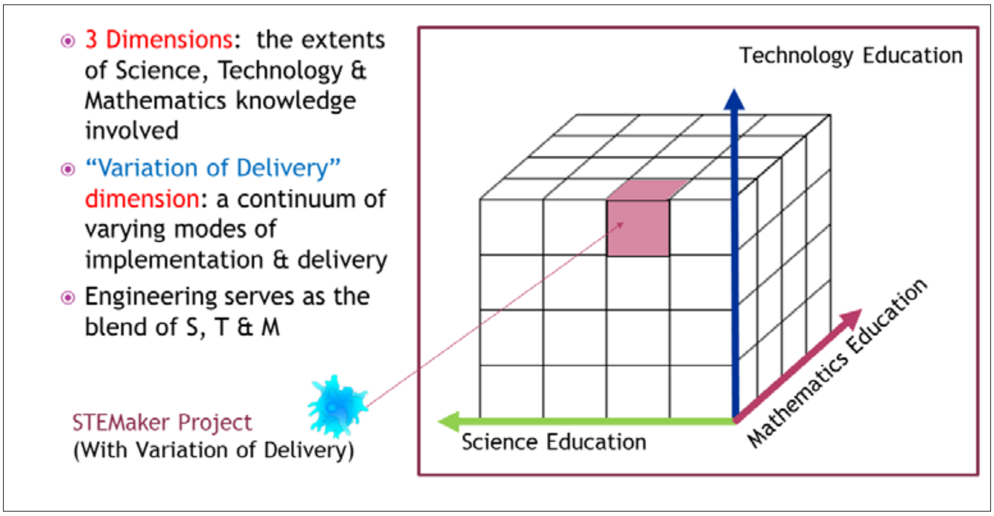

Figure 1: "4D curriculum planning tool"

Discussion: Issues and Action agenda to realise the promises

Issues of "readied STEM solutions"

As mentioned, there is a tendency that schools opt for a "readied solution" especially equipment and teaching kits to fulfill the obligation to implement STEM education. Elsewhere the authors have discussed the "resources-enhancing stance" (Wan & Lam, 2001) in uplifting the subject status of D&T. One of the lessons from this approach is that it relies heavily on the funding provided by the central agency. Therefore also at stake is the STEM curriculum justification on the procurement of certain equipment or services, which necessitate stakeholders' cognizance of the purpose of STEM education, nature of the integrative problem solving activities, goal and objectives of the project in planning etc.

[3] As there is no engineering subject in the HK school curriculum, it is regarded as the aggregated learning experiences of Science, Technology and Mathematics Education.

The issues over integration

It is explicitly stated in the "Overview" that teachers in the "KLAs of Science, Technology and Mathematics Education ….are encouraged to strengthen the cross-disciplinary collaboration at school level in planning and organising KLA-based and cross-KLA learning activities for students" (CDC 2015, para.12). However, in a recent EDB seminar aimed at experienced teachers in the STEM related KLAs to introduce the proposed curricula update for integration, fellow teachers from both Science and Mathematics KLAs coincidently voiced out the concern that the updates will overload the already fully-packed curriculum time. Not until they could make of the purpose of STEM education and justification of STEM integration would they commit and contribute to it.

Issues regarding understanding of the change and subject's sub-culture

As mentioned previously, the connotation of STEM education is opened to different interpretation so "STEM is in the eye of beholders". This renders the efforts to build shared vision and the actions to realise STEM education problematic. Under the absence of "shared vision", the existing subject subculture of teachers involved in the change will come into play. In citing literature discussing the influences of subject subcultures (Linblad, 1990; Paechter, 1992; Jones, 1999), Moreland maintains that when coming across new subject areas like TE [i.e. the curriculum change of integrative STEM education in this case], teachers often formulate learning experiences and classroom strategies on basis of their existing subject subcultures (Moreland, 2003). By building a shared-vision, it is hoped that teachers will hold shared belief in the purpose of the STEMaker education and agreement on the outcomes to be attained by students.

Action Agenda

The above issues address the need to build the "Shared vision" of the STEM/STEMaker education and as well the "Teacher readiness and competence" in STEMaker projects.

By "shared-visions" the authors mean "To nurture Hong Kong students to become STEMakers with the three desirable qualities through STEMaker projects so that they can actively participate in small innovative enterprises". This requires communication and dialogue among all stakeholders to achieve common understanding on the shared vision mentioned. The actions may include briefing sessions and workshops to introduce the conception of STEMaker, STEMaker project and "4D Curriculum Planning Tool".

Along with the efforts in shared vision-building, the actions upon the practitioners/teachers may include the enhancement of their readiness and competence in planning and offering of STEMaker projects. The need to develop STEMaker project competencies lays on the fact it is a “Big Task”[4] which, stretches across several lessons under a single purpose, and involves a range of skills, knowledge and understanding, is holistic in nature.

Further, the competence in offering “big tasks” can be conceptualised as “3 Cs”, i.e. the connectedness of technologies and knowledge involved, the coherence in purpose and the continuity of the activities across lessons. As well there are “repertoires” derived from Shulman’s model of “Pedagogical reasoning and actions” (Shulman, 1987) in planning and delivering of learning activities (QEF, 2015) including representation repertoires, instructional repertoires.

Actions regarding schools may comprise a repertoire of “STEMaker project resource and facilities lists” and “STEMakerSpaces/Centres layout plan” to enable the kicking-off of STEMaker education in schools with different backgrounds (e.g. with or without Technology Education/ D&T workshops). Also there has to be a cross-KLA curriculum collaboration framework that lays out the key features and know-how in identifying and arranging learning elements integration in STEMaker projects. At the community level, actions may include researches by academic institutions on STEMaker education learning outcomes, the nature of teacher competence in planning and delivering STEMaker projects and STEMaker education-specific pedagogical content knowledge (Shulman, 1987) that withstands the pedagogical reasoning and actions, and also offering of teacher development programmes for STEMaker educators. Business sectors may undertake financial supports for schools for the cost of resources and facilities required for STEMaker project. Moreover, they can offer funding or aid to support the incubation of potential SIEs.

Concluding remarks: What should go beyond these promises

Amid the purpose held by the central agency that TE and STEM education have to contribute to the economic competitiveness of the future generation, HKTEA believes that the intrinsic value of TE and STEMaker education should not be crowded out by the instrumental concern. Following this vein, the HKTEA has put forward the notion of “STEMaker” that congregates the 3 desirable qualities mentioned in former sections. Among them the “anthropocentric perspective” is regarded as of the utmost importance.

In debt to the "all-pervasiveness" of technology (Reid, 1988; Wan, 1997), we live in the myriad of systems and artefacts that are closely woven together with our senses, perception, practices and ways of life, present and future. In discussing the purpose of technology education, Capel (1992) holds that the "Anthropocentric" perspective in technology should be favoured over the "technocentric"

[4] The author is indebted to inspiring discussions with Prof. Alister Jones and Dr Judy Moreland of The University of Waikato for notions of a “big task” and the “3Cs” in TE in 2007.

perspective which denotes concession to “technological determinism”. Beynon (1992) maintains that "[T]echnological determinism diverts attention from such questions as the relationship of technology to human need….. that there is no choice about technology we have" (ibid. emphasis added). This implies the social decisions to use any technology or not should not be solely in the hand of “specialists and technical experts”.

In Hong Kong, the “anthropocentric perspective” finds its root in the Aim of Technology Education Key Learning Area (CDC, 2002), which is to “develop technological literacy in students through the cultivation of technological capability, technological understanding, and technological awareness to deal with the challenges of the future.” (ibid.) “Technological awareness” stipulates the imperative to arouse students’ cognizance in how technologies prevail in all aspects of our life that “… shape the way we think and behave…”and also “…why they exist in the form they do, and who and what was responsible for making its existence at all” (Burke 1978a).

By probing these inquiries along with the practices of designing and making in STEMaker projects, students will make sense of the technological phenomena they are situated in with anthropocentric perspective. Therefore they can develop positive attitudes towards technology and be well aware of the impacts of their technological decisions upon the society and the environment, so as to understand how to make change changes with socially and environmentally responsible decisions to address needs and solve technological problems (TAA, 1996; CDC 2002). Further by highlighting the human quality over equipment and artefact, it is also hoped that the younger generation could develop “big-picture thinking” to make technological decisions with ingenuity and human compassion (Davenport, 2016, cited in Fisher 2016). Thus, it could be said that STEMaker Education bears the purpose of emancipation that suggests the avoidance of the pitfalls of the “readied solution” approach mentioned in former sections. These practices are far from a broad, balanced and comprehensive technology curriculum, as they do not enable the inclusion of a multitude of learning outcomes and experiences. To make the change a sustainable one, we need to highlight the importance of deliberation on the developing in the teachers

- the understanding and conception on STEM learning elements, and competencies in pedagogy in conducting “big-task” projects;
- school-based curriculum/programme development, open-mindedness and flexibility in tackling and deciding of resource issues;
- assessment strategies and practices to support students’ learning and innovation; and
- nurturing of students’ critical awareness of the technological phenomena.

If we fail to do so, STEM will be like no more than a bonfire extravaganza with “…. loads of colourful and explosive entertainment”, leave without a trace when the excitement is over but only a warning "stenciled in big bold letters on the box of fireworks" amid the smoke, the smell and the dust: "HANDLE WITH CARE" (Kimbell, 2011).

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Appendix

Summary of HKTEA STEM Survey Proforma (2015)

Question	Response
1. Definition of STEM Education	*Teaching and learning approach in which science, technology, engineering, and mathematics (STEM) are purposefully integrated *Varies depending on the stakeholder
2. Purpose of STEM Education	*Promotes hands-on problem solving, creativity, & innovation *Promotes thinking about how STEM is connected and how impacts & shapes our lives. *Promotes interest in STEM careers as STEM-Education workforce is needed to help our country stay competitive. *Varies depending on the stakeholder
3. How STEM is implemented?	*Project Lead The Way (PLTW) *Engineering By Design *STEM Academies (Schools) *Taught as individual subjects

	*2 teachers working together on Point Projects
4. Mode of delivery	*Hands-on real-world project-based learning *Student competitions *Based around projects
5. Uniqueness about STEM programme in your country	*Often contain current tools, materials, and equipment used in STEM. For example, many STEM classrooms today have 3D printers, laser cutters, robotics, and “electronic equipment to teach about STEM. *Lots of funding being given today by government for developing quality STEM programs.
6. How to prepare teachers for STEM	*Still under debate *Teachers are given exposure to all STEM areas *Giving Technology Teachers more Math and Science *Elevating engineering design to the same level as scientific enquiry.
7. Difficulties encountered during initial implementation	*Lack of qualified STEM teachers (teachers with knowledge, skills and confidence) *Lack of University programmes to prepare teachers for STEM *Lack of STEM curriculum *Too often STEM refers to Math and Science, seldom does it refer to Technology and Engineering *School timetabling for STEM *School Structure (Teachers working together)

Research in the Informal Technology and Engineering Education through the Participant Awareness and the Program Satisfaction

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Abstract

The purpose of this study is to investigate various engineering-technology camps which are provided by CNU (Chungnam National University) Education center for Creative Future Engineers and study effectiveness for the students of the camps. The questions of the investigation are as follows. First, what kinds of camp programs are provided to students? Second, how are the participants satisfied with the camps? Third, how do the camps affect the participants?

The camps for middle and high school students consist of the following five major programs which contain many specified programs: (i) technical problem solving program, (ii) mentoring program for understanding engineering field, (iii) engineering laboratory tour program and (iv) special lectures by professional engineers and (v) ‘I will be a next engineer’ program. It is shown that engineering-technology camps of CNU Education center for Creative Future Engineers select topics of camp programs based on the student's interest and grade. The CNU Education center for Creative Future Engineers has cooperated with many research institutes located in local area in such a way that research institutes allow students to take tour of their laboratories and give special lectures.

These camp programs provide the participants with the opportunity to meet professors, engineers, specialists as well as to visit various engineering institutes that can promote their technical interest. Most of the participants are satisfied with the camp. And all participants in the camp answer that the camp would help in their career decision.

In conclusion, these engineering-technology camps have played an important role in cultivating human resource in the future of engineering field. In order to expand the engineering-technology camps, it is necessary to make a continuing effort such as more opportunity to students, more cooperation with various academic departments and institutes and enhancing public relations.

Key words: technology-engineering camp, informal education, out-of-school education

Introduction

Technology education in Korea is geared toward solving given problems creatively and cultivating the engineering skills needed in real life. Thus, technology education emphasizes inquiry and practice rather than the acquisition of knowledge.

Learning activities outside of the school environment occur in diverse venues, such as science centers, museums, research institutes, and universities. Engaging in hands-on activities allows students to experience engineering technology from various angles that are not found in textbooks, fostering a positive attitude toward technology, motivating students to major in engineering or another technology field and select related careers in the future, and enriching curricula in Korea.

However, as things stand, it is difficult for students to engage in hands-on technological activities in Korean schools, possibly because of constraints related to schools' learning conditions, personnel, time, space, budgets, et cetera. The only way to overcome these constraints, therefore, is to look for solutions outside of the school. Unfortunately, many for youth face problems associated with selecting suitable venues, finding lecturers with the requisite expertise, designing activities based simply on observation, and lacking adequate publicity.

For this reason, the present study is introducing the Academy for Creative Future Engineers, which has been operating for seven years under the auspices of the Education Center for Creative Future Engineers at Chungnam National University.

A program at the Academy for Creative Future Engineers is also being introduced, as it is intended to connect technology, engineering, and science to draw on real-life applications and thereby raise the interest and understanding of students and cultivate their integrative thinking abilities and problem-solving skills.

The aim of this study was to examine the various technology-engineering camp programs operated by Chungnam National University and provide the basic materials that other universities can use to operate similar camps.

Methods

Collected data were sorted by target students (i.e., middle school and high school participants). Participants were surveyed to obtain a brief description of camp activity and their level of progress. A satisfaction survey was distributed to participants to determine satisfaction levels with the program. Interviews were also conducted with students who attended the camp.

Results

9th to 10th grade student camp result

In August, we held technology-engineering camps for grades 9-10. For the students in grades 9-10, the camp focused on students' positive perceptions and interest in engineering technology.

We had a mentoring time with graduate students who is in engineering major course. And special lectures by engineering experts were also conducted. The program is shown in Table 1, Table 2 and Table 3.

Table 1: 9th grade Technology-engineering camp program

Day	Content	Time
Day 1	○ High Tech Experience: 3D Printer Design - Try 3D printer design. Learn about the features and uses of 3D printers. Confirm the value of 3D printers in the future. Think about the future direction of 3D printer development.	2hr
	○ Tuna boats is coming - A program to make boats using materials that are readily available from the surrounding area under limited conditions and on the boat, four tuna cans must be safely transported	2hr
Day 2	○ VR world beyond space - Learn and experience about the virtual reality. Design Virtual Reality Glass to experience virtual reality.	4hr
	○ I'm a architectural designer - Design the house that student wants. Design the house under limited conditions. Build a miniature house to match the design. This project will help the student that understand the principles of architectural engineering and technology. It can also be interested in architectural engineering.	4hr
Day 3	○ My career in Chemical Engineering - Make aspirin directly through chemical synthesis. Experiment with chemical engineering to extract vitamin C directly from orange juice. This project can help student to understand chemical engineering. And students can have an interest in chemical engineering and mathematics.	3hr

Table 2: 10th grade Technology-engineering camp program

Day	Content	Time
Day 1	○ Egg car project - A project to make a car that can safely descend the slopes with four eggs. The project will give students a sense of driving principles and safety. Students can also solve a given problem through creative ideas.	2hr
	○ DC motor manufacturing and electronic circuit configuration design - Projects that can understand the electric and electronic circuits and make engineering-based experiences by making the actual DC motor and circuit composition.	2hr
Day 2	○ Explore biotechnology - Introduce various projects in at the veterinary laboratory. And introduce the definition of biotechnology and experiments conducted around the world. This project to observe cells with a microscope and can do biotechnology experiment.	3hr

	○ Mechatronics Engineering and My Career - In this program students can make robots like one wheel-driven device via attitude control, line tracer moving along the line, quadcopter using four rotary axes, boxing robot	2hr
	○ Game make with entry - A project to create a simple computer game using entry software which is easy to use. Students can improve understanding of computer engineering and programming.	2hr
Day 3	○ My career path in architecture engineering - Introduce the history and detailed course of architectural engineering. Introduces the characteristics of architectural engineering and projects in architectural engineering lab and the construction site.	3hr

Table 3: 9^{th} -10^{th} grade Technology-engineering camp common program

Day	Content	Time
Day 1	○ Expert Lecture 1. Chemical engineering course - Easy access to chemical engineering through a brief introduction to chemical engineering and a story on chemical engineering that can be read through news. Introduce the chemical engineering vision, prospect, and career.	1hr
Day 2	○ Expert lecture 2. The world of electronics - Learn the principles of electronic engineering hidden in robotics and displays, introduction to vision and vision of electronics, and related field.	1hr
Day 3	○ Expert lecture 3. Entrepreneurship that creative the future - Introduction to entrepreneurship to be a true leader as well as knowledge. Introduce a career outlook and vision in engineering field.	1hr

7^{th} to 8^{th} grade student camp result

In August, we held technology-engineering camps for grades 7-8. For the students in grades 7-8, the camp focused on students' positive perceptions and interest in engineering technology.

We had a mentoring time with graduate students who is in engineering major course. And special lectures by engineering experts were also conducted. The program is shown in Table 4, Table 5 and Table 6.

Table 4: 7^{th} grade Technology-engineering camp program

Day	Content	Time
Day 1	○ I am an automotive engineer - After learning about the mechanical and metal fields, learn about the structure of the car and make a moving car using the motor	3hr
	○ Biennale of light and art utilizing electric circuit - A program which is based on understanding of electric and electronic engineering. Design and make the LED circuit diagram cheering stick.	3hr

Day 2	○ Aircraft model project - Find out what the plane lift does on the plane. Analyze the devices that make the plane fly. Construct capacitor plane by using capacitor and motor.	2hr 30min
	○ Switch Robot Olympics - Based on mechatronics engineering, learn the robots sensor part, control part and driving part. And make simple robot using basic principle.	2hr 30min
Day 3	○ Transport equipment lace - Based on creative design and thinking, make a transport device that can pass through a narrow and long passage using a given material.	3hr

Table 5: 8th grade Technology-engineering camp program

Day	Content	Time
Day 1	○ Aerospace engineering in my mind - After studying the aerospace engineering, learning the difference between rocket and jet plane, making various design rockets using foamed vitamin.	3hr
	○ Physical computing DIY - Learn the role of the program on the computer and the programming language, and create a moving robot using Arduino.	3hr
Day 2	○ Wood speaker design - A program to make wood speaker. Utilizing tools to process the wood. Understanding resonance and principle of speaker.	2hr
	○ Creative fire extinguisher design - Experiments to make spray fire extinguisher using acid-base reaction. And introduction of course and major subject in chemical engineering	2hr
Day 3	○ Safe automobile design project - Make a fast car that can protect eggs with creative thinking. For this project, students must have creative ideas and experiment several times.	3hr

Table 6: 7th -8th grade Technology-engineering camp common program

Day	Content	Time
Day 1	○ Expert lecture 1. Mechatronics Engineering and My Career - Learn the principles of mechatronics Engineering hidden in robotics, introduction to vision and vision of mechatronics, and related field.	1hr
Day 2	○ Expert lecture 2. Fun civil engineering - To learn the differences between civil engineering and architectural engineering. And learn the definition of civil engineering and how civil engineering fields are utilized in real life.	1hr
Day 3	○ Expert lecture 3. Creative thinking and invention - A special lecture to need of creative thinking in human life and find case of invention around our life.	1hr

Participant satisfaction result

We conducted program satisfaction questionnaire for technology-engineering camp participants. The results are shown in Table 7.

Table 7: Participant satisfaction result

Program title	Mean	SD	Grade	Program title	Mean	SD	Grade
High Tech Experience: 3D Printer	4.81	0.40	9th	I am an automotive engineer	4.70	0.55	7th
Tuna boats is coming	4.79	0.41	9th	Biennale of light and electric circuit	4.56	0.73	7th
VR world beyond space	4.67	0.56	9th	Aircraft model project	4.79	0.41	7th
I'm a architectural designer	4.65	0.83	9th	Switch Robot Olympics	4.65	0.57	7th
My career in Chemical Engineering	4.63	0.65	9th	Transport equipment lace	4.77	0.47	7th
Egg car project	4.62	0.66	10th	Aerospace engineering in my mind	4.72	0.56	8th
DC motor and electronic circuit	4.58	0.77	10th	Physical computing DIY	4.86	0.42	8th
Explore biotechnology	4.57	0.69	10th	Creative fire extinguisher design	4.86	0.42	8th
Mechatronics Engineering Career	4.56	0.77	10th	Wood speaker design	4.97	0.16	8th
Game make with entry	4.52	0.74	10th	Safe automobile design project	4.78	0.53	8th
My career path in architecture engi	4.46	0.74	10th	Mentoring with postgraduate student	4.70	0.55	7th-10th
My career in Chemical Engineering	4.43	0.73	9th, 10th	Mechatronics Engi and My Career	4.65	0.57	7th, 8th
The world of electronics	4.41	0.74	9th, 10th	Fun civil engineering	4.63	0.61	7th, 8th
Entrepreneurship that creative the future	4.23	1.02	9th, 10th	Creative thinking and invention	4.81	0.39	7th, 8th

Participant Interview result

We conducted interviews with technology-engineering camp participants. The contents of the interview are shown in Table 8.

Table 8: Participant Interview result

Classify	Grade	Interview
Program helps school life	8th	▪ I think engineering is hard and technology is boring but after this camp, engineering and technology is so fun. I will study math, science and technology hard. So I will be an engineer. Engineer is so cool.
	7th	▪ I did not know why I had to study math, when I see the engineering world, math is so close to our life. I should study hard.
Program helps in career	9th	▪ It was hard to ask question to professor, so I talked to graduate students in various departments and I think it was most value of time because I could know the real things.
	10th	▪ I just thought that I wanted to go to the engineering college, but when I met the professors and looked around the lab, it was good to know what I do in the future and what I will learn in engineering.

	7th	▪ I love content of the lecture and program. The program was not only fun but also hard to make creative thinking. But after class, I know so much about engineering field and technology. I want to go to engineering colleges.
Want	11th	▪ I hope that more students will participate. It was really helpful to me, and I believe it is same to other students.
	7th	▪ I want to visit more various majors. I am interested in aerospace engineering, but I could not attend aerospace engineering program when I participated.

Conclusion

The purposes of this study were to investigate the various technology-engineering camp activities implemented by Chungnam National University in Korea, draw out their implications, and utilize them as basic data for implementing similar camps at universities in other countries. The implications of this case study may be summarized as follows.

First, posters for the camps were sent to middle schools and high schools to recruit students interested in technology and engineering. The camp agenda encompassed two nights and three days, and most of the camp programs were organized around hands-on activities involving direct manipulation by the participants. Moreover, all programs were designed to develop skills in engineering, science, and technology. The programs enabled students to engage in hands-on activities that were not available to them at their schools. All camp programs were designed for students to have fun as they explored solutions to given problems. The camps were led by college engineering professors, technical subject teachers, and engineering specialists. Co-attendees included engineering graduate students who served as mentors to assist and guide students regarding career paths in science and engineering.

Second, an examination of satisfaction levels for each program showed that students were highly satisfied with all camp programs, especially those that enabled direct manipulation. The theme and content of each program were tailored to situations that students could encounter in everyday life, and the program configuration was based on students' interests. The programs were also adjusted to grade levels of students. Each program ran for two to three hours, thereby providing conditions under which students could maintain high levels of concentration during learning activities.

Third, interviews with participants confirmed that the technology-engineering camps were helpful for students academically and in their career planning. It was revealed that the camps aroused the interest of students in studying mathematics, technology, and science, and helped them determine their future career paths.

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The Effect of applying an Engineering-Technology Program on High School Students' Technological Thinking Disposition and Attitude toward Engineering

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Abstract

The purpose of this study was to verify the effect of an engineering-technology program on high school students' technological thinking disposition and attitude towards engineering.

To achieve, the following questions were posed. 1) How does the engineering technology program affect high school students' technological thinking disposition? 2) How does the engineering technology program affect high school students' attitude towards engineering?

For this study, the program ran from May to August in 2016. Data were collected from 138 D high school students in Daejeon, Korea.

For the statistical analysis, Windows SPSS-22 is used and a significance level of .05 was established prior to data treatment.

The results of this study are as follows:

First, participation in the engineering technology program had a significant effect on the technological curiosity disposition, technological creativity and expression disposition, technological operation disposition, and technological planning and reflecting disposition. No significant effect was observed on the technological analysis disposition and technological problem identification resolution disposition.

Second, participation in the engineering technology program had a significant effect on interest in engineering and perceptions of creativity in engineering, but had no significant effect on the perceptions of importance in engineering.

Key words: technological thinking disposition, attitude toward engineering, out-of-school education

Introduction

Technology and engineering education of the current era nurtures the technology and engineering literacy by supplying information that can stimulate interest and curiosity in the field. These two components are important in technology and engineering education because they can eventually influence students' attitude toward technology and engineering.

A positive attitude towards engineering in secondary schools is important for the development of science, technology and engineering fields. In order to foster a career in science and engineering, a variety of studies have shown that the interest and positive attitude of science and technology subjects have a positive influence on engineering.

The present study investigates how students' technological thinking disposition and attitude towards engineering can be changed by participation in a technology-engineering camp, an out-of-school program.

The purpose of this study was to verify the effect of an engineering technology program on high school students' technological thinking disposition and attitude towards engineering.

To achieve this purpose, the questions posed were as follows. 1) How does the engineering technology program affect high school students' technological thinking disposition? 2) How does the engineering-technology program affect high school students' attitude towards engineering?

Methods

For this study, the program ran from May to August in 2016. The data were collected from 138 D high school students in Daejeon, Korea.

For the statistical analysis, Windows SPSS-22 was used and a significance level of .05 was established prior to data treatment.

In this study, to measure the technological thinking disposition, Nam's technological thinking disposition measuring tool was used. This measuring tool consists of 38 questions. We use Lee & Sung's engineering attitude measuring tool, which consists of 29 questions.

Results

Results of technology engineering camp operation

The engineering and technical camps were held four times in total. The engineering program was conducted as shown in Table 1 and integrated science, technology, engineering, arts and mathematics.

Table 1: Technology-engineering camp program

Day	Grade	Program Title
First	11th	▪ Designing happy future science and engineering career path ▪ Creative capacitor plane design ▪ Biennale of light and art using electric circuit

	12th	▪ Designing happy future science and engineering career path ▪ Take the rocket to space ▪ Cable control car survival project
Second	11th	▪ Switch Robot Olympics ▪ Goldberg device design
	12th	▪ I am a building designer ▪ Chemical engineering and my career path
Third	11th	▪ New changes and 3D printers ▪ Salt water fuel cell car making ▪ Renewable energy using wind power generators
	12th	▪ New changes and 3D printers ▪ CdS and electric circuit lamp design ▪ Augmented reality and virtual reality
Fourth	11th	▪ Catching up with architects
	12th	▪ From stick to mechatronics robot arm

The technology engineering camp program provided special lectures on the science and engineering career path and on the 3D printer, which is a new technology trend. The contents of the lesson were designed to include both engineering knowledge and technical knowledge based on creative design and emotional experience.

Change in technological thinking disposition

We examined the effect of technology and engineering camp on changing technological thinking disposition by surveying 139 high school participants.

The results of the statistical analysis are shown in Table 2 and Table 3.

Table 2: 11th grade technological thinking disposition changing

Division		N	Average	SD	t	p
Technological curiosity disposition	Before	68	3.33	0.59	-3.459**	.001
	After	70	3.72	0.76		
Technological analyze disposition	Before	68	3.34	0.60	.322	.748
	After	70	3.31	0.59		
Technological problem identifying resolving disposition	Before	68	3.49	0.63	-.154	.878
	After	70	3.47	0.61		
Technological creativity and expression disposition	Before	68	3.59	0.65	-3.439**	.001
	After	70	3.91	0.47		
Technological operating disposition	Before	68	3.52	0.58	-2.083*	.039
	After	70	3.70	0.51		
	Before	68	2.81	0.27	-.759	.449

Technological planning and reflecting disposition	After	70	2.85	0.31		

Based on the response results of the questionnaire for the 11th grade, the technological curiosity disposition mean was 3.33, SD 0.59 before participation in the camp, and the mean became 3.72, SD 0.76 after. Participation in the engineering technology program had a significant effect on the technological curiosity disposition (t=-3.459, p=.001). In the case of technological analysis disposition, before the camp the mean was 3.34, SD 0.60, which became 3.31, SD 0.59 after. Participation in the engineering technology program had no significant effect on the technological curiosity disposition (t=.322, p=.748). In case of technological problem identification resolution disposition, before the camp the mean was 3.49, SD 0.63, which went down to 3.47, SD 0.61 after. Participation in the engineering technology program had no significant effect on the technological problem identification resolution disposition (t=-.1549, p=.878). In the case of technological creativity and expression disposition, before the camp the mean was 3.59, SD 0.65, after the camp the mean was 3.91, SD 0.47. Participation in the engineering technology program had a significant effect on the technological creativity and expression disposition (t=-3.439, p=.001).
In the case of technological operation disposition, before the camp the mean was 3.52 SD 0.58, which increased to a mean 3.70, SD 0.51 after the camp. Participation in the engineering technology program had a significant effect on the technological operation disposition (t=-2.083, p=.039).
In the case of technological planning and reflecting disposition, mean before the camp was 2.81 SD 0.27, and after the camp the mean was 2.85 SD 0.31. Participation in the engineering technology program had no significant effect on the technological planning and reflecting disposition (t=-.759, p=.449).

Table 3: 12th grade technological thinking disposition changing

Division		N	Mean	SD	t	p
Technological curiosity disposition	Before	67	3.45	0.57	-2.528*	.013
	After	66	3.70	0.57		
Technological analyze disposition	Before	67	3.26	0.51	-1.174	.242
	After	66	3.38	0.67		
Technological problem identifying resolving disposition	Before	67	3.53	0.52	-1.316	.190
	After	66	3.65	0.59		
Technological creativity and expression disposition	Before	67	3.71	0.60	-2.162*	.032
	After	66	3.91	0.49		
Technological operating disposition	Before	67	3.69	0.62	-1.354	.178
	After	66	3.82	0.49		
Technological planning and reflecting disposition	Before	67	2.76	0.26	-3.079**	.003
	After	66	2.90	0.27		

Based on the response results of the questionnaire for the 12th grade, technological curiosity disposition mean was 3.45, SD 0.57 before the camp, and after the camp, the mean was 3.70 and SD 0.57. Participation in the engineering technology program had a significant effect on the technological curiosity disposition (t=-2.528, p=.013). In terms of technological analysis disposition, the mean was 3.26, SD 0.51 before camp, and after, the mean was 3.38, SD 0.67. Participation in the engineering technology program had no significant effect on the technological curiosity disposition (t=-1.174, p=.242). In the case of technological problem identification resolution disposition, the mean was 3.53, SD 0.52 before camp, and the mean was 3.65, SD 0.59 after camp. Participation in the engineering technology program had no significant effect on the technological problem identification resolution disposition ((t=-2.162, p=.032). In the case of technological creativity and expression disposition, the mean and SD before and after was 3.71, SD 0.60, and 3.91, SD 0.49, respectively. Participation in the engineering technology program had a significant effect on the technological creativity and expression disposition (t=-2.162, p=.032).

In the case of technological operation disposition, the mean was 3.69 SD 0.62 before, which increased to a mean of 3.82 SD 0.49 after camp. Participation in the engineering technology program had no significant effect on the technological operation disposition (t=-1.354, p=.178).

In the case of technological planning and reflecting disposition, before participating in the camp, the mean was 2.76, which became 2.90 after the camp. Participating in the engineering technology program had a significant effect on the technological planning and reflecting disposition (t=-3.079, p=.003).

Change in attitude towards engineering

We collected data before and after participation in the camp to find changes in attitude towards engineering.

The results of the statistical analysis are shown in Table 4 and Table 5.

Table 4: 11th grade engineering attitude changing

Division		N	Average	SD	t	p
Interests in engineering	Before	68	3.79	0.73	-2.462*	.015
	After	70	4.10	0.74		
Perceptions of creativity in engineering	Before	68	3.09	0.54	-2.745**	.007
	After	70	3.35	0.59		
Perceptions of importance in engineering	Before	68	3.77	0.44	-.398	.691
	After	70	3.80	0.55		

After participating in the engineering technology program, there was significant effect on interest in engineering and perceptions of creativity in engineering.

In the case of 11th graders, before participating in the camp, the interest in engineering mean was 3.79, and remained the same after participation. There was significant effect on interest in engineering (t=-2.462 p=.015). Before participation in the camp, the perceptions of creativity in engineering mean was 3.09, which increased to 3.35. There was significant effect on interest in engineering (t=-2.745, p=.007).

However, perceptions of importance in engineering had no significant effect on perceptions of importance in engineering (t=-.398, p=.691).

Table 5: 12th grade engineering attitude changing

Division		N	Average	SD	t	p
Interests in engineering	Before	67	3.53	0.76	-2.552*	.012
	After	66	3.85	0.70		
Perceptions of creativity in engineering	Before	67	3.15	0.58	-2.171*	.032
	After	66	3.38	0.64		
Perceptions of importance in engineering	Before	67	3.69	0.48	-.457	.649
	After	66	3.73	0.59		

For the 12th grade, before participating in the camp, interest in engineering mean was 3.53, which increased to 3.85. There was significant effect on interest in engineering (t=-2.552 p=.012). Before participating in the camp, the perceptions of creativity in engineering mean was 3.15, which increased to 3.38. There was significant effect on interest in engineering (t=-2.171, p=.032).

However, perceptions of importance in engineering had no significant effect on the perceptions of importance in engineering (t=-.457, p=.649).

Conclusion

The purpose of this study is to apply the technology engineering camp to high school students and to record the change in the technological thinking disposition and the attitude towards engineering.

The conclusion of this study is as follows.

First, nine technology engineering programs (first day 3 programs, second day 2 programs, third day 3 programs, fourth day 1 program) were applied to each grade. The technology engineering camp has been applied variously to lectures on technology and engineering career design, new technology trends, technical problem solving project class, and classes requiring engineering knowledge. In the 11th grade, the program focuses on technical problem solving projects based on technical knowledge. In the case of the 12th grade, the program focuses on engineering knowledge.

Second, in the case of 11th graders, after participating in an engineering technology program, there was significant effect on the technological curiosity disposition, technological creativity and expression disposition, and technological operation disposition. However, no significant effect was observed on the technological planning and reflecting disposition, technological analysis disposition, technological problem identification and resolution disposition. In the case of 12th graders, after participating in the engineering technology program, there was significant effect on the technological curiosity disposition, technological creativity and expression disposition, technological planning and reflecting disposition but no significant effect on the technological operation disposition, technological analysis disposition, technological problem identification and resolution disposition.

When given technical problems based on technical subject knowledge, it is found that activities for solving problems increase the technological curiosity disposition, technological creativity and expression disposition of learners.

Third, the technology engineering camps were found to be effective in terms of interest in engineering and perception of creativity in engineering in the 11th and 12th grades.

This result shows that the task can be performed in an interesting manner unlike in the existing class and by giving challenging tasks to demonstrate the creativity of students. An exciting and interesting engineering program can better stimulate students to learn about engineering, and can reduce the tendency of students to avoid science and technology subjects, and can ultimately lead to advancement of the science and engineering fields. Based on this research, it is expected that out of school technology engineering education will become more active if high-quality technology engineering programs are developed.

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Effects of applying an Engineering Design Process in a STEM-based Learning Activity to help Develop Engineering Design Thinking among Pre-service Technology Teachers

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Abstract

Encouraging engineering design thinking is a key component of pre-engineering technology curricula for future engineers. This study explored the effects of applying an engineering design process in a STEM-based learning activity to help develop engineering design thinking among pre-service technology teachers. A quasi-experimental method comprised of non-equivalent pre- and post-tests were used in teaching experiments. The experiments involved 15 pre-service technology teachers in an experimental group, which applied an engineering design process in a STEM-based learning activity, and 13 pre-service technology teachers in a control group, which applied a problem-solving process in a STEM-based learning activity. For the pre- and post-tests, a flow-map method was utilized to analyze cognitive structures and information-processing strategies for engineering design thinking among pre-service technology teachers. Analysis of flow-maps yielded the following conclusions: (1) high-level information processing strategies for engineering design thinking should be improved among pre-service technology teachers; and (2) the STEM-based learning activity involving engineering design process is beneficial for improving cognitive structures and information-processing strategies for engineering design thinking among pre-service technology teachers, but the effects should be improved.

Keywords: engineering design process, engineering design thinking, preservice teacher, STEM

Introduction

Engineering activity is defined as the process of identifying human needs and providing solutions according to the engineering design principle (Simon, 1996). Engineers can effectively meet the social demands for goods and services through the engineering design process (Sheppard, 2003). To cultivate engineering design thinking among students, it is important to teach them procedural knowledge involved in engineering design, and to teach them to clearly express ideas and plan a complete procedure in order to achieve a task. Therefore, it is important to incorporate training in problem-solving and developing innovative designs into technology education.

Many researchers believe that the development of engineering design thinking is related to cognitive development, and that engineering design methodology, cognitive models, situated cognitive models, and cognitive structures can all be engaged to encourage this kind of thinking among students (Lawson, 2006; Mehalik & Schunn 2007; Visser 2006; Cross, 2006). Thus, it is beneficial for students to participate in the processes of analyzing, creating, and applying engineering designs to help develop their cognitive structures. This study explored the effects of applying engineering design processes in STEM-based learning activity to develop engineering design thinking among pre-service teachers. In turn, this will enable teachers to encourage the cognitive structures required for engineering design thought among their students in the future.

The idea of 'STEM education' is becoming more popular, but how to implement the technology and engineering components of STEM education is still in need of further exploration. In this study, a STEM-based learning activity was developed with technology focused on hands-on skills, and engineering focused on engineering design thinking. The design of this STEM-based learning activity was expected to clarify students' definitions of technology and engineering; it was also expected to help develop their cognitive structures needed for engineering design thinking.

Each country has different systems, objectives, and preferred methods for educating teachers. Considerable research has demonstrated that engineering design thinking is a critical element for pre-service technology teachers and could be useful if developed further. Much of the current research in design has sought to answer questions concerning how to generalize, universalize, and internationalize a training method for pre-service technology teachers. For example, if expert practitioners engage in the same practices as more novice students, but in a more comprehensive way, this may encourage the development of design expertise across the learning spectrum (Atman et al., 2007).

As a result of these findings, there has been growing awareness of the importance of equipping pre-service technology teachers with engineering design learning skills throughout their educational experience. In this study, we focused on pre-service technology teachers who gather significantly more information, cover significantly more categories, typically consider a number of alternative solutions, and use high-quality solution timelines involving iterative processes (Atman et al., 2007). Our goal is to encourage these characteristics among all pre-service technology teachers. Therefore, we plan to continue to analyze our data, and data from other participant groups, to deepen our understanding of engineering design thinking among individuals with varying levels of expertise.

In the past, engineering design thinking was evaluated based on the results of tests. Although learners can achieve temporary effects after teaching, they may not be aware of the full effects of learning. Therefore, we explored the cognitive structures related to engineering design thinking among pre-service technology teachers using in-depth interviews, the flow-map method, and meta-listening techniques (Anderson & Demetrius, 1993; Tsai & Huang, 2002). In accordance with the previous research background, the research purposes of this study were:

1. To explore the cognitive structures related to engineering design thinking among pre-service technology teachers.
2. To explore how engaging in engineering design and problem-solving processes help develop the cognitive structures related to engineering design thinking among pre-service technology teachers.

Methods

Subjects

The subjects of this study were 28 pre-service technology teachers from two classes at a National Normal University in Taiwan. By using a quasi-experimental research approach, one class of 15 pre-service technology teachers was assigned to an engineering-design instruction group, while the other class of 13 pre-service technology teachers was assigned to a problem-solving instruction group. Before conducting the study, these two groups did not differ significantly in their engineering design thinking scores ($p > 0.05$). All participants in each group were taught by the same technology professor.

Research procedure

The research treatment was conducted for twelve weeks (100 minutes per week), and the topic of the STEM-based learning activity was a 'mousetrap car.' For the experimental group, the STEM-based learning activity focused on the engineering design process (Atman et al., 2007); concurrently, the STEM-based learning activity for the control group focused on the problem-solving process.

Data collection and analysis

In-depth interviews, the flow-map method, and meta-listening techniques were employed in this study to explore cognitive structures related to engineering design among pre-service technology teachers (Tsai & Huang, 2002). The in-depth interviews included five questions used by Anderson and Demetrius (1993) and Tsai (1998a) in their research: (1) Please tell me about your main ideas of 'engineering design thinking'; (2) Could you define the elements of these ideas that refer to function and other important concepts? (3) Could you please explain the concepts you have just mentioned? (4) Could you tell me about the relationship between the ideas you have already told me about? and (5) Could you tell me more about what you have just mentioned, are there any other relationships that exist? Interviews were all tape-recorded with the permission of subjects.

The next step involved a ‘meta-listening’ technique, which can help explore a subject’s additional conceptual knowledge. Figure 1 presents a flow-map for the engineering-design instruction group. A flow-map is constructed by entering statements in the sequence they are given by a subject. The sequence of discourse is examined, and recurrent ideas represented by recurring word elements in each statement (presenting a connecting node to the prior idea) are linked by connecting arrows. The flow-map in Figure 1 shows a sequential pattern beginning with differences in engineering design thinking, to observations about the mousetrap car activities. Subjects also provided some descriptions about engineering design thinking. Recurrent arrows link revisited ideas to the earlier steps where the related ideas first occurred. For example, Statement 6, “Using modern engineering design theory and method” includes one revisited idea, “design theory.” Therefore, Statement 6 has one recurrent arrow drawn back to statement 5. Two types of arrows are used in the flow-map. The linear or serial arrows show the direct flow of the learner’s narrative, while the recurrent arrows show the revisited ideas among the statements displayed in the flow-map (Wu & Tsai, 2005).

All interviews were transcribed and translated into a visual flow-map. This study also investigated information-processing strategies among subjects based on the content analysis of their recall narratives, which is presented at the top of each flow-map. The categorization framework for information processing strategies was adapted from Tsai (1991), and included five levels:

- Defining: Providing a definition of a concept or engineering design thinking term, e.g., “Engineering design thinking is characterized by the realization of methods, systems thinking, stimulating creativity, etc.”
- Describing: Depicting a phenomenon or a fact, e.g., “Engineering design thinking will progress from shallow to deep reasoning.”
- Comparing: Stating the relationships between (or among) subjects, things, or methods, e.g., “Engineering design thinking involves the external process of learning from the inside, which will occur through the process of logical thinking.”
- Inferring: Describing what will happen under certain conditions, e.g., “Mutual help between peers can help a team achieve a goal.”
- Explaining: Offering a way to justify the causality of two facts or events, e.g., “There are many convenient and practical designs in our life, such as mobile phones and folding tables, which help accommodate our needs.”

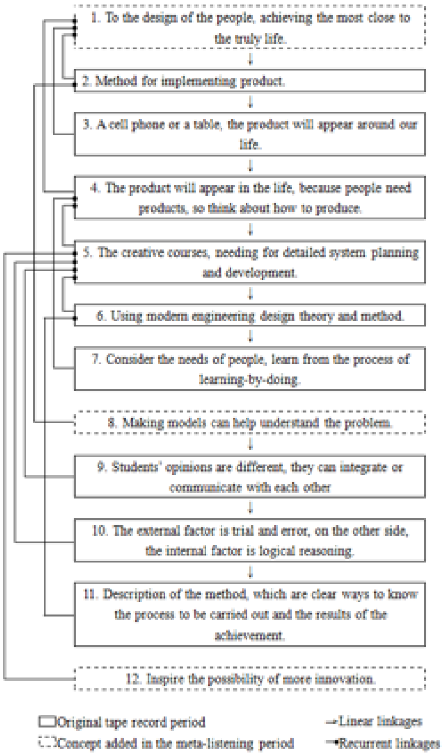

Figure 1. A flow-map for engineering design thinking among the engineering-design instruction group.

Previous research has shown that these traditional assessment methods can be used to compare two groups of pre-service technology teachers, and to reveal how learners' understanding of engineering design thinking actually contributes to their reasoning. For example, Wu (2013) found that some university students had learned content knowledge regarding a socio-scientific issue, as evidenced by their performance on an achievement test. In the present study, the flow-map method, meta-listening techniques, and core concept analysis were used to obtain data about engineering design thinking and knowledge structures among pre-service technology teachers.

The statements in each flow-map were categorized. Next, the frequencies of the five-level information-processing strategy used by each learner were counted. The concepts described by respondents were classified into five strategies: "defining," "describing," "comparing," "inferring," and "explaining," as marked on the upper right corner of each concept. This method was used to transcribe interview narratives into the visual display of the flow-map. This yielded 28 representational flow-maps revealing the cognitive structures developed in each group: engineering-design instruction and problem-solving instruction groups. Based on the results, several quantitative variables appear to be related to changes in cognitive structures (Tsai & Huang, 2002):

- Extent: the number of ideas contained in cognitive structures.
- Correctness: the number of alternative conceptions in one's cognitive structures, or the number of correct conceptions.

- Integration: the connection of cognitive structures. A well-organized cognitive structure is similar to a well-structured database: users can find information efficiently.

- Availability: the availability of cognitive structures can be represented by the information-retrieval rate, i.e., the time required to mobilize and retrieve ideas can indicate the availability of cognitive structures (Tsai, 1998b, 2001).

- Information-processing strategy: by means of content analysis of cognitive structures, researchers can investigate individuals' information-processing operations, such as their use of defining, describing, comparing, inferring, and explaining (Tsai, 1999).

To ensure the reliability of scores, all flow-maps were independently scored by two different researchers. The similarity ratio values were all beyond 0.8, indicating good scorer reliability (Anderson & Demetrius, 1993; Wu, 2005). Therefore, the flow-map method was deemed sufficiently reliable for the purpose of this research.

Results

Cognitive structure of engineering design thinking among pre-service technology teachers

To understand the cognitive structures of engineering design thinking, this research focused on the experimental group and the control group of pre-service technology teachers that were interviewed. The semantic analysis method was used to analyze the flow-maps of the cognitive structure of their engineering design thinking. According to Tsai and Huang (2002), the cognitive structure of engineering design thinking can be divided into five dimensions: "extent," "correctness," "integration," "availability," and "information processing strategy," as shown in Table 1.

Table 1. Cognitive structures of preservice technology teachers: quantitative analysis of pre-test data. (n=28)

Dimensions of factor	*M*	*SD*
Extent	12.18	5.72
Initial linear linkages	5.86	2.80
Final linear linkages	6.32	2.98
Correctness	0.00	0.00
Number of error statement concepts	0.00	0.00
Integration	11.02	5.84
Initial recurrent linkages	4.86	2.80
Final recurrent linkages	5.32	2.98
Complexity of initial linear concepts	0.41	0.12
Complexity of final linear concepts	0.43	0.09
Availability	0.95	1.79

Change of linear concepts	0.46	0.88
Change of recurrent concepts	0.46	0.88
Change in complexity of linear concepts	0.02	0.08
Information processing strategy	6.32	2.98
Defining	0.71	0.90
Describing	4.21	2.06
Comparing	0.50	0.79
Inferring	0.68	0.67
Explaining	0.21	0.42

Applying engineering design processes in a STEM-based learning activity to develop engineering design thinking among pre-service technology teachers

A series of t-test analyses were conducted to examine differences in cognitive structures between the engineering-design instruction and problem-solving instruction groups. Table 3 presents the data on cognitive structure outcomes and information-processing modes gathered from the flow-maps.

Table 3. Comparison of cognitive structures between engineering-design instruction and problem-solving instruction groups. (n=28)

	Experimental group (N=15)		*Control group (N=13)*		
Engineering design process	*M*	*SD*	*M*	*SD*	*t*
Extent					
Initial linear linkages	13.73	4.48	11.31	4.40	1.44
Final linear linkages	15.13	5.44	11.54	4.41	1.90
Correctness					
Number of error statement concepts	0.00	0.00	0.00	0.00	N/A
Integration					
Initial recurrent linkages	12.73	4.48	10.31	4.40	1.44
Final recurrent linkages	14.13	5.44	10.54	4.41	1.90
Complexity of initial linear concepts	0.48	0.01	0.47	0.01	1.13
Complexity of final linear concepts	0.48	0.01	0.47	0.01	1.35
Availability					
Change of linear concepts	1.40	2.20	0.23	0.60	1.86
Change of recurrent concepts	1.40	2.20	0.23	0.60	1.86
Change in complexity of linear concepts	0.00	0.00	0.00	0.00	0.93
Information processing strategy					

Defining	2.07	1.28	1.23	1.09	1.84
Describing	8.93	2.52	7.15	2.51	1.87
Comparing	1.87	1.13	1.15	1.21	1.61
Inferring	1.47	1.68	1.15	1.34	0.54
Explaining	0.80	0.94	0.85	0.90	-0.13

Note: *p<.05

Conclusion and Implications

Based on the experimental results of this study, using an engineering design process in a STEM-based learning activity is helpful in developing cognitive structures related to engineering design thinking among pre-service technology teachers. However, the t-test revealed that the difference between the two groups was not significant. The results also revealed that post-intervention, the pre-service technology teachers scored better on the concepts of "extent" and "integration" but that scores for the concepts of "availability" and "higher level of information processing strategy" need to be further improved. These findings are similar to those of Tsai and Huang (2002), who focused on exploring students' cognitive structures through science-learning activities. Therefore, more research is needed to explore how to stimulate higher-level information-processing strategies among pre-service technology teachers. Analyses of flow-maps yielded the following conclusions: (1) availability and high-level information-processing strategies of engineering design thinking should be improved among pre-service technology teachers; and (2) the STEM-based learning activity that applied an engineering design process is beneficial for developing cognitive structures and information-processing strategies of engineering design thinking among pre-service technology teachers, but these effects need to be improved.

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Manufacturing Wooden Toys as STEAM Teaching Practice Framed by Waves/Showers-of-Emotion Theory

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Abstract

This paper deals with the manufacturing wooden toys as STEAM teaching practice framed by waves/showers-of-emotion theory. We have developed many moving wooden toys as teaching materials for the manufacturing class in school (kindergarten, elementary school, junior high school, high school, and university). In the manufacturing classes, the students make and play with the moving toys and then study about the operating principle, physics, designer's invention, how to use tools with their surprise and pleasure. They experience the other's emotion, surprise, laughter, interest, pleasure, challenge, failure and success. After every class, they play with the moving toys and talk about the toys with their family at home, and then reconstitute learning contents and strengthen their feelings of self-esteem.

Keywords: Manufacturing, Moving toy, Teaching material, STEAM, WET/SET

Introduction

In the government course [curriculum] guidelines for elementary school [1], it is described "To enable pupils to make tools for play and devise ways to play by using natural objects and things in their immediate environment, to recognize the charm and wonder of such objects and things, and to be able to enjoy playing with everyone."

In the government course [curriculum] guidelines for kindergarten [2], it is described "Developing an interest in surrounding things and play equipment, and thinking about creative ways to make the best use of them. Developing curiosity about the concepts of quantities and diagrams in everyday life."

Then, we study about the manufacturing wooden toys as STEAM teaching practice framed by waves/showers-of-emotion theory (WET/SET). We have developed many moving toys as teaching materials for the manufacturing class in school (kindergarten, elementary school, junior high school, high school, and university) [3]-[5]. The main moving toys [5] are the moving toy on the string by the law of inertia, the climbing toy on the strings by frictional force, and the passive walking toy by gravity and leverage principle.

In this study, we suggest the other low cost moving toys made of paper, and automata (mechanical toy), wooden clock, etc. as teaching materials.

In the manufacturing classes, the students make and play with these toys, and they study about the operating principle, designer's invention, how to use tools with their emotions, surprise and pleasure. And they experience the other's emotion, surprise, laughter, interest, pleasure, challenge, failure and success. After every class, they play with the toys and talk about the toys with their family and friends at home, reconstitute learning contents, and strengthen their feelings of self-esteem. WET/SET consists of "The Four-Phase Model of Interest Development" (Hidi & Renninger [6]) and "Stages to Transform in Intrinsic Motivation from Extrinsic Motivation" (Ryan & Deci [7]). In the classes, the expressed emotion and stages of developing interest are appeared with considerable frequency. Then, the students enhance their intrinsic motivation.

We have manufacturing wooden toys as STEAM teaching practice and analyze the activity and transformation of students by evaluating the questionnaires for the students, guardians, and teachers.

Development of teaching materials

In this chapter, we describe about the moving toys developed as teaching materials for manufacturing classes. By manufacturing the moving toys, the students study the operating principle, and they are able to learn scientific contents, energy, gravity, friction, .

Figure 1 shows the flow chart of manufacturing class. The manufacturing classes are constituted to become the flow where students continue studying about something. They study the operating principle, designer's invention, and how to use tools with their emotions. They experience surprise, laughter, interest, pleasure, challenge, failure and success. After every class, they play the toys with their family and friends at home, reconstitute learning contents, and strengthen their feelings of self-esteem.

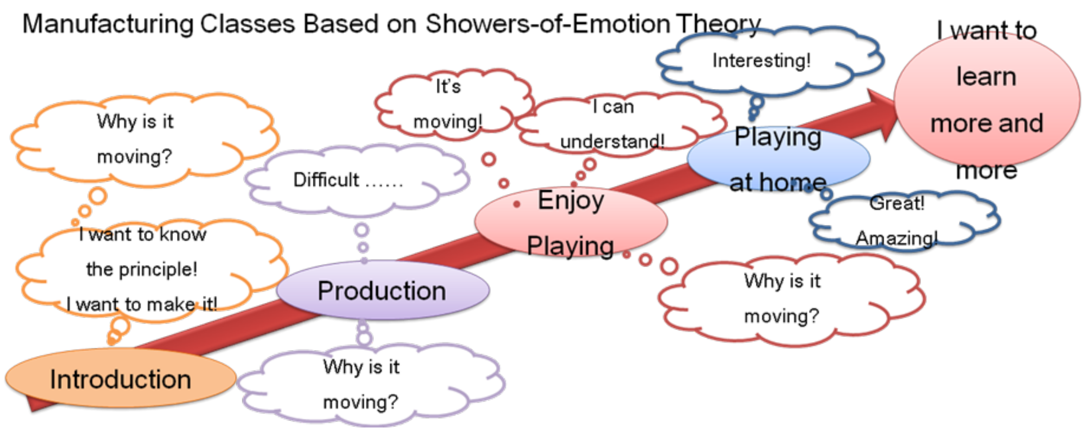


Figure 1. Manufacturing class framed by WET/SET

Passive walking toy as stem teaching materials

We have developed the passive walking Dinosaur toy shown in Fig. 2. The passive walking toy is put on the slope and, by the first rolling, keeps walking. It has a foreleg, which is glued on the body, and the foreleg moves with the body. While, the hind leg is put on the body by shaft and it turns around the shaft.

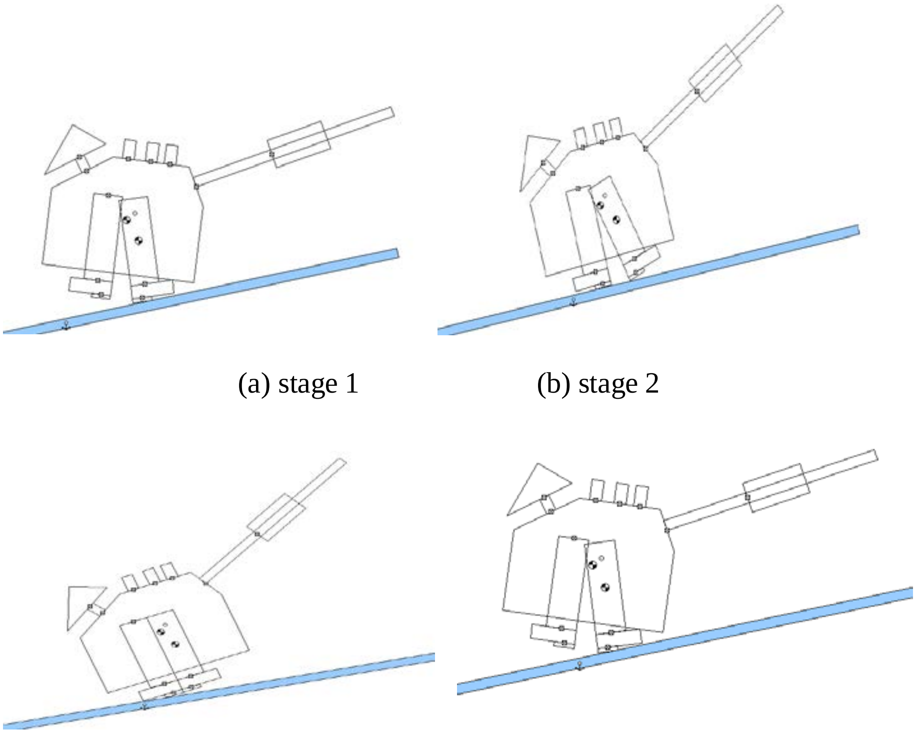
The experimental results of walking success ratio and toy's Angular velocities are shown in Table 1 and Figure 4, respectively.

(a) Dinosaur toy (b) Shape of sole and toe

Figure 2. Passive walking Dinosaur toy

Source: URL of wooden toy movie is https://www.youtube.com/watch?v=QJGpVh3YtCI

URL of metal toy movie is https://www.youtube.com/watch?v=wB69LtFDFgQ



(a) stage 1 (b) stage 2

(c) stage 3 (d) stage 4

Figure 3. Dinosaur toy's walking stages

Table 1. Experimental results of walking success ratio [%] for the slope angle θ and the weight position L

θ [°]	L[mm]									
	10	20	30	40	50	60	70	80	90	100
7	80	100	100	0	0	0	0	0	0	0
8	100	100	100	60	0	0	0	0	0	0
9	100	100	100	100	0	0	0	0	0	0
10	100	100	100	100	90	0	0	0	0	0
11	10	100	100	100	100	0	0	0	0	0
12	0	100	100	100	100	100	100	0	0	0
13	0	10	100	100	100	100	100	0	0	0
14	0	0	0	100	100	100	100	100	100	0
15	0	0	0	100	100	100	100	100	100	100

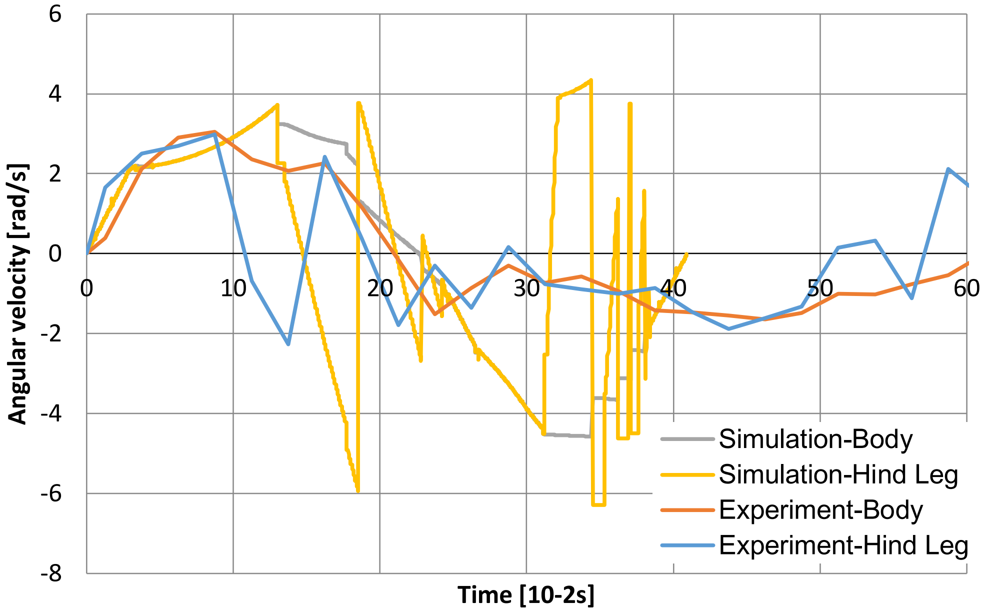
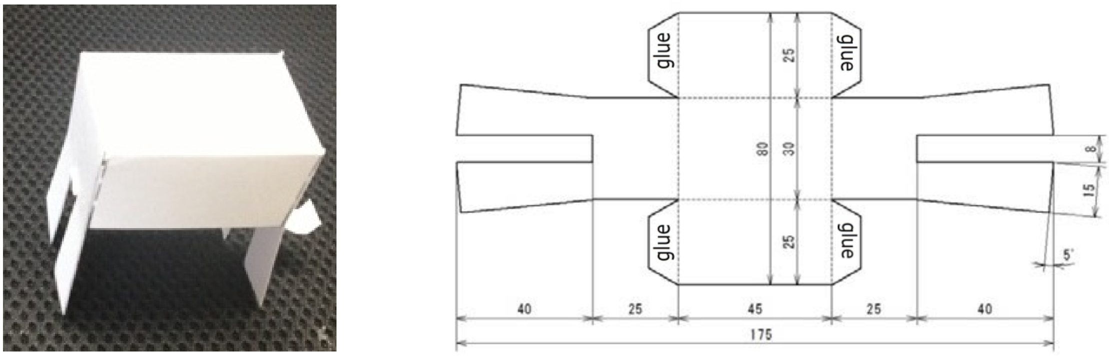


Figure 4. Angular velocities of the body and hind leg with time variable by experiment and simulation

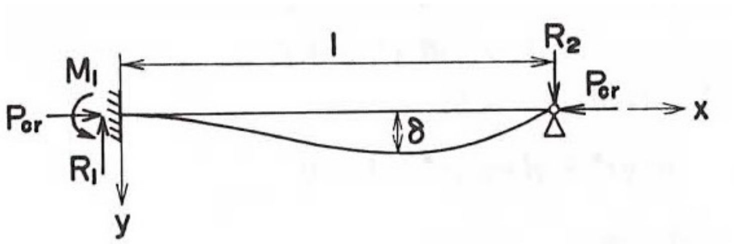
Quadrupedal paper toy is shown in Figure 5. It is made by scissors and glue. And it walks by use of gravity, rolling and leg's deformation shown in Fig.6.

Figures 8 (a) and (b) show the footprint and reaction forces of the toy, respectively. Because the reaction forces of foreleg are bigger than the hind leg, the deformations of foreleg are bigger than the hind leg. The frictional forces are also similar. Therefore, slips occur at the hind leg's grounding point shown in Fig. 8 (a). The learning contents and subjects in manufacturing the passive walking toys are shown in Table 2.



(a) Paper robot (b) CAD (JW-CAD)

Figure 5. Quadrupedal paper toy



$$y = 0.7326\delta(\sin[4.493(1 - x/l)] + 0.976(1 - x/l)),$$

$$y_{\max} = y_{x=0.6017l} = \delta$$

Figure 6. Deformation of the grounding leg

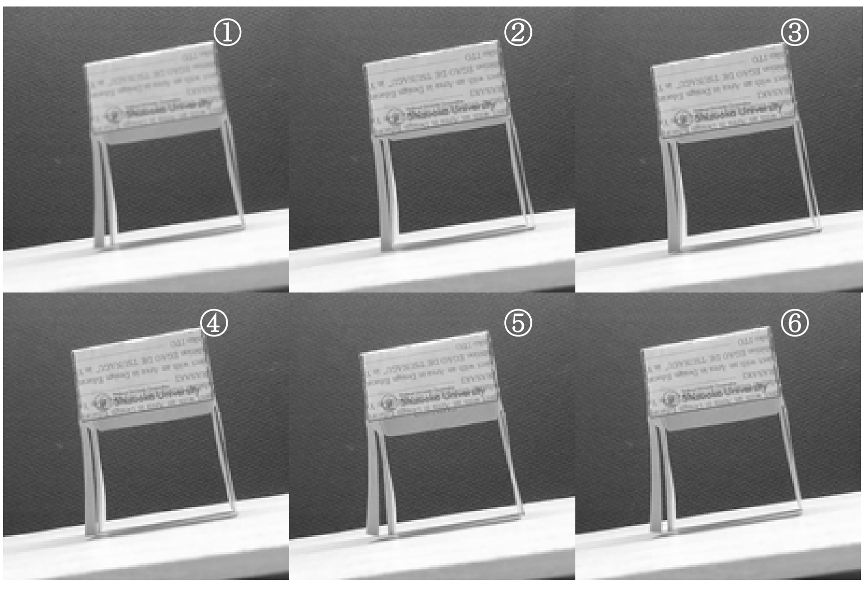
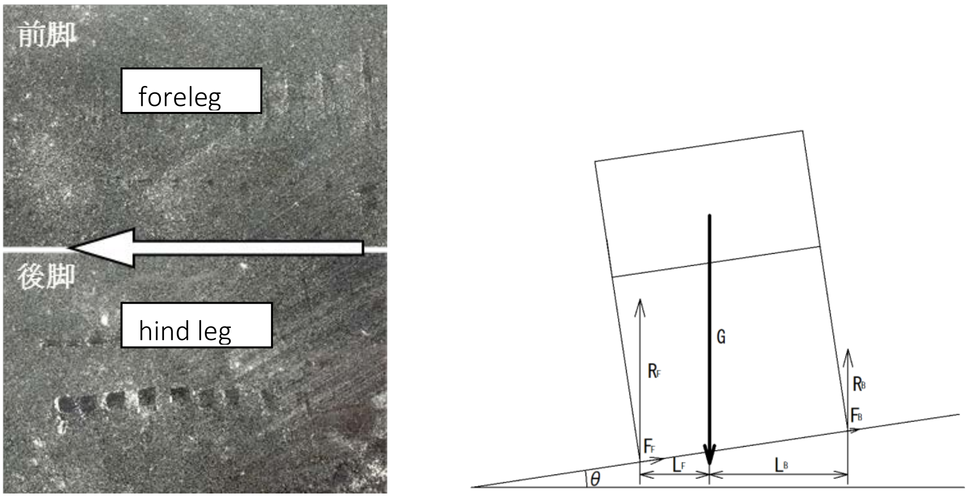


Figure 7. Paper toy’s walking stages



(a) Footprint (b) Gravity and reaction forces

Figure 8. Quadrupedal paper toy

Table 2. Learning contents in manufacturing the passive walking toys

	Kindergarten	Elementary school	Junior high	High school	University
material	Paper: glue *STE		paper; glue; metal sheet (aluminium, copper, zinc) *STE		
Tool	Scissors *T		Scissors; cutter knife; tin snips *T		
Knowledge	• Straight line *M • Discovery of regularity *S	• Straight line *M • Right angle *M • Vertical, parallel *M • Centre of gravity *S • Pendulum *S • Principle of leverage *S	• Metal working*T • Kinetic energy *S • Potential energy *S • Moment of force *S • Acute angle, obtuse angle • Period of pendulum *S	• Equation of motion *S • Kinetic energy *S • Potential energy *S • Moment of force *S • Period of pendulum *S	• Moment of inertia *S • Buckling *E • Flexural rigidity *E • Elastic curve equation *E • Deflective curve equation • Inverted pendulum *E
Dexterity	• To cut and bend it along a line *T • To glue *T • To understand a procedure *T	• To cut and bend it exactly *T	• To understand a metal property *TE • To use it with an appropriate processing method *TE		
Creativity	• Colouring *A • Decorating *A • Child's play *STE	• Design drawing *EAM	• Design of toy (design drawing) *EAM	• Design of toy (2D CAD) *EAM	• Design of toy (3D CAD) *EAM

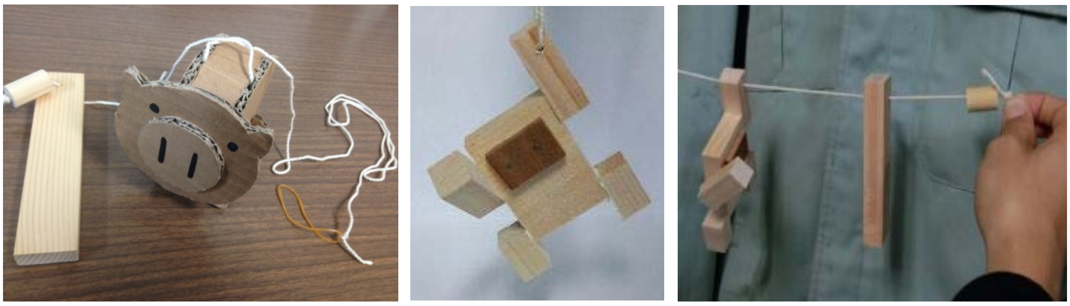
Notes: *S, *T, *E, *A, *M indicate subjects concerned with STEAM

Moving toy and climbing toy on the strings

The moving toy and climbing toy on the strings are shown in Figures 9 and 10, respectively. We suggest these toys as low cost teaching materials made of paper.

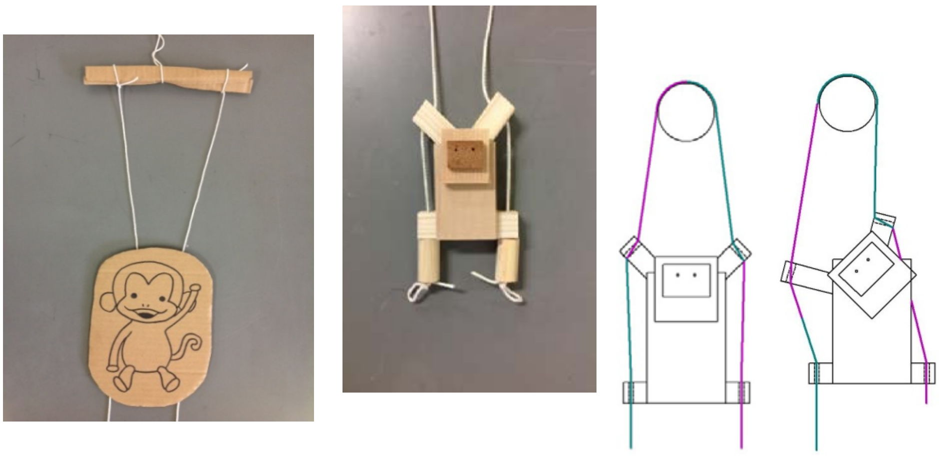
At first, we describe about the operating principle for the moving toy on the string. When the stick is pulled, rubber band elongates, and the string and the pig move. And then, only the string goes through the toy's hole by elasticity of the rubber band when the stick is thrown, and the pig stays in the same place (inertial law). In this way, the pig moves on the string.

Next, we describe about the operating principle for the climbing toy on the strings. Two arms turn by the moment of tension when a string is pulled, and frictional force changes, and the string goes through the hole of the arm, and the other arm is raised with the string.



(a) Paper toy (b) Wooden toy[5] (c) Parts' position

Figure 9. Tightrope moving toys "Pig" and "Gorilla"



(a) Paper toy (b) Wooden toy[5] (c) Operating principle[5]

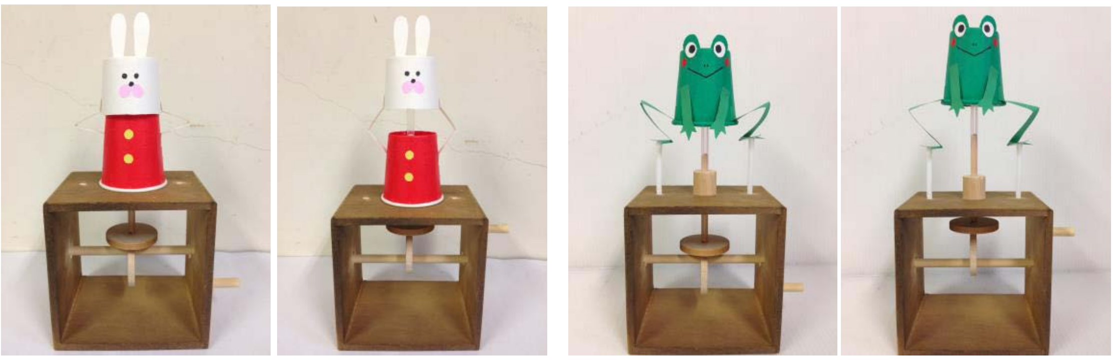
Figure 10. String Climbing Toys "Monkey"

Automata (mechanical toy) as steam teaching materials

Automata as STEAM teaching materials are mechanikal toys with gears, cams, and links (Figs. 11-13). The Animals start moving, when we turn the hundle. In the manufacturing class, the students make automata as children's toys.

(a) Gear type *(b) Cam type* *(c) Link type*

Figure 11. Automata (mechanical toy by use of 100yen-wooden-box)



(a) Rabbit's head get out of place *(b) Jumping frog*

Figure 12. Automata (mechanical toy with a cam)

Source: URL of automata movie is https://www.youtube.com/watch?v=cCDnSiqhUqk&feature=youtu.be

Figure 13. Automata (mechanical toy with gears)

Figure 14. Mechanical driven balance type clock

Source: URL of automata movie is https://www.youtube.com/watch?v=StKELJJeKbc URL of clock toy movie is https://www.youtube.com/watch?v=_7GY_Wxbj3M

Other toys

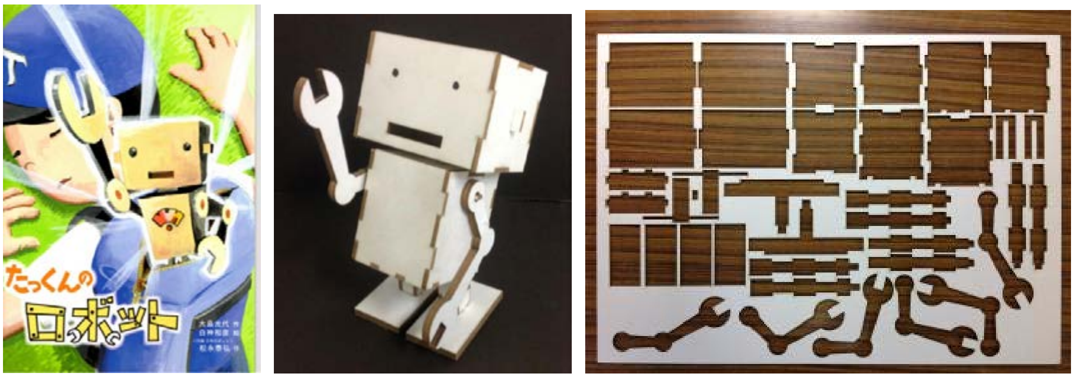
Mechanical driven balance type clock is shown in Fig. 14. The clock is a teaching material for junior high school students. Three dimensional passive walking toys are shown in Figs. 15-16. The toys' sole has a projection (shown in Fig. 15(b)) which causes the toy's rolling.

Figure17 shows rolling elephant toy as a teaching material for kindergarten. The wheels roll on the slope, and the elephant's body rolls at the difference of the slope's edge.

(a) Walking toy with arms (b) The shape of sole and toe

Figure 15. Three Dimensional Passive Walking Wooden Toy

Source: URL of toy movie is https://www.youtube.com/watch?v=x2YmfW1otcw



(a) Picture book (b) Paper robot (c) Paper processed with a laser

Figure 16. Picture book with the robot to assemble

Source: URL of toy movie is https://www.youtube.com/watch?v=pgjdaWXNXx8&feature=youtu.be

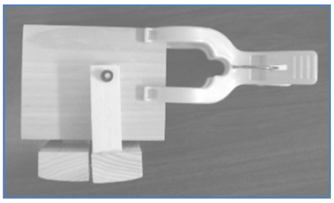
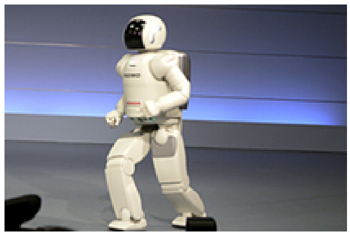
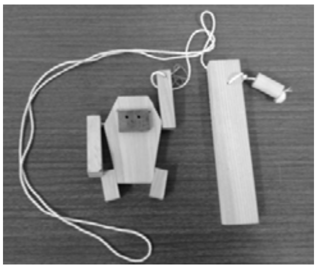
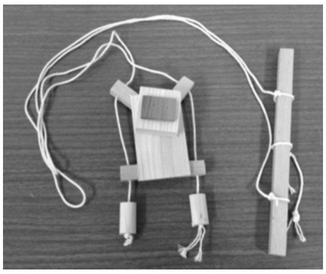
Figure 17. Rolling elephant toy at the difference of the slope's edge

Manufacturing classes

The flow charts of manufacturing class and teaching materials for STEM education are shown in Figures. 1, 18 and Table 3. The manufacturing classes are constituted to be the flow of student's continuing study. They study STEM's contents of the operating principle, designer's invention, and how to use tools with their emotions. They experience surprise, laughter, interest, pleasure, challenge, failure and success. After every class, they play with the toys and talk about the toy with their family and friends at home. They reconstitute learning contents, and strengthen their feelings of self-esteem.

We had some teaching practices framed by WET/SET for Mongolian, Brazilian, and Japanese students. The pictures of the classes are shown in Figs. 19-21. We analyzed the activity and transformation of students by evaluating the questionnaires for the students, guardians, and teachers. We analyzed the questionnaires for guardians by content analysis, and show in Table 4. The individual evaluation shown in Table 5 was performed by Tapestry Analyze Method.

Table 3. Teaching materials for STEM education

Teaching material	Theme "Inquiry of Wonder"	Introduction	Tools
Passive walking toy 	"Why does it walk?" Gravity, Friction, Moment of force, Potential energy)	HONDA ASIMO's movie 	knife sandpaper
Moving toy on a string 	"Why does it move?" (Law of inertia, Elastic strain energy, Friction, Deformation)	BMW's "Dinner for RR" movie 	handsaw drill sandpaper
Climbing toy on strings 	"Why does it climb?" (Friction, Moment of force)	Panasonic EVOLTA Challenge Grand Canyon movie 	handsaw drill sandpaper

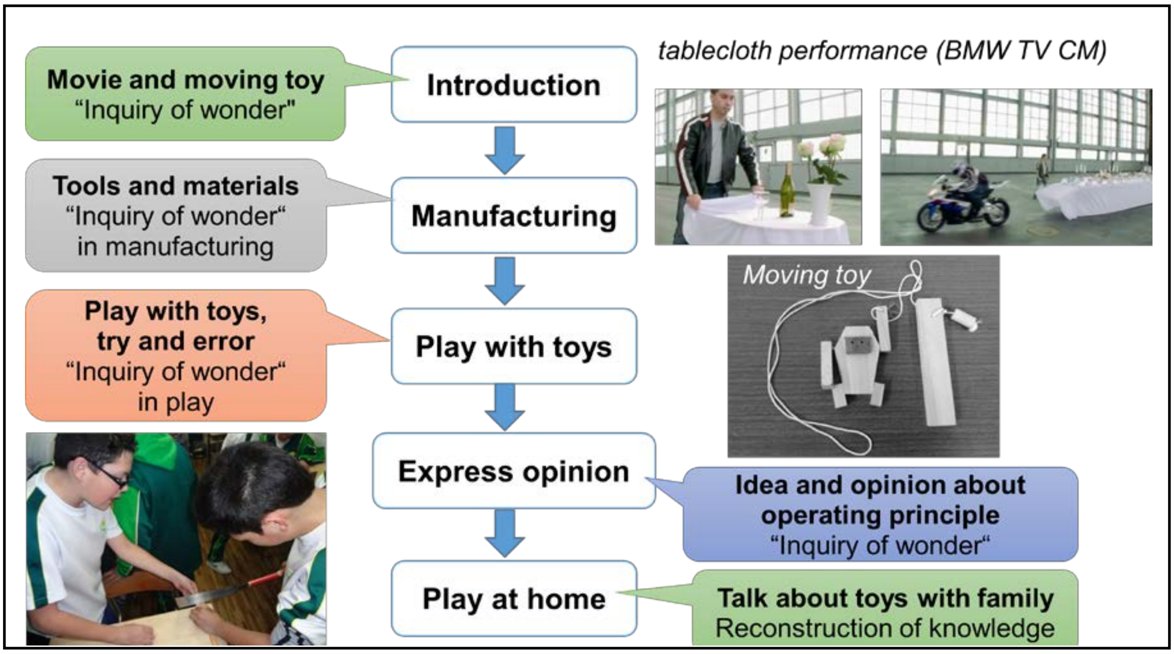


Figure 18. Flow chart of the manufacturing class

(a) Playing with the toys (b) (c) Making the paper toy and playing with the toys

moving on a string walking on a slope

Figure 19. Manufacturing classes in Mongolian school

(a) She uses her hair clip in substitution for (b) Shaving the wood by a knife

a passive walking toy's weight

Figure 20. Manufacturing classes of Brazilian school in Japan

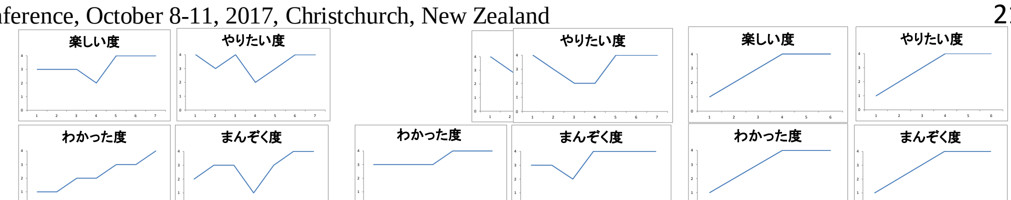
Figure 21. The 5th grade manufacturing class of elementary school in Japan

Table 4. Content Analysis of the guardian's comments

Question: What did your child talk about the manufacturing class at home?
And what was the state of your child like at that time?
(Number of answers is 44.)

TEXT CODE	Sample	No
Happy So happy Glad Pleased Great Excite	**(1) Showing the toy and talking about manufacturing classes** The appearance that my son made something on his own and show off something seemed very happy every time.	30
	(2) Talking about using tools It seems that my daughter fought a bit for the first saw, but I was glad that she talked happily.	
	(3) Explaining the operation principle As soon as my daughter got back from school, she took a toy and let me do it. She taught me, "Why do you know what will go up? It's friction." She seemed very happy.	
	(4) Playing with the toy My son was explaining his younger brother how to move the toy. Two sons were very happy to move it.	
Operating principles	My son showed his toy and asked me "Why do you think this will happen?" "It's the energy of friction !," "It's energy on a slope!" He explains with his blind eye.	11
Tools	My daughter was told me that it was difficult because she never used saws, sculptors etc at home. However, it seemed fun for her to work with saws.	11
Sense of accomplishment	It seemed to be difficult for my daughter to use a tool, but it seems there was a sense of accomplishment when it was completed.	6
Relationship with others	My son was explaining his younger brother how to move the toy. Two sons were very happy to move it.	5
Toy products	My daughter looked very happy and was playing at home. She improved her toy at home, and completed it with beautiful appearance that was easy to use.	5

Table 5. Individual evaluation for a student A



		Climbing paper toy on strings	Climbing wooden toy on strings	Passive walking wooden toy
Student A	Impression on every class	I couldn't understand frictional force, but became understand it by teacher's explanation and be happy.	I was happy at 1^{st} class, but I was more happy at 2^{nd} class. Because I like wooden toy than paper toy.	Today's toy is best among three toys. I'm very very happy.
	Impres -sion	At home, I made another climbing paper toy by using of paper and straw, string. I made the toy very well. The toy could climb on the strings. I want to make the other wooden toys, if I get the material and tools. I am very sad, because this is the last manufacturing class with university students. I like "manufacturing". I'll keep making something.		
Guardian		She told me about the toy happily and made another paper toy at home.		
Teacher		【ordinary behavior of student A】 She is quiet in class and not good at mathematics and national language, society. She does not announce her opinion at class. She does not associate with a friend positively. 【behavior at manufacturing class】 She advised a friend and asked a teacher anything that she did not understand and was in trouble, positively. She made another climbing paper toy at home.		

Conclusion

We studied manufacturing wooden toys as STEAM teaching practice framed by waves/showers-of-emotion theory (WET/SET).

- We have developed the moving toys based on WET/SET.
- We performed teaching practice framed by WET/SET for Mongolian, Brazilian, and Japanese students.
- We evaluated the transformation of the student, and analyzed the guardian's comments about how a child explained the toy at home.

Acknowledgement

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The Girl on the Bus or the Spider in the Bathroom? Students' enduring memories of learning experiences outside the classroom in technology education

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Abstract

This paper explores the planning and management of Education Outside the Classroom (EOTC) as it relates to curriculum-based learning and teaching in schools and in this instance specifically to teaching technology education in the primary and secondary classroom. These types of experience away from the four walls of the classroom often evoke very strong memories for all of us, but frequently it is of the social context rather than the intent of the learning experience. This paper looks at Falk and Dierking's (2000) Contextual Model of Learning and how consideration of the four over-lapping contexts of this planning model, can enhance the quality of student experiences and their learning opportunities. It will look at examples of long-term achievement and retention of student learning, the impact of an experience on student learning, and the characteristics of a successful EOTC experience.

Introduction

Taking students on a learning experience away from the four walls of the classroom may conjure up an alarming image of forms to be filled, permissions to be gained and sometimes, an overly zealous expectation from school management to manage the facility that is being visited. A recent story from an irate teacher who was planning to take a group of students to an animal park in the next town, described a request from the EOTC supervisor at his school to explain how he would manage his students if a lion escaped from its enclosure. The nature of his (light-hearted) response referred to the practice of the Ancient Romans who would offer the sacrifice of one of their party to appease the Gods, and then make a rapid escape (C. Milne, personal communication, August 17, 2017). Joking aside, it seems that there are high levels of frustration in-amongst teachers who are time poor but enthusiastic about the advantages of taking their students out of the classroom for experiences which they cannot replicate in the classroom.

This paper is not about setting up a School Safety Management System, planning EOTC Event Procedures or considering the safe behaviour of students during a visit. This paper illustrates why we *should* go to the trouble of providing opportunities for students to experience first-hand, engaging, and relevant experiences away from the classroom that students are likely to remember for a life time.

Education outside the classroom is fundamentally good (Milne, 2015) and as a child growing up in New Zealand the 'school trip' evokes strong memories for many of us. Regardless of how many years have passed since an event occurred, most readers will remember, with some clarity, a day when they boarded a chartered bus and set off through the school gates on a class excursion. The enduring memories of these experiences tend in most cases to be of the social dimensions of the visit, with only tenuous links to the intended learning of the day. This is the focus of this paper – what do we know about students' long-term memories of experiences outside the classroom and how can we promote improved recall of the educational learning goals of teacher planning?

What is EOTC and LEOTC?

The Ministry of Education has committed extensive research, funding and resources for education outside the classroom in order to better inform and complement the wide range of opportunities provided by schools. This began in June 2004 with a research project that investigated the effectiveness of programmes for curriculum based learning experiences outside the classroom (Moreland, McGee, Jones, Milne, Donaghy & Miller, 2005). More recently, the Ministry has updated *Bringing the Curriculum Alive - EOTC Guidelines for schools* (Ministry of Education, 2016) which provides information and resources promoting the value and purpose of EOTC, safe practices during an EOTC experience, planning, and the legal responsibilities of the school.

There are a number of terms, used internationally, that describe this type of learning, usually under the umbrella of informal learning. EOTC in the New Zealand curriculum describes curriculum-based learning and teaching that occurs outside the classroom. LEOTC or Learning Experiences Outside the Classroom, is a Ministry of Education contestable fund for providers who can demonstrate support for the New Zealand curriculum. Currently this includes sites such as Zealandia in Wellington (Karori Sanctuary Trust, n.d.), the Rotorua Museum of Art and History (http://www.rotoruamuseum.co.nz/), the Waitomo Glow-worm caves http://www.waitomo.com and Dance Aotearoa New Zealand (Dance Aotearoa New Zealand, n.d.) These and other sites may apply for funding from the Ministry of Education every three years and the key factor in their role an as LEOTC provider is to provide services that have the potential to benefit all students enrolled in New Zealand schools. It is expected that these sites will provide links between classroom studies and real world experiences, with a learning focus that include hands-on, interactive tasks, under-pinned by the experiential model of learning. Excursions that are substantively for the purpose of recreation or entertainment, are usually precluded from the EOTC and the LEOTC categories, although as this paper will attest, fun and enjoyment are valuable elements of these experiences.

'Enduring memories' and supporting literature

Interestingly, most of us have excellent recall of the school visits that we experienced as children and can remember where, and with whom, we went, and at least three aspects of what occurred during the visit (Falk & Dierking, 1997; Rennie & Johnston, 2004). If these levels of recall are possible within the social context of a visit, how can we replicate this when planning curriculum based learning for school-aged students?

Figure 1: Display from the Tainui exhibition at Te Papa

As outlined in the work of Falk and Balling (2001), the most valuable and memorable learning experiences outside the classroom are 'novel' experiences – those which are new, and of high interest to the students. In comparison, multiple visits to one site can result in the detail of the visit becoming blurred, and the specifics of any single visit tending to be lost over time. Visiting Te Papa[5], for example, to view a short-term exhibition on the origins of the Tainui[6] people, may offer far greater visitor focus than frequent holiday visits wandering through the same long-term exhibitions year after year (see Figure 1). Research suggests that a one-off, focused visit has the potential to offer students an enhanced and memorable learning opportunity (Falk and Balling, 2001).

Anderson (2003) argues that this type of memory is also "overwhelmingly dominated and mediated by the socio-cultural identity of the individual at the time of the visit" (p. 405) and the lens through which the experience is viewed, strongly influences what is noticed and what is remembered. Furthermore, these memories are influenced by the age of the students, what is important to them and the emotional engagement they experienced at the time of the experience. They give the example of a pre-schooler who may clearly remember the spider in the bathroom during a comfort stop on the way to the circus, but forget the children (s)he travelled with. On the other hand, it is likely that an adolescent male's

[5] Te Papa – translation to English means Our Place: Museum of New Zealand, situated in Wellington, New Zealand.

[6] Tainui is a tribal waka (canoe) confederation of New Zealand North Island Māori iwi or tribes.

memories of a visit may include considerable interest in the girls he travelled with and little for the spider in the bathroom" (Anderson, Thomas, & Ellenbogen, 2003).

A further example observed during a Ministry of Education research project (Moreland, et al, 2005) when a class of students was taken to the City Gallery in Wellington to view an art exhibition. The most frequently recalled incident of the visit was the students' shock as they entered the gallery and needed to step over an artificial 'dog poo', which had been deliberately positioned in the hallway by the artist. The sight of the deposit was met with loud protest from the students, before it was explained by the Gallery's education officer that it was an intentional joke provided by the artist. Not surprisingly, it was this emotionally charged element of the visit that the students referred to most frequently in the stories and pictures they drew afterwards, rather than the details of the exhibition itself.

Research in the field of EOTC suggests that prior knowledge of exhibits at a site and a clear purpose for the visit, helps give focus to the experience and enables a student to engage more readily with the displays that s(he) encounters. Past experiences, (prior knowledge) be they cognitive, affective, behavioural, social or cultural, will help structure the new learning in personal ways (Rennie & Johnston, 2004). For example, a group of students viewing examples of technologies from the eighteenth century will have their experience and learning opportunities and interest heightened if they are guided by a desire to obtain specific information. If students visit a site with some prior knowledge of the exhibits and a clear purpose, e.g. to gather information for a teacher-directed task, the combined elements will help give focus to their experience, and their prior knowledge or familiarity with the exhibits will enable them to engage more easily with each display. In contrast, a group touring for recreational purposes may well overlook much of the information available to visitors because of limited interest, lack of prior knowledge and no defined purpose for their enquiry.

Lambert and Balderstone (2000) argue for teachers creating a 'need to know' factor amongst students prior to going on a visit, effectively arming them with an authentic research purpose to be accomplished during the visit.

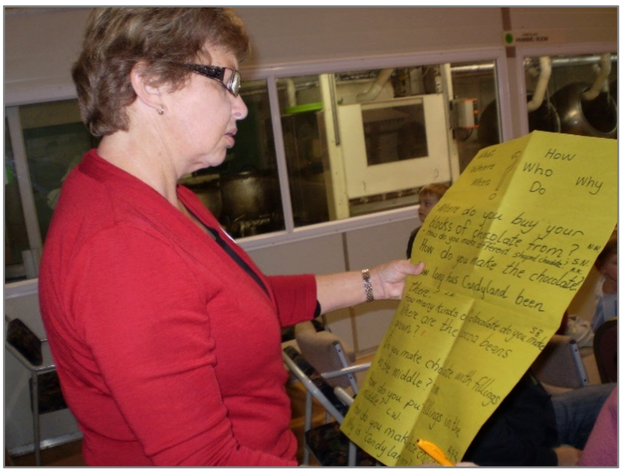

Figure 2: Questions for the presenter during an EOTC experience

This type of learning, under the umbrella of 'informal learning', is best described as 'perceived choice' learning. Students motivated by the 'need to know' factor ideally approach a visit with a sense of freedom to select or take note of items that appeal to them and processes they think would have relevance to complete a classroom based task. In effect they decide when, where and what to learn. An example from my own research (Milne, 2015) was students visiting a chocolate factory to find out how to make their own chocolates to celebrate Mothers' Day. Prior to the visit the students and their teacher wrote up a list of questions to ask the presenter at the factory so they could find out the ingredients they would need, how to make different kinds of chocolate, and how they could put fillings in the middle of the chocolate (see Figure 2). This information informed the students own practice on their return to school.

Further points of interest may be drawn from the work of Ash and Klein (2000) who highlight a number of valuable features which they consider enhance students' informal learning experiences outside the classroom. They argue that this type of experience must be enjoyable, visually oriented and offer opportunities for co-operative learning. Exhibitions should have elements of interactive activity, and tasks should be open-ended and non-structured.

Table 1: Contextual Model of Learning (Falk & Dierking, 2000)

PERSONAL	SOCIO-CULTURAL	PHYSICAL	TIME
This includes motivation and expectations, prior knowledge, interests and beliefs, and choice and control	This context includes within-group socio-cultural mediation and facilitated mediation by others	This includes advance organisers and orientation, design and reinforcing events and experiences outside the museum	Managing random events that impact on the quality and quantity of learning

A planning framework

Bringing many of these ideas together, Falk and Dierking (2000) developed the Contextual Model of Learning (see Table 1). This is a valuable planning framework that consists of three over-lapping contexts, the personal, the socio-cultural, the physical (Falk & Dierking, 2000) and latterly, the addition of time (see Table 1 for further details). These contexts play an important role in structuring the three phases of planning necessary for a learning experience outside the classroom – (i) what happens before a visit, (ii) during a visit and (iii) the follow-up to the visit (see Table 2).

Table 2: Summary planning chart: Considerations for EOTC and Technology focused visit

EOTC Event Procedures		
Planning		Managing
Before Visit	During Visit	After Visit
Contact and visit site to establish shared view of the learning opportunities	Visit to factory in groups, each with a	Follow-up to factory visit: • review and confirmation of new concepts

and planned curriculum learning intentions	'knowledgeable other' to ensure focus on LIs	
Liaise with supervising staff/ helpers to clarify their role in the visit		Connect final three phases of students' technological practice with the knowledge gained during the visit and their final outcome
Prepare students for visit procedures and clarify purpose of the visit		Facilitate: • market research and design process; • product construction process; • review and reflection of design and final outcome – 'fitness for purpose'

The Contextual Model of Learning (Falk & Dierking, 2000) guided the structure of the planning framework seen in Table 1, and the following list summarises the key points from this and other literature that were identified as being important. Teachers planning for an EOTC visit will find this helpful when planning their own EOTC experience for both primary and secondary students. The key ideas are generic across all levels.

Firstly, a teacher's reason for taking students on a visit is *the* most important decision when planning a learning experience outside the classroom. Is it to motivate students, is it to introduce new ideas or is it to consolidate previous learning? Secondly, the selection of the site and the match between the cognitive level of students and the thought processes required by the exhibits during the visit will also significantly affect the students' engagement so this decision is a particularly important one. Once these decisions are made, the following points, are worthy of teachers' consideration. They are organised under the headings of the Contextual Model of Learning (Falk & Dierking, 2000).

(i) Personal context

- Consider the extent to which students are familiar with the setting of the visit i.e. where possible, the selection of a site is of "appropriate novelty" that will link directly to the classroom programme (Falk & Balling, 2001, p28).
- Ensure there is clarity around the purpose of the visit from both the teacher's perspective and that of the students (Jarvis & Pell, 2002).
- Ensure the teacher is well prepared prior to the visit but also the students are knowledgeable of where, how and why they are visiting a site i.e. they should acquire a 'need to know' motivation for the visit (Tofield et al., 2003; Anderson, 2003).

- Gather data that will identify the students' prior knowledge of the context of the visit and will enable the teacher to plan appropriate pre and post visit activities that will both reinforce and extend student learning (Rennie & Johnston, 2004; D'Angelo, Touchman & Clark, 2009).

(ii) Socio-cultural context

- Plan for the provision of the 'knowledgeable other' (Vygotsky, 1994) – parent helpers and/or staff who understand the learning intentions of the visit and will assist and guide students during the visit (Schauble, Gleason & Lehrer., 2002).
- Consider the social aspects of the visit and how this will impact on student learning – students should be organised into small groups based on their interests and the knowledge they bring to the experience (Falk & Adelman, 2003).

(iii) Physical context

- Consider the degree of structure required for the visit to enable a safe, enjoyable and focussed experience where students have easy access to bathrooms, exits from the site and reasonable access to refreshments (Falk & Dierking, 2000) and as per EOTC events procedures documentation.
- Organise pre-planning to ensure the visit includes hands-on exhibits and experiences (Rennie & Johnston, 2004).
- Select an experience outside the classroom that is novel, relevant, real world and age-appropriate for the students (Anderson et al. 2003).

(iv) Time

- Select shorter focused visits rather than all-day events (Falk & Balling, 2001).
- Plan the timing of visits to avoid peak visiting time and unnecessary distractions (Milne, 2015).
- Organise the visit so that unexpected events can be managed (as per EOTC events procedures).

Concluding comments

Access to expert practice in the 2007 Technology Education curriculum is fundamental to the development of students' technological literacy and whilst this may be acquired within the classroom, the viewpoint of this paper is that this is achieved most effectively in concert with learning experiences outside the classroom. Students in all sectors of the New Zealand education system have increasing access to digital technologies, the internet and an ever expanding availability of worthwhile virtual experiences. However, the literature quoted in this paper supports the notion of real-world contexts and real-world experiences, which when linked to students' studies within the classroom, can significantly influence their learning.

Providing students with first-hand, engaging and relevant experience outside the classroom, in which there is an emotional or sensory connection with the exhibits, enables students to transfer understandings from one experience to a new one, and has the potential for key ideas to be recalled many years later. Education outside the classroom is fundamentally good (Milne, 2015) and despite the sometimes arduous task of completing consent documentation, the educational outcomes are unquestionably beneficial for both students and teachers.

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Proposal of Digital Craft Introduction Model at Faculty of Teacher Training

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Abstract

The introduction of digital craft to school education is also beginning. Looking at the spread of digital craft, it is necessary to involve the introduction of digital craft to faculty of teacher training. Therefore, we propose a class introducing digital craft to construct a digital craft introduction model in undergraduate faculty of teacher training in this research. As class for undergraduate students, we propose 1) class targeting students majoring in technology education, and 2) class targeting students of elementary school. We practiced the proposed lesson and verify educational effect. As a result of the post survey, a certain educational effect was obtained in elementary school class. We also confirmed problems in practical implementation.

***Keywords**:* Digital Craft, Digital Fabrication, Teacher training

Introduction

In recent years, processing Technology (digital craft) by utilizing digital processing machines such as 3D printers and laser cutters are also spreading to individuals. The citizen's studio (FabLab) of the digital craft originating in the United States has been developed worldwide and is also spreading to the country (Gersenfeld,2012. Watanabe,2014). Meanwhile, along with programming education, introduction of digital craft into school education is also spreading internationally. For example, US President Obama announced the introduction of 3D printers to 1,000 schools in the United States in

2013 and became a topic. The UK and other countries are similar as well (*Ministry of Internal Affairs and Communications*,2015).

Taylor covers not only the technology of digital craft but also the maker movement as a learning model linked with that community (Taylor ,2016). The learning model of the maker movement is positioned in the STEM education as a student acquires skills of the 21st century type and connects hands and mind with cognitive and physical ability. Of course, it is also raised that it is necessary to carefully examine the educational use of digital craft, just like introducing other digital technologies (Nemorin,2016). Such international movements and discussions will be further accelerated in the future. Meanwhile, at the stage of teacher training, we are not yet proceeding and considering such digital craft. As with educational use of ICT, it is necessary to urgently discuss how to handle digital crafts in education and how to instruct them.

Therefore, as the first step in utilizing the digital craft education, we thought about the introduction and correspondence of digital craft to faculty training faculties.This includes not only technical acquisition of digital craft but also educational use and consideration. The purpose of this research is to propose a class introducing digital craft to verify the educational effect, in order to construct a digital craft introduction model in undergraduate faculty training system.

Method

Study design

As classes subject to undergraduate students, 1) teaching for junior high school technology department, 2) practicing lesson for elementary school, and verifying educational effect.

Survey method

As a verification of educational effect, a questionnaire survey was conducted in subject classes of other major students who had a large number of classes. About the content of each exercise, we conducted a questionnaire survey by five methods on interest interests, difficulty levels, and educational use. The first survey was carried out at the stage of practicing the cutting machine (20 people, response rate 100%). The 2 nd survey was conducted at the stage of practicing the laser processing machine (16 people, response rate 80%). The third survey was conducted at the stage when the entire class was over (20 people, response rate 100%)

Lesson proposal

Class for junior high school technology education

Lesson development assuming introduction to junior high school technology education, to make systematic understanding and skill to digital craft master.

Syllabus

The class name is "Machining". It is a lesson of the undergraduate 3 - 4 grade subjects, and it is a licensing subject of the junior high school teaching technology education. The outline of the syllabus is shown Table 1.

Table 1: Syllabus of "machining"

	Content
The 1st	Monozukuri education at junior high school
The 2nd	Introduction to Digital Fabrication
The 3rd	Basic operation on 3D CAD (1)
The 4th	Basic operation on 3D CAD (2)
The 5th	Outline and theory of laser processing machine.
The 6th	Basic practice of laser processing machine
The 7th	Basic operation of 3D printers
The 8th	Basic operation of 3D printers
The 9th	3D printer output by 3D CAD modelling
The 10th	3D laser processing machine output by 3D CAD modelling
The 11th	Production of Contest Entry Work 1
The 12th	Production of Contest Entry Work 2
The 13th	Challenge Production of "Hina Dolls"
The 14th	Summary of Hina Dolls
The 15th	Conclusion

Major equipment and software

(1) Major equipment used:

- 3D printer, Laser processing machine , Milling machine, Arduino (microcomputer board)

(2) Main use software:

- Fusion 360 (3D CAD), ArduinoIDE (development environment)

Outline of classes

Classes were practiced for five students of Information and Manufacturing Course of Miyagi University of Education Faculty of Education. In the lesson, after performing the basic operation of Fusion 360 which is 3D CAD twice, after performing the basic operation of 3D printer, laser processing machine and milling machine once respectively, we worked on cooperative production in group. In 3D CAD, 1) extruding a plan view to draw a rectangular parallelepiped or cylindrical solid object, 2) drawing a rotating object by axially symmetrically rotating the plan view, 3) combining these to create 3D data . 3D data was created in STL format. In addition, two-dimensional data necessary for laser processing machine was created based on the plan drawing created with the same 3D CAD. In the basic operation of a digital machine tool, we aimed to be able to do power-on, read the appropriate data, carry out safe processing operations, turn off the power and clean up after all. Because data preparation is only lack of time due to class hours alone, we decided to create them at home.

After making simple parts by basic operation, we decided to work on one piece work by modeling by sharing members in a group of five people. Considering that there are variations in the degree of difficulty and the idea cannot be remembered when it is a complete free assignment, the theme is presented here. The theme that We first worked on was the octopus dish. Model two or three of the contents of the section dish by themselves and output from the 3D printer. Also, boxes containing dishes were processed with a laser processing machine. Figure 1 shows the dishes and hood boxes produced.

The second theme we worked on was the Hinamatsuri which is a traditional event in Japan. It was a suggestion theme from the students. Modeling was done by investigating and investigating productions. Since the doll has a shape combining a plurality of parts, readjustment was sometimes necessary in consideration of fitting (Figure 2).

Classes targeted at elementary schools

Figure 1: Osechi cuisine and overlay box

Figure 2: Hinamatsuri

In addition to widely experiencing the digital craft itself, learning to develop teaching materials that make use of the features of digital craft technology.

Syllabus

The class name is "Introduction to Manufacturing". It is a lesson of the undergraduate 3 - 4 grade subject, and it is a licensed subject (selection) of elementary school teacher. The outline of the syllabus is shown table2.

Major equipment and software

(1) Major equipment used:

- Cutting machine , 3D printer, Laser processing machine

(2) Main use software:

- Inkscape (2D design) , "Let's make it V2" (3D CAD for education)

Outline of classes

Classes were practiced for 20 students of Shinshu University Faculty of Education.

In the lesson, we placed a video file of theoretical explanation in practical training on the e-Learning system and combined it with a small test to prepare. In addition, we shared every mini-report on the net so that we can learn from each other. In the mini report I gave work photos as well. At the introduction stage of the lesson, we carried out simple handling of wood and simple electric construction after doing theoretical learning of manufacturing education at elementary school level. In hand processing of wood, we used puzzles using boards. In electric work, we made a simple robot that works with vibration using a motor. Because there are some students other than technical education major, I also let you experience analog processing.

Table 2: Syllabus of "Introduction to Manufacturing"

	Content
The 1st	Monozukuri education at junior high school
The 2nd	Basic practice of processing methods using wood
The 3rd	Simple robot making practice
The 4th	Digital Fabrication Overview
The 5th	Working practice of cutting machine
The 6th	Working practice by laser processing machine
The 7th	The concept of original teaching materials
The 8th	Processing practical training of original teaching materials
The 9th	Outline and theory of 3D processing
The 10th	Practice of design by 3D CAD

The 11th	Practice of processing with 3D printers
The 12th	Conception of free tasks
The 13th	Production practice of original production (1)
The 14th	Production practice of original production (2)
The 15th	Mutual evaluation of original production

In digital fabrication, we introduced it from a cutting machine cutting machine that cuts paper. By exercising 2D data processing method by creating cutting machine data. Next, using a laser processing machine, a coaster was made using an acrylic plate as a material. Because data preparation is only lack of time due to class hours alone, we decided to create them at home. After experiencing the 2D processing, the students conceived and produced the original teaching materials. Students made puzzles on maps and suggested various teaching materials such as cutaway works (Figure 3).

In 3D processing, we used 3D-CAD "Education try" for education and designed the name plate. Extrusion from planar figures was mainly used. Students were able to design in a short time because they are software designed for education. One 3D printer was prepared in the group, but some students did not finish within time. Students who did not complete the 3D output came out after hours and outputted. Next, as a way to rotate the figure, we designed and output toy frames. It is also necessary to remove support material from the frame. The students made in consideration of various sizes and shapes.

In addition, the students actually enjoyed rotating and doing mutual evaluation of the works.

Finally, we have students tackle free tasks. The theme was to design and produce products that solve the problems that student think about inconveniently. Students brainstormed in group and materialized the idea. The 3D printer and the laser cutter are made to be utilized according to the design. It takes time to output the 3D printer, so we tackled it outside of class hours. From assignment setting to design, production and evaluation, we made it into a presentation file. At the end, we held presentations of the tasks and conducted mutual evaluation (Figure 4).

Table.3 Result of the post-survey

Question item	1	2	3	4	5	Denial	Positive	p	
The first survey n=20									
Q01 I think that processing with a cutting machine was fun	0	2	1	5	12	3	17	0.00	**
Q02 I think that processing with a cutting machine was difficult.	0	9	5	3	3	14	6	0.01	*
Q03 I think learning of machining with a cutting machine will be useful in elementary school	0	1	4	10	5	5	15	0.04	*
Q04 I think that creating data on the cutting machine was interesting	0	0	4	10	6	4	16	0.01	*
Q05 I think it was difficult to create cutting machine data	0	9	3	7	1	12	8	0.50	ns
Q06 I think learning data preparation for cutting machine will be useful in elementary school	0	1	3	11	5	4	16	0.01	*
Q07 I would like to utilize the cutting machine by myself	0	0	0	14	6	0	20	0.00	**
Q08 I would like to have children use the cutting machine	0	0	3	11	6	3	17	0.00	**
Q09 I think I got confidence to use a cutting machine	1	0	5	10	4	6	14	0.12	ns
The 2nd survey n=16									
Q10 I think that processing with a laser cutter was fun	0	0	0	9	7	0	16	0.00	**
Q11 I think that processing with a laser cutter was difficult.	0	2	5	7	2	7	9	0.80	ns
Q12 I think that learning process with a laser cutter is useful in elementary school	0	0	6	9	1	6	10	0.45	ns
Q13 I think that data creation of laser cutter was interesting	0	0	3	10	3	3	13	0.02	*
Q14 I think it was difficult to create laser cutter data	0	2	7	5	2	9	7	0.80	ns
Q15 I think learning of laser cutter data creation will be useful in elementary school	0	0	4	10	2	4	12	0.08	+
Q16 I would like to use the laser cutter by myself	0	1	3	6	6	4	12	0.08	+
Q17 I would like to have children use the laser cutter	0	0	4	7	5	4	12	0.08	+
Q18 I think I got confidence to use a laser cutter	1	0	4	10	1	5	11	0.21	ns
The 3rd survey n=20									
Q19 I think that processing with 3D printers was fun	0	0	1	11	8	1	19	0.00	**
Q20 I think that processing with a 3D printer was difficult.	0	3	4	11	2	7	13	0.26	ns
Q21 I think learning of processing with 3D printers will be useful in elementary school	0	0	4	14	2	4	16	0.01	*
Q22 I think that creation of 3DCAD data was fun	0	1	2	11	6	3	17	0.00	**
Q23 I think it was difficult to create 3DCAD data	0	5	3	8	4	8	12	0.50	ns
Q24 I think that learning data creation of 3DCAD will be useful in elementary school	0	1	4	13	2	5	15	0.04	*
Q25 I would like to try using 3D printers myself	0	1	1	12	6	2	18	0.00	**
Q26 I would like to have children use the 3D printer	0	0	2	12	6	2	18	0.00	**
Q27 I think I gained confidence to use 3D printers	0	2	4	12	2	6	14	0.12	ns
Q28 I think the final task was interesting	0	0	1	7	12	1	19	0.00	**
Q29 I think that mutual evaluation of the final tasks enabled me to learn from each other	0	0	1	8	11	1	19	0.00	**
Q30 I think that I could deepen the reflection more than individuals by sharing the review	0	0	5	8	7	5	15	0.04	*
Q31 I think that learning has deepened more than individuals by working on exercises in the group	0	0	1	12	7	1	19	0.00	**

Results and discussion

About the answer result, I scored a score from "I do not think at all" 1 point to "quite like" 5 points. A score of 1 to 3 is a negative answer, and 4 and 5 are a positive answer. Q 02, Q 05, Q 11, Q 14, Q 20 are reversal items. A direct probability test was conducted on negative numbers and affirmative numbers (Table 4). For cutting machines, there were significantly more positive numbers than Q05, Q09. However, in the laser processing machine, there was no significant trend or no significant difference except for Q 10 and Q 13. For 3D printers, there were significantly more positive numbers than Q20 and Q23. The final task was significantly more positive in all items. It seems that setting of final task was appropriate. The reason why the result of the laser processing machine was low may be influenced by the number of processing machines. We used one cutting machine and 3D printer for each group. However, there was only one laser processing machine. Because it is only one, it may be influenced by the fact that the frequency of operation of the machine was small. Is not it a cause that I felt that it is difficult to use the laser processing machine at an elementary school because it is expensive. As a countermeasure against this, it is conceivable to utilize a small laser processing machine. Also, in any processing, the students felt the difficulty of data processing. It is also necessary to devise training exercises to facilitate data creation. Also, is not it useful to utilize educational software that is easy to operate. Students thought that "I would like children to use it" in any processing. As a result of the survey, although there are issues, students were able to experience the digital craft and become conscious about the educational use. Also, in both classes, students were able to work on and accomplish the tasks that were set.

Conclusion

This research aimed to propose a class introducing digital craft and to verify its educational effect for constructing a digital craft introduction model in faculty training faculties. As a lesson subject to undergraduate students, we proposed and practiced two classes: 1) junior high school teaching classes, and 2) elementary school classes. In each lesson, students were able to work on various tasks and achieve results. In addition, as a result of investigating the educational effect in classes targeted at elementary schools, we were able to confirm certain educational effects. From the above, we were able to confirm the effectiveness and problems of the proposed class. However, it is still insufficient to provide knowledge based on actual practices and to consider such considerations. This point is a future task.

Supplement

This paper is a summary of the following research presentations and has been summarized.

1) Hiroyuki, M. Kazuo, K. (2016), Proposal of a Digital Craft Introduction Model in Faculty Teacher training, Summary of the 59th Annual Meeting of the Japan Society of Industrial Technology Education (p.212), Japan.

2) Kazuo Kadota (2016), Practice of Digital Craft Introduction Model at Faculty Teacher Training, Tohoku branch meeting of Japan Industrial Technology Education Society, Japan.

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Advancing the Iteration Deficit Reduction Model

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Abstract

Through analysis of a case study from student design practice, this paper describes the refinement of an adaptable learning model designed to address the problem of 'iteration deficit'. We call this model the *Iteration Deficit Reduction Model* (IDR). 'Iteration deficit' is a term created by the authors, to describe a form of fixation in the practice of novice designers, where divergent thinking becomes suppressed by convergent thinking during a design project. Before application of the full-detail of the model to the learning context, here we examine the primary principles of the IDR model in practice, through an advanced-level student product design project at the University of Technology Sydney. The project reveals that a constructive design research methodology that incorporates experimentation through prototyping for each iterative learning cycle, correlates with key features of the adapted IDR model. A notable part of this correlation is that hypothesis-making in research-oriented product design practice is central to the iterative construction of prototypes as a means to advance the nature of the innovation in a knowledge-intensive way. Further, by positioning the construction of prototypes as the method for convergence-based learning in product design projects, we are better able to assign and schedule appropriate methods and support for divergent-based learning, identified as being critical to the development of innovation pathways in product design education.

Keywords: product design, iteration deficit, constructive design research, design education

Introduction

This paper seeks to build on previous work by the authors presented at the Technology Education Research Conference 2016. There the term 'iteration deficit' was introduced along with presentation of a teaching and learning model - the Iteration Deficit Reduction (IDR) Model. The IDR model was developed to mitigate the phenomenon of 'iteration deficit' in product design projects, particularly those that respond to ill-defined or ‘open’ briefs. We use the term 'iteration deficit' to describe a noticeable reduction in the number of iterative events evident during design development. The occurrence of 'iteration deficit' can be recognised when the designer locks onto a typology, interaction feature or form, obsessively, to the detriment of further exploration of the design outcome (a focus on convergence). The IDR model may serve as a prescriptive tool to support iteration through promotion of divergent thinking throughout the design process by pairing learning cycle stages with appropriate research methods. The importance of iteration cannot be overstated. Iteration is considered a base feature of the design process (Chusilp & Jin, 2006) and a key factor in successful design outcomes

(Cross, 2000). Berends and Reymen (2010) identified that iterations in the design process lead to rapid learning, adaptation, flexibility and short-term results which indicate that a more proactive approach to iteration in design studio may help negotiate the paradox of working through ill-defined problems and the significant time constraints of tertiary design programs. Through iterative practice - the act of progressively and repeatedly exploring and refining the concept (Lidwell, Holden, & Butler, 2003) - complexity in design is made ordered, and given form. In order to understand the application benefits of the IDR model, this paper aims to contextualise a case study from student design practice within the University of Technology Sydney, Integrated Product Design Honours program. The Honours program is knowledge intensive and driven by a practice-based research approach. Prototyping is the core research device driven by hypothesis-making within iterative cycles of design development. Hence, the paper explores how the conduct of an advanced level tertiary product design project maps over key elements of the IDR model and how this model design might be more widely implemented and applicable.

Literature Review

The notion of cycling through modes of thought and action has been addressed in a number of design models (Koskinen & Krogh, 2015; Stappers, 2007). Notably, the ‘The APU design & technology model’ or ‘The Interaction of Mind and Hand’ by Kimbell and Stables (2007), identifies that there are movements between imaging and modelling inside the head, and confronting reality outside the head (which relates to practice). Further, Kimbell and Stables note that these ‘movements’ cannot be prescribed in advance and that the iterative cycles of movement between thought and action must be “engaged responsively” (Kimbell & Stables, 2007, p. 16). This indicates that there is a form of ‘hypothesis-making’ at key stages in the process, necessary to direct each iteration. Research by Bang, Krogh, Ludvigsen and Markussen (2012) refer to hypothesis-making as part of a strategy for operationalising practice-based design research (particularly in product design or related fields). The structure of the IDR model is determined by the real-world constraints of a teaching program with the increased importance of managing and supporting iterative-design practice, particularly for complex, knowledge-intensive university product design courses. Yilmaz & Daly (2016) identify the need for supporting divergent thinking cycles throughout the design process and Daly, Yilmaz, Christian, Seifert and Gonzalez (2012) proposes that concept generation that leads to innovation is dependent on the development of multiple and diverse ideas. The model takes into account that an iterative process aids concept diversity and can be linked to innovation (Brophy, 2001; Liu, Bligh, & Chakrabarti, 2003). The management of iteration cycles is maintained by Kolb’s four-staged Experiential Learning Theory (1984), comprising of concrete experience, reflective observation, abstract conceptualisation and active experimentation in that sequence and as continuous experiential learning loops (Kolb & Fry, 1975). Additionally, transitional learning-style phases are acknowledged in the IDR model (Kolb, 1985) as described by Kvan and Jia (2005) and McLoud (2013) in the form of converging (strong practical application of ideas), accommodating (reacting to immediate circumstances and reliance on people for information), diverging (generation of ideas and seeing multiple perspectives) and assimilating (creation of theoretical models into concise logical forms). The IDR model structures iterative learning cycles that intentionally ‘grow’ from a formative cycle to a summative cycle, inspired by the work of Dewey (1938/1969) that describes the importance of an in-build and linked series of cumulative experiences, noting that not all experiences are necessarily educative in nature. To gain a better understanding of how to assign methods to the IDR model, we attempt to map the conduct of a successful research-through-design by one of our Honours students over key elements of the model. This project was selected because it uses prototyping consistently as a central research device and innovates through socially significant research. The project features many attributes that we hope to develop in all our students at an advanced and well-articulated level.

Context

Advanced-level product design projects in the IPD course are conducted in the Honours Degree. An aptitude for prototyping of three-dimensional physical models has long been a feature of the UTS product design program. It aligns with the strategic goals of the Faculty particularly in connection with 'technology-led thinking' and 'practice-oriented learning' (Lie & Walden, 2015). The Honours Degree is where we can really test the connection between prototyping and design-iteration. The degree requires students to conduct research-through-design (Frayling, 1993), though the term we adopt and prefer is constructive design research (Koskinen, Zimmerman, Binder, Redström, & Wensveen, 2011) because of the importance it places on prototyping as a research device activated through clearly defined modalities of research. Constructive design research is defined as "design research in which construction - be it product, system, space, or media - takes center place and becomes the key means in constructing knowledge." (Koskinen et al., 2011, p 5). Consequently, the prototypes developed by students in the Honours Degree become a core means of building connections between fields of knowledge (Stappers, 2007) and as described by Overbeeke, Wensveen and Hummels (2006) a form of 'physical hypotheses', or hypotheses contextualised into physical form. By way of further defining the nature of prototyping in the course, we find definitions provided by Weensveen and Matthews (2015) to be useful, notably: *as physical embodiments of research concepts* for expository analysis, and *where the research contribution is tied to the process of crafting the artifacts* for case analysis. Additionally, investigation of the operationalisation of constructive design research was published by Bang et al. (2012). Their research demonstrates an iterative relationship between motivation, hypothesis-making and experiments that often manifest as prototypes in our degree.

Methodology

The research presented here is based on case study analysis involving both participant observation and critical review of documentary sources. Participant observation was conducted through reviewing the progress of the project each week and discussing the progress with both student and studio instructors. The documentary source is the research dissertation produced by the student at the conclusion of the project. Investigation of the source material motivates the research. The structure of the IPD Honours Degree requires the study of 48 credit points over two 12 week sessions. Session one consists of two interlinked studio subjects: 'Research and Development (R&D) A' and 'Conceptualisation' with a common lecture component. The deliverable for the 'R&D A' class is a preliminary research report and for the 'Conceptualisation' class, the production of multiple iterative prototypes are required. Session two consists of two interlinked subjects: 'Research and Development (R&D) B' and 'Realisation'. 'R&D B' class requires the finalisation of the research report (the research dissertation) and ‘Realisation’ class requires the production and exhibition of a high quality artefact. These four subjects combine to form the capstone project for the IPD Honours degree. For the following case study, data collection was undertaken in R&D classes during individual studio consultations of 30 minutes per week with the respective student. The student would present information for discussion to the studio leader generated through a constructive design research methodology in the form of text, sketches, still images and video as well as iterative prototypes. The most intensive phase for iterative prototyping occurred throughout an 8 week period which would coincide with university timetabled weeks of 9 through to 16. It is important to note that the R&D classes provide the theoretical underpinning to drive experimentation and prototyping in both Conceptualisation and Realisation classes. The research dissertation is a comprehensive document that must demonstrate the way that the student has contextualised the entanglement of theory and practice to develop their product design outcome.

Data Analysis

The project described here is a capstone project developed in the IPD Honours Degree. Though the broader project developed a family of homeware products, for clarity we focus on the development of the ‘Beanz’ tray design. The motivation at the start of the project begins with a concern for improving product-consumer attachment in response to the unsustainable growth of consumerism. Formative stage literature research, helps to set a focus on the cultural connections with which we identify through materials, processes and experiences. Inspired by research from Jung, Bardzell, Blevis, Pierce and Stolterman (2011) and by Schifferstein and Zwartkruis-Pelgrim (2008) the first exploratory prototype of a serviette platter (Figure 1) investigates the hypothesis:

> that consumer-product attachment may increase through the deliberate introduction of an aesthetically crafted surprise element considered to improve aficionado-appeal with a rare product feature.

Figure 1: Serviette Platter

> The image above shows the scrap timber parts used to create the serviette platter. The joint was located in the final assembly according to the most efficient use of material, and not where it might be most ‘logical’ in the final design aesthetic. However, the joint is very precise and finely crafted to signal the mismatch of

the timber grain.

The serviette platter is made using two pieces of scrap timber that are shaped and formed to join precisely at an ‘illogical’ assembly point determined not by the function of the platter, but based on the most efficient use of the scrap material. Notably, the precision of the joint assembly combined with the seemly deliberate misalignment of the timber grain, generates a degree of surprise and encourages the user to query the motives of the designer in a way that may represent the starting-point for the deep narratives normally associated with kept and valued items. Learning from the serviette platter prototype and by accommodating new insights from the testing performed, the designer is supported in the direction they take to diverge away from the narrow focus of the project at this early stage. Another perspective on product-consumer attachment is framed around research that suggests that if we design products that are more culturally relevant, they will be more highly valued, kept and maintained. Extending further upon research by Schifferstein and Zwartkruis-Pelgrim (2008) the next hypothesis for the project (Figure 2) is:

> that there is a process for appropriating Australian material histories and by doing so, new meanings can be formed that forge a strong and culturally binding consumer-product attachment.

Figure 2: Storage Tray in recycled timber / European beech

> The images above are of two storage trays with exactly the same utility. The one on the left is made from a piece of recycled timber with the silvered and splintered surface exposed at the top. The one on the right from a new piece of European beech, finished in a modern way with smooth edges and surfaces. (Description from Walden & Koskinen, 2016)

Two timber trays for holding small items such as a wallet and keys, were made in exactly the same size and with the same form. One made from a piece of old, weathered timber, and the other from a new piece of European beech. The design using recycled timber was machined so that the top edge was left unfinished, exposing the 'silvered' and splintered weathering of the material. The version made with reused ‘silvered’ timber reveals a history of past-use through the material, and an appreciation of the fact that each version of the product would be slightly different because control over the behaviour of the material during processing is impossible. Learning from the performance of these prototypes, divergent-thinking was supported in the next iterative cycle by more deeply incorporating embedded memories and Australian material histories. Using an old timber weatherboard taken from a recently demolished house previously owned by a family member, a new tray was designed (not shown). The demolished house was very characteristic of Australian home design and construction from a particular point in Australian history. As with the previous prototype, selected surfaces were left unfinished, this time to ensure that the features of the original weatherboard piece were identifiable. Prototype evaluation both of the product concept and the processes used to define how the concept would be fabricated, contributed to the investigation of product-consumer attachment by permitting the user to provide the source material. Divergent-thinking in the next learning cycle, moved away from an entirely controlled process of material selection and appropriation, to one that is co-designed. Inspired by Mugge, Schoormans & Schifferstein (2009a), the hypothesis evolved to become

> that there is a co-design process for renewing personal product histories and by doing so, new meanings can be formed that forge a strong and culturally binding consumer-product attachment.

The designer conducted many experiments using different historical products and different materials, producing a series of outcomes, including moulded trays in leather that replicated features and forms from existing historical items (Figure 3). Both leather and felt were investigated for this purpose, though leather reproduced the original surface features of the historical products in greater definition. The transition from the ‘consumer’ to the ‘prosumer’ (Toffler, 1981) is identified as an appropriately workable concept in the context of this project and serves to extend the project beyond product innovation and toward process innovation. At this point the designer has a basis for challenging design conventions and contributing new ideas (possibly new knowledge) to the practice of product design in a contemporary context. We consider, for this subject, that to reach this point is to *transition* from the Formative stage to the Summative stage of the project.

Figure 3: 'Beanz' Tray

The enamel baking tray pictured above was used as the basis to explore the introduction of personal items in the design process. Modifying historical products by machining them was substituted for molding leather over the tray as a means to explore ways of giving the product renewed meaning. (Description from Walden & Koskinen, 2016)

The notion of the prosumer is expanded upon by Mugge, Schoormans and Schifferstein (2009b) by identifying that product personalisation stimulates emotional bonding with products as they become an expression of the owner's identity. The use of leather does not damage the original item but enables personalization and facilitates the accumulation of memories through the wear sustained through repeated uses of the product (Mugge, Schoormans & Schifferstein, 2005). The hypothesis was iteratively evolved in the next learning cycle to become:

> that there is a co-design process for renewing personal product histories through non-destructive replication of features to create new products with enriched meanings that forge a strong and culturally binding consumer-product attachment.

The next series of experiments produced prototypes that are made up of two (primary) parts: the original (historical) item and a new component made of leather or felt that is formed by moulding it over the original product. These included a frying basket with a felt tray-lid that was moulded using the frying basket itself. And a return to the Beanz[7] tray (Figure 4).

Figure 4: 'Beanz' Tray with Leather Lid

> Experimentation through prototyping, of the evolved hypothesis leads to the solution concept above that uses the existing beans tray product, but augments it with a leather moulded lid accessory. The leather moulding is essentially a 'tracing' of the original product. (Description from Walden & Koskinen, 2016)

Through a series of further iterations that produce more prototypes, the hypothesis develops to become:

[7] The ‘Beanz’ tray is a name given to the enamel baking dish used in the designer’s prototypes. According to the designer’s childhood memory, the baking dish was used by the designer’s grandmother as a tray for beans, hence the name.

> Tracing History is a co-design, co-production process for renewing personal product histories, through non-destructive replication of features, to create new products and product assemblies with enriched meanings that forge a strong and culturally binding consumer-product attachment.

The moulding method is a metaphor for ‘tracing history’ by reproducing the surface features of products through the making of a new component, that can then be combined with the original item to renew its meaning and extend the life of the product. The final stage of the project iteratively explores the function of the co-design process as a means to use the ‘tooling’ developed for the moulding technique, as a component of a new product assembly, that includes a final secondary leather moulding (Figure 5). The new product effectively ends the production cycle, since it uses the tooling, extending the concept of the value of rarity in product-consumer attachment to include *rarity of production*.

Figure 5: New Tray with Leather Lid made from 'Beanz' Tray tool.

> The 'timber loop' used to brace the original enamel tray is further machined and finely finished in American Walnut to act as a base in a new version of the design. The tool becomes the product ending the cycle for this series. (Description from Walden & Koskinen, 2016)

Discussion

The study of an (advanced-level) university product design project, that adopts a constructive design research methodology, serves to advance the development of the Iteration Deficit Reduction (IDR) Model, proposed by Nemme and Walden (2016), by providing clearer guidelines for managing design iteration in product design education. An adapted version of the IDR model is shown in figure 6. The case study described in the paper provides some verification that the process described by the IDR model is evident in the mentoring of constructive design research in product design. Further it indicates that prototype-centric iterations can be managed and supported in studio so that these prototypes function both as (using definitions provided by Matthews & Wensveen, 2015) *physical embodiments of research concepts* and *where the research contribution is tied to the crafting of the artifact.* We consider that by meeting these conditions the process can serve in achieving the Degree’s learning objectives, notably, the development of designs that innovate meanings and experiences, becoming accomplished at using prototyping methods as a central research device and to manage complex self-initiated design projects responsibly and professionally. It is possible to track this project by connections between hypothesis-making and prototypes constructed at key stages. By aligning the prototyping activity with *experimentation* (a terminological correlation made also by Bang et al. 2012) and the 'making of hypotheses' with *abstraction* in Kolb's learning cycle, we logically set-up the broad function of the other parts of the learning cycle as depicted in Figure 6. With reference to the model, It is important to describe the two functions of the design studio. Firstly, it must provide exercises that enable students to develop their design project according to the phase of the IDR model that has been reached, for that week. And secondly, it must set guidelines for the completion of work associated with the upcoming phases, so that every week, students complete a single learning cycle.

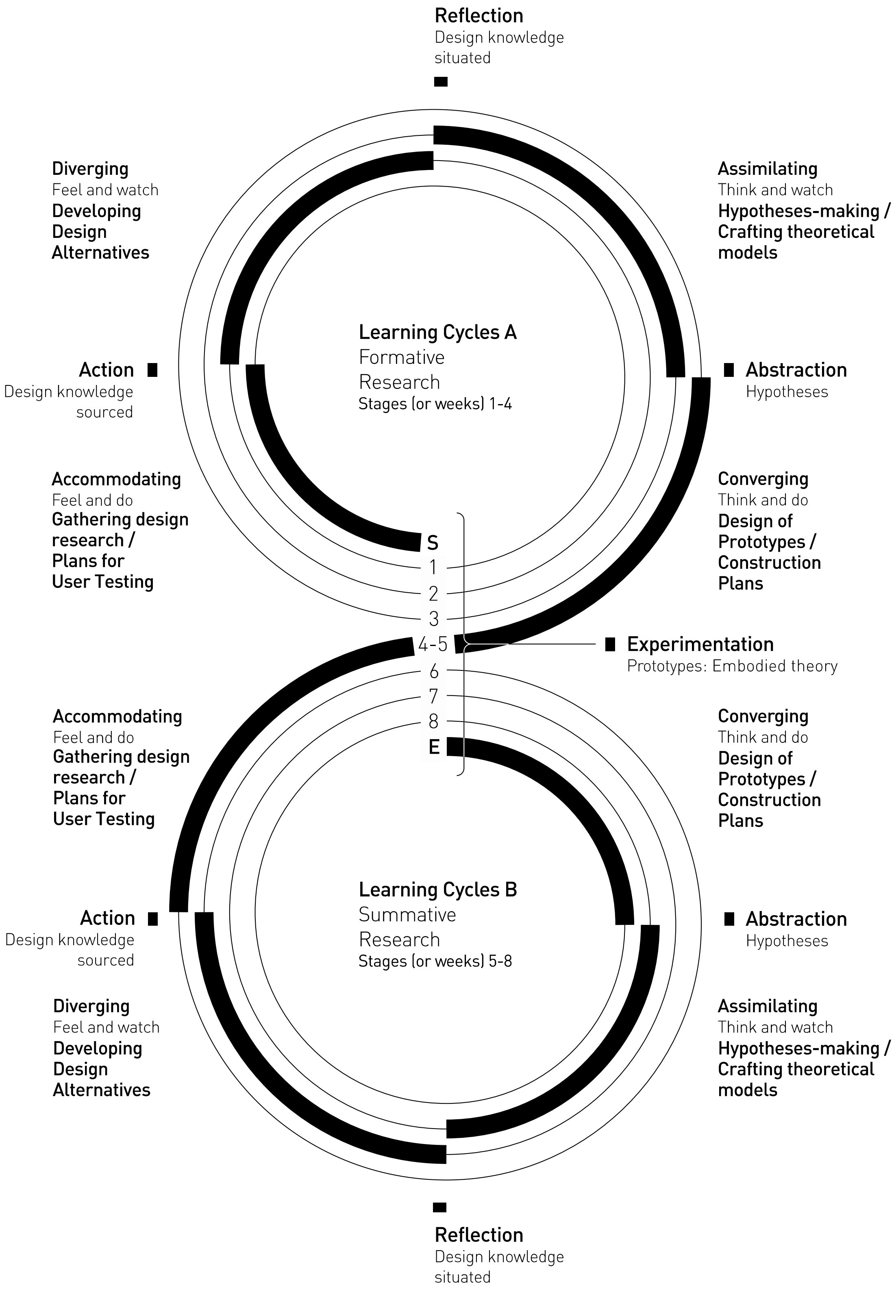

Figure 6: An adapted version of the IDR model (Nemme & Walden, 2016) where the learning styles described in Kolb's Experiential Learning Theory (Kolb, 1985; McLeod, 2013) are contextualised for

university-based constructive design research in product design. Hypothesis-making is assigned to the assimilation learning style in order to set-up prototyping for the experimentation phase. This correlation is supported by the case study presented in this paper and provides guidelines for the assignment of methods for other parts of the learning cycles, A and B.

Conclusion

With the goal of assisting students in moving towards a prudent iterative design process through use of learning device, the IDR model has been established. There is a necessity to support divergent thinking at every design stage in order to reach innovative outcomes. Although iteration itself is important, iterative practice remains an essential component of successful design projects and can be maintained through use of the IDR model. In the context of the IPD Honours Capstone Project, we can see connections between prototyping and design-iteration through each iterative cycle. The notion of cycling through modes of thought and action has been addressed by a number of design models (Stappers, 2007; Koskinen & Krogh, 2015; Kimbell & Stables, 2007), therefore it can be asserted that hypothesis-making and prototyping are essential to underpin the iterative process in pursuit of innovation. The development of hypotheses in the pursuit of knowledge was evident as a feature of Honours projects, and from a teaching perspective, providing a theoretical understanding of these concepts to our advanced level students is of notable concern. With reference to the IDR model, it can be concluded that the conduct of the capstone project discussed in this paper correlates with key features of the model, and this is evident in the way hypothesis-making aligns with the assimilation learning style, through interactions with the construction of prototypes, which aligns itself with the experimentation phase.

A future research pathway might be concerned with the tangible benefits for product design students. For undergraduate students with a less advanced aptitude (such as second year), key features and characteristics of the IDR model could be incorporated into the subject outline program. Here it would reside without graphic form, but could still engage students in the iterative process through the undertaking of a prescribed research method per cycle, albeit in a collective manner. For advanced students, the IDR model could be presented at the beginning of a project in order to visualise and guide the constructive design research process and enable responsible management of a student's individual iterative process. This might then enable students to find 'open', ill-defined and complex problems less intimidating. We can then observe if it inspires better, novel and more innovative design outcomes.

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Pre-service Primary Teachers' Preparedness to teach Design and Technology: A Western Australian Perspective

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Abstract

The importance of Design and Technology (D&T) in the new Australian national curriculum is great and covers all year levels from k-10. So while previously the area could be given lip service by teachers this is no longer the case. In the context of this, the researchers set out to examine the perceptions of existing Edith Cowan University School of Education primary and early childhood student teachers towards the teaching of D&T to determine the nature of any preconceived views relating to the area of D&T and how well their university course has prepared them to teach D&T. An online survey was developed and delivered in 2016 via a Qualtrics (Qualtrics, Provo, UT) commercial survey engine. The survey was voluntary and was administered to School of Education primary and early childhood students via the university's learning management system. A sample of students across all years and courses responded, 95% of whom were female giving a sample that roughly paralleled the School's male/female population in those courses. Amongst the findings is a clear indication that before entering university many students' views towards D&T were biased and stereotyped based upon school experiences, which supports the researchers' previous findings (Pagram & Cooper, 2015). Just over half of respondents felt comfortable teaching D&T and most had either no formal training in D&, or half an online unit during their course. This paper discusses these findings and their implications for the School of Education at Edith Cowan University and primary and secondary schools in general.

Keywords: teacher education, student perceptions, online surveys, design and technology (D&T)

Introduction

This paper reports upon a small research project carried out in the School of Education at Edith Cowan University (ECU) in Perth Western Australia (WA), that sought to examine the perceptions of existing

Edith Cowan School of Education primary and early childhood studies (ECS) student teachers towards their teaching of Design and Technology (D&T) to determine the nature of any preconceived views relating to the area of D&T and how well their course has prepared them to teach D&T. In this paper the authors will describe the setting and method for gathering the data, followed by a discussion of selected findings. The paper will conclude with the implications for education at ECU.

Edith Cowan University (ECU), is situated in the metropolitan area of Perth Western Australia, is a large university with approximately 29,000 students, 17,546 of whom are female. These students are spread over three campuses. Historically, ECU has its foundations in teacher education and training and its School of Education is the largest in Western Australia, with 5617 students and 104 academic staff (ECU, 2016).

Currently in Australia we are at a point of change as a new National Curriculum is being rolled out across the nation. The implications of this are great for D&T in Western Australia, as it becomes an area that is less focused upon the final product and more focused on the process of design and production (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2017). It is now about the problem solving process of design applied across a wider range of years and subjects.

Previously confined to lower secondary school (8-10), D&T will now cover the years K to 10. This is combined with the positioning of the subjects of home economics and design and technology under the one area of design and technologies. It is in this context that the current research is being undertaken.

Teachers' perceptions of technology & technology education

The major aim of design and technology curricula for primary schools requires students to fully understand the nature of technology. In order to achieve this aim, it is expected that teachers should be the first ones to understand technology and technology education. Moreover, it has been indicated that teachers' perceptions of the nature of technology may affect their perceptions of technology education and their way of teaching this subject (Forret, Edwards, Lockley, & Nguyen, 2013). Therefore, it is necessary to investigate teachers' perceptions and understanding of D&T.

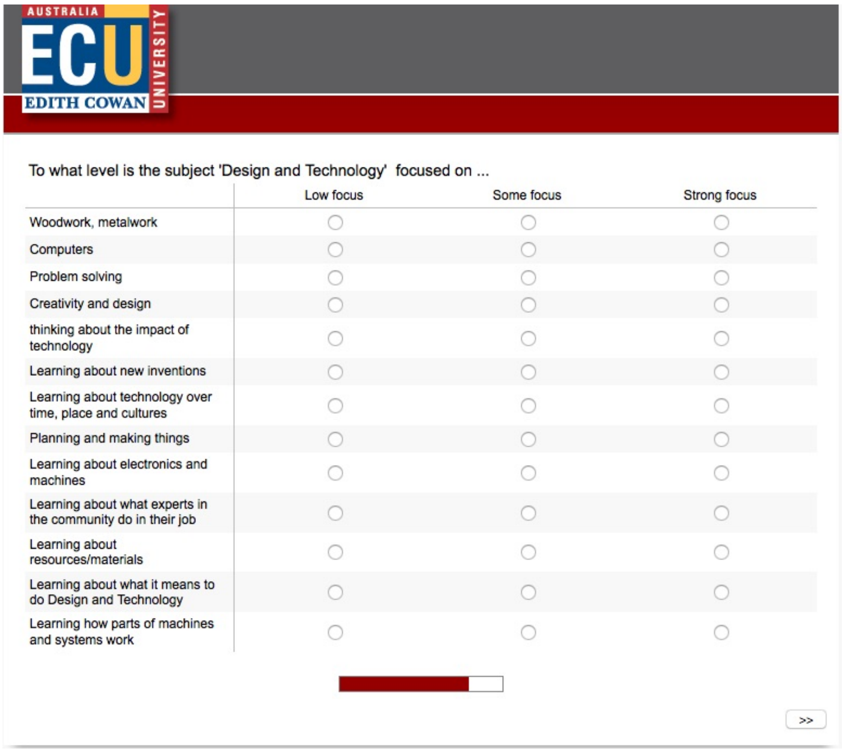
Research has found that many teachers had little understanding of D&T because they had been given little support (Office for Standards in Education, Children's Services and Skills [Ofsted], 1995). Similar results have been concluded from other research, which also indicated teachers' limited understanding of design and technology (Jarvis & Rennie, 1996; Jones, 1997; Jones & Carr, 1992). In the same way as teachers, school students were also found to have narrow views of design and technology (Rennie, 1987; Rennie & Jarvis, 1995a, b), which suggested that teachers' perceptions of D&T would affect their students. Furthermore, Mcrobbie, Ginns and Stein (2000) found that few teachers had the knowledge to make plans and engage students in a design-process, which resulted in the failure to achieve a major aim of design and technology education.

According to Benson (2013), innovation and authenticity were excluded when teachers were asked to indicate six words or phrases that best describe the nature of D&T, which indicated that teachers did not appreciate core concepts of D&T. Forret et al. (2013) also pointed out the importance of understanding the nature of technology and technology education. From their research, pre-service teachers had a narrow view of technology and technology education before entering university.

Also because of the nature of D&T, teachers are required to use varying pedagogies and often have inadequate knowledge and experience of combining technology with the traditional subjects they teach (Ankiewicz, 2003). This problem can be solved by conducting more professional teacher training to equip teachers with the necessary knowledge and skills (Engelbrecht, Ankiewicz, & Swardt, 2007).

Method and participants

The investigation was undertaken via an online survey developed and delivered via the Qualtrics survey engine. A paper based Science, Technology, Engineering and Mathematics (STEM) survey developed by, and used at, the University of Waikato (Forret et al., 2013, pp.166-172) was used as a starting point for the questions and these were added to and adapted for local conditions. Education ECS and Primary students were informed of the survey via a link placed on the ECU Blackboard Learning management system. Figure 1 shows a screen captured from the survey and illustrates how it was designed with an uncluttered layout and utilised radio buttons to facilitate accurate data entry. A progress bar indicated how far participants were through the survey to encourage them to continue through to the end.



AUSTRALIA ECU EDITH COWAN UNIVERSITY

To what level is the subject 'Design and Technology' focused on ...

	Low focus	Some focus	Strong focus
Woodwork, metalwork	○	○	○
Computers	○	○	○
Problem solving	○	○	○
Creativity and design	○	○	○
thinking about the impact of technology	○	○	○
Learning about new inventions	○	○	○
Learning about technology over time, place and cultures	○	○	○
Planning and making things	○	○	○
Learning about electronics and machines	○	○	○
Learning about what experts in the community do in their job	○	○	○
Learning about resources/materials	○	○	○
Learning about what it means to do Design and Technology	○	○	○
Learning how parts of machines and systems work	○	○	○

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Figure 1. Screen capture from the online survey.

In all 65 students completed the survey. Only 3% percent of the respondents were male meaning the ratio of male to female students was a fair reflection of the actual ratio among Education ECS and Primary students at ECU. Seventy percent of respondents were under thirty years old with 54% studying straight from school. Overall the sample while small was a reasonable representation of the student population under examination (see Figure 2).

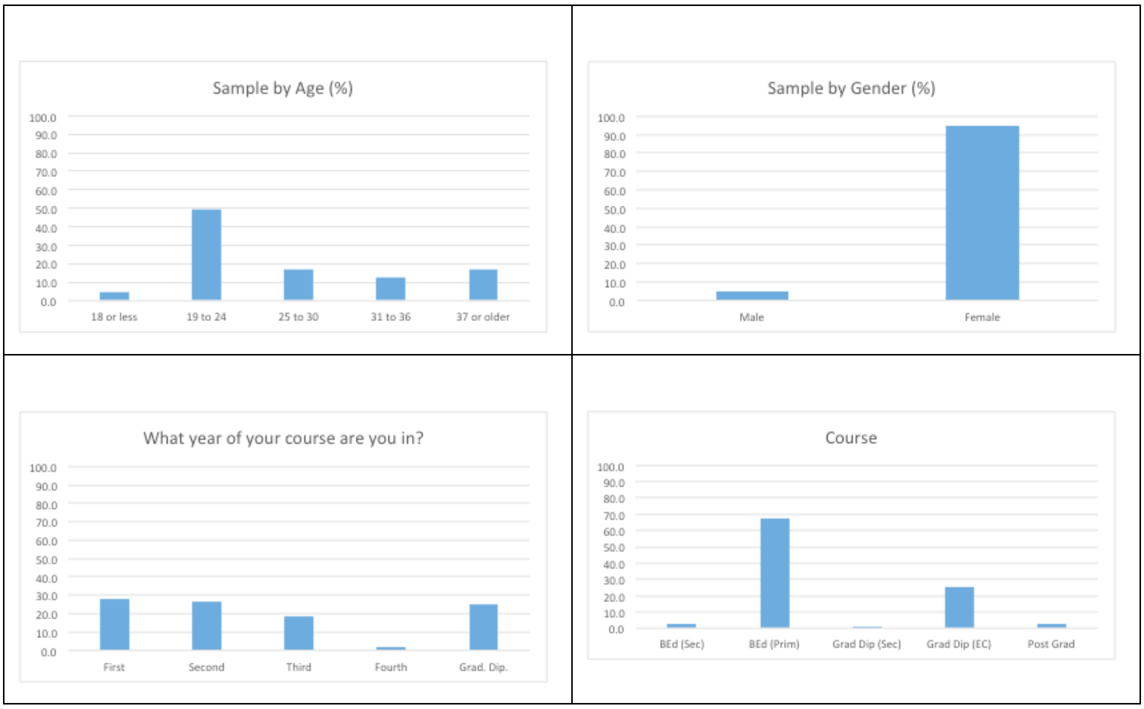

Figure 2. The Sample.

Findings

Results presented here pertain to the results of interest that emerged from analysing the survey data. For the purposes of this paper only those results with particular relevance to the topic of this paper are presented. Most come from the analysis of data from the closed questions within the survey but some pertain to the results from the interpretation of open-ended questions.

Impact of Studying D&T at School

The researchers were interested to know how many of the sample had studied D&T at school, as this was likely to affect their perception of the subject. Overall 85% of students reported having studied D&T at school (see Figure 3), mostly home economics and woodwork. This prior study appears to have been the source of confidence in teaching discussed later.

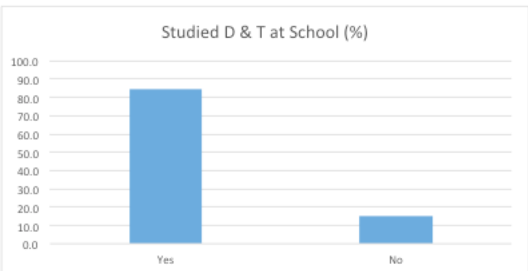

Figure 3. D&T studied at school.

Perceptions of D&T

The respondents were asked a number of questions relating to their perceptions of the D&T Subject area and these are summarised in Figure 4.

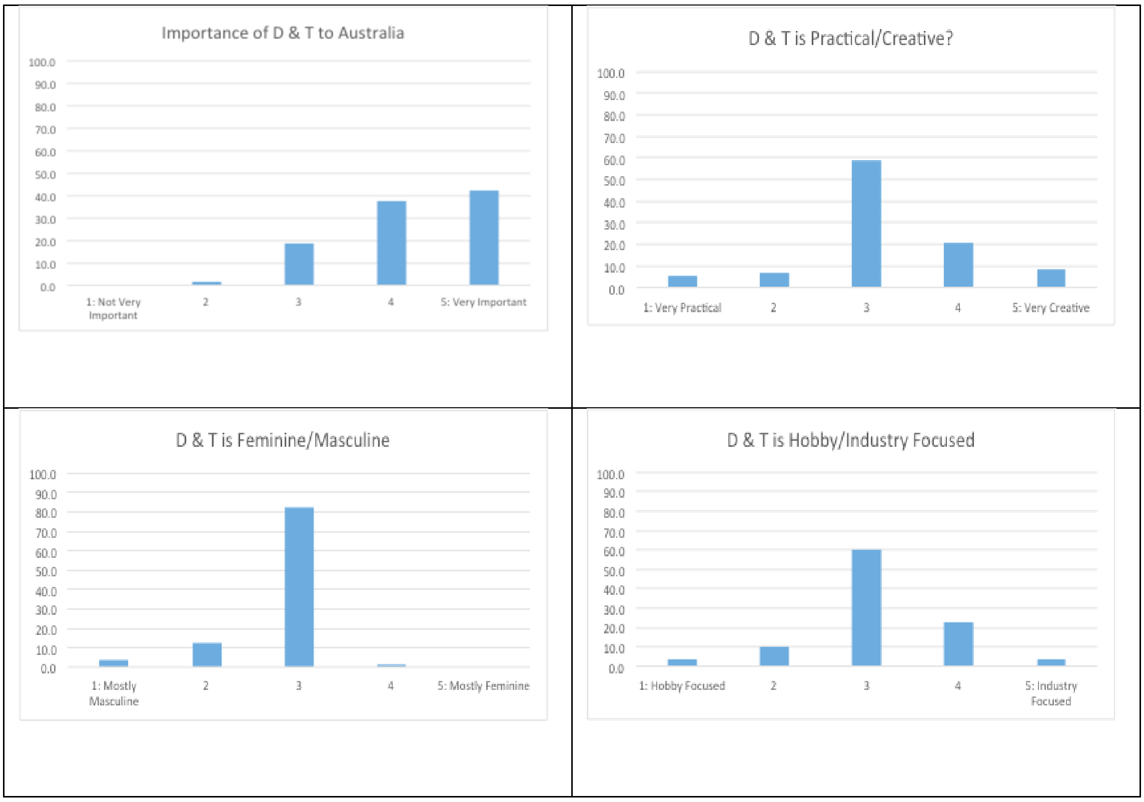

Figure 4. Respondent perceptions of the D&T subject area.

The first of these was: *How important you think Design and Technology is to Australia as a country?* D&T is perceived by respondents to be of great importance to Australia. Given the age of the respondents this perception is likely to have come from their experiences in secondary school (see Figure 4).

The respondents had the opportunity to give a reason for their response and typical reasons given were that: "…children need to be able to explore and construct their ideas that they may have; …children also need to be able to bring to life their ideas and creations; …the whole of STEM is focused around it and it is important for the future; It provides children the practical and hands on skills needed in life; and Technology is the future of the generation and in order for the Australia to continue moving forward as a country, design and technology should not be taken lightly."

Those respondents perceived the subject to be more creative than practical and this was a surprise as previous studies had shown the opposite (see Figure 4). Given the nature of students' school experiences that the results did not tend even further toward the practical side of the scale, as the curriculum in WA schools they would have experience would have been practical in nature.

The open ended question: "When someone says Design and Technologies what do you think of? gave very traditional responses like Woodwork, Home Economics, building, constructing; and woodwork, metal work, building things;" with only a few having responses like "The design process of children designing, planning, making and reflecting upon their own projects."

D&T is perceived as a gender-neutral subject with only a few respondents choosing the masculine or mostly masculine options. The inclusion of home economics in the D&T curriculum area would have helped shape this view. Respondents also believe that D&T is slightly more *Industry* than *Hobby* focused (see Figure 4).

The open question, which asked, What type of people would you find in a D&T classroom*?* was interesting in that a response of *Creative thinkers;* or "People who are good at working with their hands," was very typical with only a few having comments like *"Usually quite masculine teaching staff."*

Table 1 shows the responses to the question Indicate which items apply to Science, Design and Technologies, and Art (multiple selections were allowed).

Table 1: Responses to the question: Indicate which items apply to Science, Design and Technologies, and Art

Question	Science		Design & Technologies		Art		Total
Experiments	98.31%	58	61.02%	36	44.07%	26	59
Making things	45.61%	26	94.74%	54	89.47%	51	57
Problem solving	91.38%	53	91.38%	53	50.00%	29	58
Creativity	44.07%	26	89.83%	53	94.92%	56	59
Considering the impact of our actions on others	90.91%	50	70.91%	39	43.64%	24	55
Learning about new inventions	83.93%	47	92.86%	52	28.57%	16	56
Risk taking	73.68%	42	92.98%	53	80.70%	46	57
Planning and designing	67.24%	39	98.28%	57	86.21%	50	58
Learning new things	93.10%	54	89.66%	52	81.03%	47	58
Investigating Aboriginal & Torres Strait Islander ways	33.96%	18	54.72%	29	96.23%	51	53

The results from these questions reinforced the message that respondents see D&T as problem solving, creative and design focused, but also very practical.

Preparedness to teach D&T

One of the most important things the authors wanted to know was how prepared for teaching Design and Technologies the students were and how much training they were provided with in their University course.

Table 2 shows that on a sliding scale of 0-5 with 5 being very confident and 0 not confident, students responded close to the middle (being neither confident nor unconfident) with a Home economics being the area with the most confidence.

Table 2: Responses to the question: How confident are you to teach...?

Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
Design and Technology	0.00	5.00	2.61	1.26	1.59	59
Digital Technologies	0.00	5.00	2.72	1.23	1.51	58
Home Economics	0.00	5.00	3.19	1.56	2.43	58

Figure 5 shows that while comfort in the D&T classroom varies most students are comfortable and not intimidated by the workshop environment.

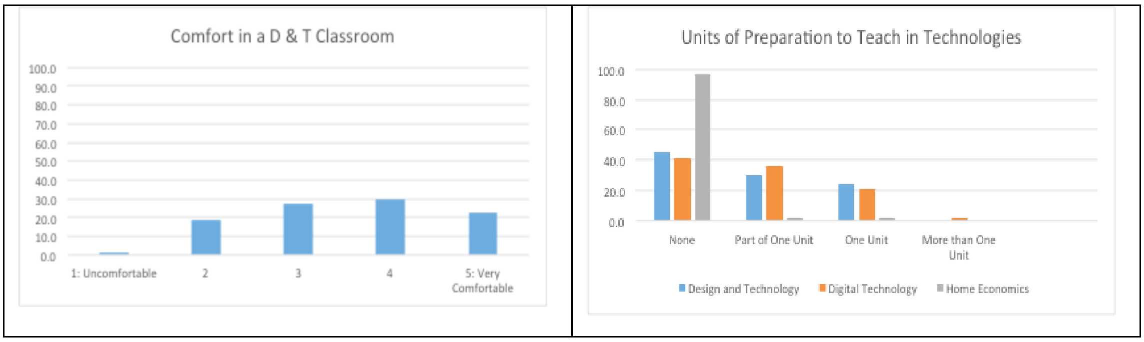

Figure 5. Preparedness to Teach and comfort in D&T Classrooms.

The amount of training students believed they received is shown in Figure 5 with home economics in particular showing little or no training at all and the other areas also being low with none or part of a unit being common.

Conclusions

It appears from the survey that while all participants had an understanding of what D&T is and how important it is in education, these views were greatly influenced by their experiences at school. The survey has also shown that D&T not perceived as too masculine. D&T is seen by many as on a parallel with art as a creative and practical subject and with science as a problem solving subject. So student teachers have positive attitudes towards D&T. While these findings fit well with the intent of the new curriculum, the training and preparation given to the students does not. Most students have little or no training across the Technologies area and Design and Technologies in particular. Students are relying on past experiences in school to give them content knowledge. This is an issue that needs to be addressed, and quickly, by teacher education institutions such as ECU, because currently training in this area is out of step with the curriculum the students are being prepared to teach.

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Teachers’ Perceptions of the Technology Curriculum: The Influence of the School Context for Meaning-Making and Knowledge for Practice

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Key words: Classroom practice, meaning making, mediation, professional development, teachers’ perceptions, technology education.

This research paper focuses on initial findings from a PhD study to investigate the ways that teachers’ perceptions influence their interpretation and enactment of the technology curriculum in two New Zealand schools. It explores the relationship between teachers’ perceptions and the mediation of school-based professional development and describes emerging knowledge about the ways that teachers “make meaning” of the curriculum when motivated to develop their classroom practice.

The theoretical concepts that underpin this research include interpretivist and socio-cultural perspectives as well as activity theory. An interpretivist paradigm enables the acknowledgement of both researcher and participants’ beliefs and their perceived impact on the nature of technology education. The research is positioned as being subjective in nature and is designed to explore how understanding can be deduced from a participant’s actions, which are shaped and manifested in culturally meaningful ways. Within this research, cultural-historical activity theory facilitates the identification of factors, which can influence a teacher’s professional practice. Of particular interest is how language is a key-mediating tool, which can limit, moderate or enable actions, such as the engagement in professional development activities.

The findings from school-based professional development meetings in two case study schools will be presented. Engeström’s (1987; 2001) activity system is used to illustrate how six teacher’s meaning-making processes are influenced by their context, with a view to define and represent some of the threshold concepts that, once understood, can further support the development of a teacher’s practice.

Introduction

Technology education is a subject that has seen significant change in the way that it is conceptualised in the curriculum. The manner in which technology education is enacted is influenced by teachers’ perceptions, specifically their beliefs, values and ideologies, which are based on a system of ideals and likely to be formed as the result of economic or political affiliations (Giddens, 2013). The way that a curriculum is interpreted affects the knowledge that a practitioner will choose to emphasise in their classroom (Buntting, Williams, & Jones, 2015). Teacher practice is also influenced by the dominant discourse within a school, which determines whether practitioners feel enabled to interpret and enact the curriculum in their context.

Technology education in the New Zealand curriculum (Ministry of Education (MoE), 2007) has three strands: Technological Practice, Technological Knowledge, and the Nature of Technology. Technological Practice consists of the content from the previous curriculum document (MoE, 1995), and is generally about concepts that inform the development and making of products. Technological Knowledge focuses on the processes and properties of materials that can be used in product development. The Nature of Technology strand encourages a focus on the conceptual aspect of the subject where students can explore the interconnectedness of technology and society (MoE, 2007, p. 32).

The changing nature of technology education

Jones, Buntting and Williams (2015) argued that, "in an ever-changing environment, some things stay the same" (p. 271). Teachers in New Zealand are encouraged by government to adopt a "future-focused approach" towards education, to be flexible in their approach, and accommodate students' learning needs. In the context of an Innovative Learning Environment which is defined as a place "where the National Curriculum is being expressed in the way it is intended…to keep pace with the world we are preparing young people for" (Ministry of Education, 2017, para. 2), emphasis is placed on open and adaptable teaching spaces, and the use of digital technology to enhance learning opportunities (Osborne, 2016). Of interest here, is whether a continued need to change practice leads teachers to sustain or retreat to historically placed practices (Paechter, 1995) that contradict or minimise the intent of the technology curriculum.

The New Zealand curriculum in technology education (MoE, 2007) counters past interpretations of the subject and provides opportunities for teachers to offer future-focused, and innovative learning opportunities for all learners, regardless of their social or academic need (Reinsfield, 2016a). Individual teacher perceptions and the dominant discourse within a teaching community however, influence the way that professionals interpret, make meaning, and develop their practice (Biggs, 2006; Dakers, 2006; de Vries, 2005; Fox-Turnbull & Sullivan, 2013; Kadi-Hanifa & Keenan, 2016; Zlatković, Stojiljković, & Djigić, 2012).

The focus of this paper is to illustrate how 6 technology teachers are affected by the discourse within which they practice, particularly when engaging in professional development that is intended to develop their thinking of the concepts presented within the technology curriculum. This research is significant because some technology teachers' perceptions and attitudes towards the nature of the subject are strongly embedded (Williams, Jones & Buntting, 2015). My research explores teachers' evolving knowledge for practice, in relation to their curriculum understandings, which can be shaped in culturally meaningful ways, and asserts that by identifying teachers' troublesome knowledge, professional learning can be more effectively supported (Meyer & Land, 2005; Peter, Harlow, Scott, McKie, Johnson, Moffatt, & McKim, 2014). Troublesome knowledge can appear counter-intuitive or conceptually difficult (Meyer & Land, 2003), and in the case of technology teachers can lead to challenges during curriculum interpretation and enactment.

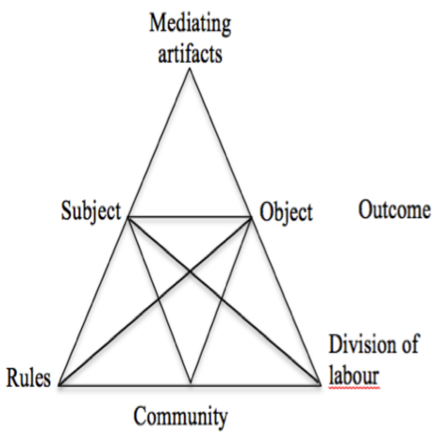
Methodology

This paper reports on research, which used socio-cultural theory as the lens to explore pedagogy within a defined social, historical and cultural context (Sewell, 2011, p. 63). Case study method provided a way to communicate how a teacher's context impacted on their engagement with, and meaning making of curriculum concepts in school-based professional development activities (Gee & Green, 1998; Reinsfield, 2016b).

Two schools were selected for the research because of their convenient location. Lakeside Academy was a well-established school with a well-documented reputation for the teaching of technology education in the specialist area of Resistant Materials. Bernadette was the newly appointed Head of Faculty, supported by Mike and Helen who were teachers in charge of the specialist areas of Digital and Food Technology.

Greenhill School was a Junior High School, an Innovative Learning Environment that had just opened, and was in its establishment phase. This learning area was lead by Alice, an experienced teacher of Product Design, with support from Graham who was a subject leader of Food Technology. Colette was an Assistant teacher of Resistant Materials in both schools, having moved from Lakeside Academy to Greenhill School during the data collection phase of the research.

Three of the six participants were purposefully selected because they were known (to the researcher) as being effective teachers of technology education. The other three teachers were volunteers who were keen to engage in professional development and deepen their understanding of the technology curriculum.



Activity theory was the analytical framework used to identify the teacher roles during the professional development, to clarify motivations, and commonalities relating to the nature and purpose of technology education in the two differing school contexts (Barnard, 2010; Kuuti, 1996). Engeström's expanded activity system models (1987; 2001) were used to generate understanding of the thinking and practice, as represented within and across the two schools. According to Engeström's model (see Figure 1), the elements within an activity system are goal directed and comprise instruments, subjects, objects, rules, community, division of labour and outcome.

Figure 1: Engestöm's expanded activity system model (1987).

The terminology used here is associated with the following meanings. The subjects were teachers of technology who described themselves as specialists in Digital Technology, Food Technology, Resistant Materials and Product Design. The mediating artifacts were the tools used to facilitate understanding during the professional development activities. The object was the intent and purpose of the activity and the division of labour was how the meeting was organised and managed. The rules related to the discourse driving the school environment and the attitudes determining the way that the professional development should be mediated. The concept of community recognised that teachers were encouraged to work both collaboratively and independently to make meaning of the curriculum, and to apply new or evolving knowledge to their practice. The outcome referred to a desired result, and the means by which the objective was transformed during an activity, or as the result of consequent mediation.

Findings and discussion

The reported findings are based on data collected over 18 months, from semi-structured interviews and school-based professional development meetings that were deemed by the participants to be of benefit to the research focus. This phase of data collection explored how teachers were making meaning of the technological concepts being discussed, how they communicated their differing ways of thinking, and the ways that they mediated this process. The findings illustrate the professional development positioned the participants who had their own defining experiences, and were influenced by the systems' rules and conventions. The elements of the activity system using Engeström's expanded theory of activity systems (2001) are presented as a graphic below.

Lakeside Academy

Lakeside Academy's technology teachers had previously taken part in a national online discussion forum, facilitated by Otago University and including a number of schools from across the country. During this online forum, all department staff were exposed to information about the Nature of Technology strand, as conceived within the official curriculum (MoE, 2007).

In the second department meeting, Bernadette, Helen and Mike were engaging in further professional development about the Nature of Technology (NoT) strand of the curriculum (MoE, 2007), and Bernadette explained that it could contextualise the learning and support students' understanding of product development. (Department Meeting 1, line 8)

Bernadette had previously described her professional learning aims, which looked to develop and consolidate understanding of the NoT strand of the curriculum, across the department. Bernadette explained that this was to support teachers to make sense of the technological concepts, for their specialist area. (Baseline Interview, line 249) She also explained that she was well positioned to do this because of her own experience during the curriculum's development. (Baseline Interview, lines

258, 262 & 277) Below is the diagrammatic representation of an activity system for the second department meeting.

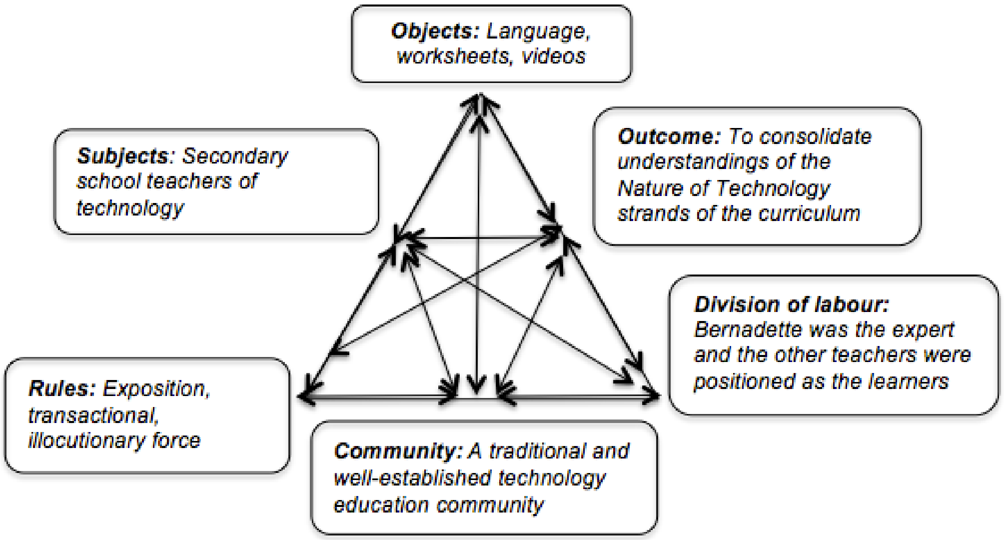


Figure 2: A professional development activity system for Lakeside Academy, adapted from Engeström's third generation of activity theory (2001).

Figure 2 represents an activity system where Bernadette directed the nature of the meeting, because of her role as the Head of Department. She positioned herself as the expert, and determined the discourse. During the meeting Bernadette acknowledged that the information presented was from her perspective, and based on her experience of teaching these technological concepts at a variety of year levels.

Both Bernadette and Mike used illocutionary force through the rules they established, to assert their beliefs in their own practice within the culturally defined setting, to reinforce how the technology curriculum should be interpreted, and could be enacted from their perspectives. For example, towards the end of the meeting, Bernadette reiterated her intended outcome, acknowledged the teachers' specialist area expertise, but also encouraged them to use her approach, suggesting that the concepts within the NoT strand were easy to enact.

Throughout the meeting, Bernadette checked for understanding of the curriculum concepts being presented and emphasised the importance of the NoT strand for students' work in technology education. Bernadette regularly focused her attention on Helen who was experiencing difficulty engaging with the concepts from the curriculum but had also expressed a motivation to develop her knowledge for practice. To achieve the outcome of the meeting, Bernadette provided food-specific examples for Helen, who appeared to engage with the content and make meaning of the examples cited. For example, Helen referred to some worksheets being exemplified by Bernadette and asked questions about their application, to apply in her own practice. (Department Meeting 1, line 359)

Helen's meaning making was motivated by the need to determine where her new knowledge for practice might fit into the junior food technology programme. (Department Meeting 1, line 633)

Greenhill School

In Greenhill School, there were two meetings where data was collected. During the first meeting, the intention was to "extract the essence" of technology education in that school context, with staff working together for the first time. When describing the specialist areas of technology education, Alice made associations to the names used to describe the subject and argued that the team's choice would affect the way that it would be perceived. She stated that the name of the learning area had to connect with their intended exemplary practice. (Department meeting 1, line 64) Alice also asserted that it was important that the teachers of technology had a common understanding of the purpose of the subject. (Department Meeting 1, line 23) At this point of the data collection, all teacher dialogue was conceptual because there were no students in attendance at the school. Participants occasionally made reference to their previous teaching experience and much of the discussion was centred upon the terminology and philosophy of the official curriculum (MoE, 2007).

During the meeting Alice encouraged discussion from and between the teachers. The rules were established from the outset of the first meeting where Alice asserted that whilst she was leading the meeting, her role was not from a position of authority. Figure 3 represents the department meeting in Greenhill School.

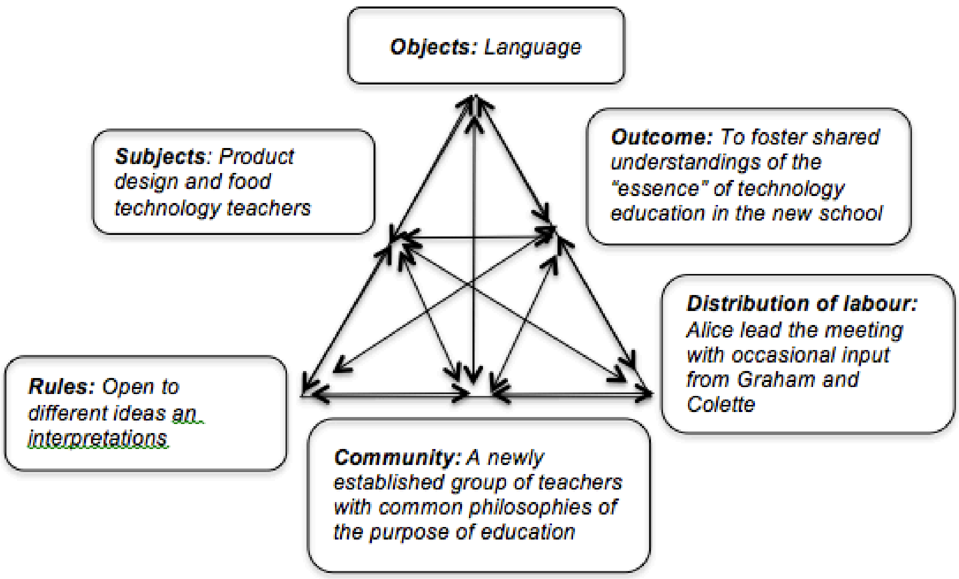


Figure 3: A professional development activity system for Greenhill School, adapted from Engeström's third generation of activity theory (2001).

This research explored the relationship between a teacher's collaborative and independent action, as well as their derived meaning. To explore such a view, I investigated whether teachers actively constructed knowledge as the result of their discussions in department meetings. Table 1 outlines the ways that teachers' identified their meaning-making processes, in relation to understanding the nature of the curriculum.

Table 1: The participants' identified meaning-making processes

School	Teacher	Processes Identified.
Lakeside Academy	*Bernadette*	Working on the Beacon project with like-minded colleagues Testing ideas and providing feedback Generating resources Delivering and reviewing teaching Making links with industry
	Helen	External professional development Reproduction of recommended strategies and tasks Developing a template to follow
	Mike	External professional development Digital Technology teachers Trial and error
Greenhill School	*Alice*	External professional development
	Colette	Adaption of resources from online, national professional development
	Graham	External professional development Technology Online Academic readings Delivering new concepts and reviewing teaching

Only Helen and Colette made reference to their school-based professional learning as a means to develop understanding and both were at an emergent stage in terms of their understanding of the curriculum concepts.

The nature of the professional development in both schools differed in terms of their objective, rules and distribution of labour. In Lakeside Academy, Bernadette positioned the other teachers as learners and herself as the expert, with the rationale that this would maximise the time available for school-based professional learning. At Greenhill School, the activity focused on defining technology education and determining its "essence", in their newly established school context. At Lakeside Academy, Bernadette aimed to consolidate understanding of the curriculum, to align with her interpretation, whereas Alice at Greenhill School collaborated with the teachers to negotiate an agreed understanding.

Every participant identified that they had experienced troublesome knowledge at some point when engaging with and enacting the technology curriculum. Troublesome knowledge is one of the features of a threshold concept, which once understood, can transform a teachers' thinking or practice (Perkins, 2006). There were differing emergent beliefs about the nature of change in technology education as well as commonalities driving the practice in both contexts. To illustrate this, Alice and Helen's perspectives are described.

At Greenhill School, Alice attributed a lack of subject identity to the curriculum's "inconsistency in language" (Department Meeting 1, Line 152), and also expressed frustration at the lack of change within the technology teaching community. Alice believed that technology teachers had "put up barriers" to rationalise their traditional practice. (Baseline Interview, line 18).

All participants asserted that the subject should not solely be defined by its practical nature, but argued that it was a means to engage their learners. Alice and Helen both described their troublesome knowledge, which was experienced at differing stages of the curriculum interpretation and enactment process, as illustrated in Figure 4 below.

There were some significant challenges to Helen's practice. Her professional priority was to manage her workload, rather than to address the curriculum or engage her learners. Helen's exposure to the curriculum was limited to the transmission of concepts during professional development experiences where she attempted to make sense of content for her specialist area of food technology. Helen adopted ideas from her colleagues and developed templates, and then replicated the concepts for each topic throughout the year, in the junior secondary context.

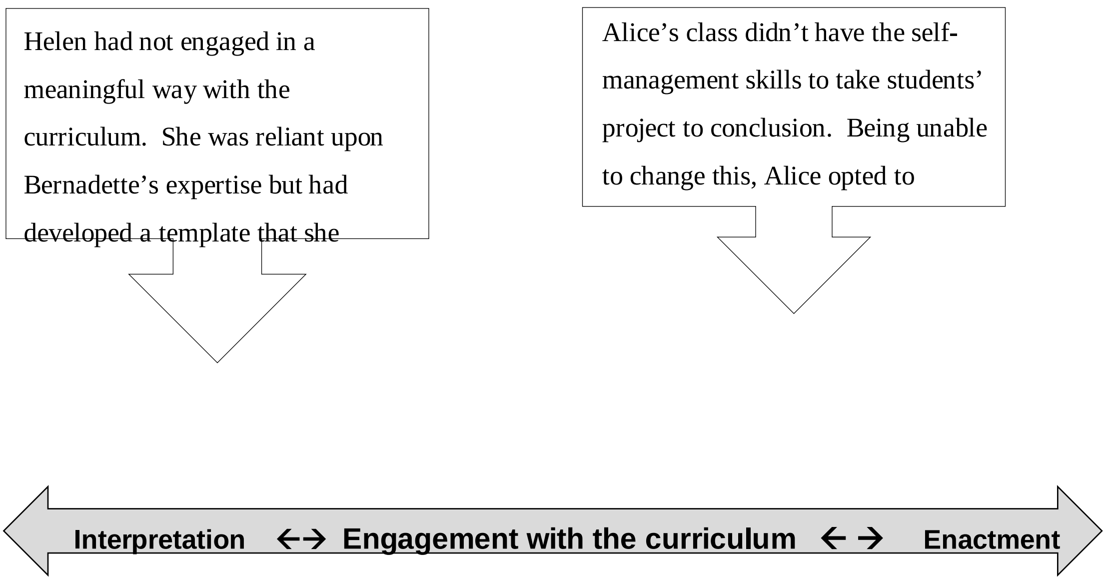


Figure 4: The stages at which Helen and Alice experienced troublesome knowledge, which limited their practice.

Helen experienced troublesome knowledge in all aspects of her practice, because her philosophy juxtaposed with the intent of the curriculum. Helen did not engage with the curriculum content during the data collection phase and her practice was minimised to a form of mimicry, without any understanding of the intent behind enacted practice. To develop her professional practice, Helen would have benefitted with some understanding of the philosophy driving technology education in the current New Zealand context.

During her final interview, Alice described some challenges to her practice in the newly established school. She had discontinued a project at the end Term One and reverted to the making of outcomes that provided pre-determined stages of manufacture. For Alice, the troublesome knowledge was not how to interpret the curriculum or develop ideas for its enactment, but instead how to manage a collaborative project in a structured manner. Alice described a need to establish classroom expectations in the new school context, with students who were demonstrating challenging behaviours. Faced with this situation, Alice reverted to a traditional approach to technology education and explained that this was because she needed to develop students' capability and skills. Alice explained that this experience motivated her to reflect upon her practice and she aimed to develop projects that incorporated all strands of the technology curriculum.

Conclusions

There is no doubt that technology education has seen significant change since its inception and that teachers' beliefs about the nature of the subject heavily influences its enactment. By investigating two school contexts, differences and commonalities have been established by exploring the ways that practice is manifested in culturally meaningful ways. The initial findings from this research suggest that whilst there may be some engagement with the Nature of Technology and Technological Knowledge strands of the curriculum, there remains an emphasis on the Technological Practice strand both to make meaning of the curriculum, and in teachers' practice.

Whilst Innovative Learning Environments may provide the opportunity for teachers to foster learning in an open and flexible space, and use digital tools as a means of enhancing learning, other challenges to practice (such as student behaviour) can still be limit the enactment of the curriculum if learning needs are not responded to.

For Helen, the department's discourse was enabling her to continue to practice in a manner that reproduced the thinking of more experienced colleagues, rather than engage with the curriculum to develop her knowledge for practice, in a beneficial way. For Alice, her students' prior knowledge and engagement with collaborative learning limited success, despite her sound understanding of the curriculum and it's intent.

Threshold concepts can be identified with a view to develop strategies and make recommendations to support teachers' practice during their interpretation and enactment of the curriculum. This paper asserts that teachers need to feel empowered and committed to the development of their own approaches to the curriculum, within their specialist areas of technology. By interpreting the curriculum, teachers are more likely to make meaning of its intent and take responsibility for their own professional learning. To develop their practice, teachers require both an understanding of technological issues, as well as the way that technology education is conceived within the curriculum (MoE, 2007). The alternative is that technology teachers may feel that their professional knowledge is insufficient, and as a consequence sustain or retreat to historically placed practices, that ignore, contradict or minimise the intent of the technology curriculum.

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The Localisation of Technology Education Curriculum in Botswana: Benefits, Challenges and Implications for Future Planning

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Abstract

This paper shares perceptions and experiences of various stakeholders regarding a change from a British model of technology education curriculum to a locally designed one for senior secondary schools (17-19 year olds) in Botswana. Within this context, the paper explores the nature of change, the organisational conditions under which the change took place and the capabilities that needed to be developed for a successful implementation. Management of change in technology education is a topic where little research has been done within the context of Botswana. For this reason, a change management model known as ADKAR (Awareness, Desire, Knowledge, Ability, and Reinforcement) was employed as a diagnostic tool to assess the nature of this change. The study adopted a qualitative case study approach situated within a social constructivist research paradigm because most of the data collected were based on perceptions and experiences of the in-service officers and teachers trying to implement a new curriculum. Methods included a questionnaire and individual interviews with senior teachers and in-service officers, literature review as well as document review. The findings revealed that many of the key stakeholders who included mainly senior education officers, curriculum developers, in-service officers and teachers (50%) embraced the departure from the Cambridge curriculum which they described as too academic and also not relevant to the socio-economic needs of Botswana. However, several factors which hindered the implementation effort were reported. Noted were: inadequate communication with teachers regarding the change; limited change management capability; little or no administrative support and limited teacher capability especially in the implementation of new technology content areas. This paper draws together significant factors and challenges identified. The paper concludes with suggestions for policy makers and curriculum developers in terms of the future planning and the capabilities need to drive future curriculum changes.

Keywords: ADKAR Change Model, Change management, Botswana, Cambridge, Localisation, Technology Education.

Introduction

This paper shares insights gained from a study which investigated the management of change from a British model of Design and Technology (D&T) curriculum to the Botswana model designed for senior secondary schools. The paper begins by providing the background to the localisation of the D&T curriculum in Botswana. This is followed by a description of the change process, its principles and challenges. Selected findings of the study will be presented and discussed. The paper concludes by using insights gained to forward proposals for more effective change management strategies for future implementation.

Background to the study

The year 2000 ushered a new era in the provision of the public education system for Botswana. This was when a locally developed programme intended for senior secondary schools (17-19 year olds), *aka* the Botswana General Education for Secondary Education (BGCSE) was introduced. The BGCSE programme itself was the product of the Revised National Policy on Education (Republic of Botswana, 1994), which advocated the need to align the education system to the socio-economic needs of Botswana (Republic of Botswana, 1992). The introduction of the BGCSE programme culminated three decades of a British education system, which schools had followed through collaboration between the government of Botswana and University of Cambridge Local Examinations Syndicate (UCLES).

Rationale for the localisation of the curriculum

The BGCSE model of technology education was adopted from the Cambridge model (England) which at a time was still in transition from the traditional crafts (Rasinen, 2003; Eggleston, 1996; Ndaba, 1994). The philosophy and emphasis of the Cambridge curriculum were different. For example, within the context of England, it was noted that owing to the many different variations; separate and independent examination boards; there was no standard model of D&T education offered across schools (Atkinson, 1990; Banks, 1994; Eggleston, 1996). Wright (1993) also noted that *"the exposure students have to technology varies among schools"* (p.61). Likewise, Banks noted that technology is still a new area in many national curricular and the aims and purposes of its inclusion are often unclear (De Vries, 1995; Rasinen, 2003).

Given this background then, one notes that in the context of Botswana, the development of the BGCSE D&T curriculum evolved from the Government's desire to modernise a predominantly agro-based economy (Republic of Botswana, 1994). The D&T curriculum was designed to provide students with a platform of prevocational knowledge and skills to enhance future career choices especially in technology related areas. Through the RNPE of 1994, D&T education was identified as one of the key subjects which had the potential of contributing to the development of Botswana's industrial and technological bases (Ministry of Education and Skills Development, 2000). From this perspective, deliberate attempts were made to include more advanced technologies as opposed to the craft, design and technology (CDT) based content which had been inherited from the Cambridge D&T model (Fox, 1988; Moalosi, 1999; Ruele, 2015).

Statement of the problem

Research leading to this research showed that since inception in 2000, the BGCSE D&T curriculum has only been reviewed once in 2009. This means at the time of writing this paper, the curriculum in question was already entering a third phase without being reviewed.

The senior secondary level of schooling is deemed a key stage for Botswana because it is a prevocational level which was designed to equip children with skills for further education and training as well as possible employment (Republic of Botswana, 1994).The lack of research at this level is not only a cause for concern but it also limits the efficiency of any future curriculum review process. Additionally, the authors noted considerable research into this area especially in more developed countries, notably England, Australia, New Zealand and the United States (Atkinson, 1990; Finger and Houguet, 2009; Hughes, 2005; Rasinen, 2003; Williams, 2007). The contexts of these countries differ significantly to that of a developing country like Botswana (Ndaba, 1994; Lewis, 2000; Williams, 2007).

It is against this background that this research was undertaken to explore the organisational conditions under which the change took place, the capacity to implement the change, the teachers' knowledge and skills and the support system and other issues related to its implementation. Hence, the primary research question which drove this inquiry was: *What is the nature of change from the Cambridge D&T curriculum to the Botswana model and how are teachers being supported to implement the curriculum?*

Objectives and research questions

To address the research question stated above, the following objectives were established:

1) Gain insights into the nature and scope of change from the Cambridge curriculum to the locally developed D&T curriculum for senior secondary schools in Botswana.
2) Measure the level of awareness and support for the new D&T curriculum among the various stakeholders involved with the implementation of the curriculum in Botswana.
3) Identify and validate the key factors that facilitated or hindered the implementation of the BGCSE D&T curriculum in senior secondary school schools and consider how these might be overcome to ensure effective implementation;
4) Apply the findings of the study to make informed suggestions for appropriate change management capabilities and competencies needed for effective implementation of the BGCSE D&T curriculum.

The objectives led to formulation of the following research questions:

1) What factors have necessitated change by the government of Botswana from the Cambridge D&T curriculum to a locally developed BGCSE D&T curriculum?
2) What change management capabilities and competencies were developed by the sponsor to facilitate effective implementation of the planned change?
3) What organisational factors have facilitated or inhibited effective implementation of the BGCSE D&T curriculum?

4) What change management capability needs to be developed to facilitate effective implementation of the BGCSE D&T curriculum?

Theoretical framework

This section establishes the theoretical framework which will enable us to understand the nature of change and its management processes. The section will explore the ADKAR change management model which has been used as diagnostic tools to help organisations to mitigate some of the common problems that impede success.

Change is a constant feature in human lives (Kotter, 2012; Harvard Business School Press, 2003; Hiatt and Creasey, 2012; Hiatt, 2006; Cameron and Green, 2012). Organisations continuously introduce changes in response to internal and external stimuli (Newton, 2007; Stacey, 1993). Some of these changes focus on processes, technologies and others on the structure of the organisation. Research on change management showed that education as one of the drivers for socio-economic development has often been caught up at the receiving end of these changes (Fullan, 2001; Morrison, 1998; Murray, 1990; Stacey, 1993). It has been observed that change initiatives are often poorly managed, not well resourced and not seen through by the sponsor (Kotter, 2012; Harvard Business School Press, 2003; Hiatt and Creasey, 2012; Hiatt, 2006; Cameron and Green, 2012).

Definition of terms

The purpose of this section is to develop a working definition of change management and its associated terms as used in this paper.

A variety of definitions of change management (CM) have been found in the literature, as such it is necessary to provide a working conceptual framework. This paper will use the definition first suggested by Hiatt and Creasey (2012, p.9) who define CM as: “the application of processes and tools to manage the people side of change from a current state to a new future state so that the desired results of the change are achieved”. Accordingly, Kotter (1996, p.25) CM can be defined as: “a set of basic tools or structures intended to keep any change effort under control”. Kotter (1996) adds to this point by asserting that change management is a way of making a big change and keeping it under control and also ensuring that it proceeds in an orderly manner. The above definitions were deemed sufficient for the purpose of laying the theoretical framework for subsequent discussions on this topic.

To sum up, the foregoing section sought to establish a working relationship between change and change management. Hiatt and Creasey (2012) have underscored the notion that if we are to effectively position change management in our organisations, we need to start the conversation about the current state, transition state and future state for the organisation. And then continue the conversation to focus on individual current states, transition states and future states. Hence, change management is about supporting individual employees impacted by the change through their own transitions; from their own current state to their own future state that has been created by the project or initiative.

Table 1 summarises key factors which arose from a review of change management literature.

Table 3: Literature summary of key factors affecting change

Key Factors	Explanation
Driving forces for change	Fullan (2001) and Stacey (1993) observed that the need for change within organizations is driven largely by external factors such as the economic, technological, social, political and cultural environment. However, change may also be driven by internal factors such as employee demands, organizational politics, and top management changes.
Commitment to change	Major changes can only be successful in the head of the organization is an active supporter (Kotter, 1996) .
Clear and shared vision for change	The need for change must be clearly articulated at all levels and embedded in the culture of the organization. Effective communication is critical to implementation from the outset (Kotter,1996; Harvard Business Essentials, 2003).
Visionary and supportive leadership	Leadership sets the new direction or vision for the organization. The leadership must take responsibility its success or failure.
Stakeholder participation	Effective change demands collaboration between willing and motivated parties. Everyone must be taken on board.
Capacity to manage change	Capacity is the resources that the organization needs to implement the change effectively (Harvard Business Essentials, 203). The organization's capability in terms of human, financial and physical resources needs to be assessed beforehand. Commitment to change is evidenced by provision resources including time and incentives.
Implementation strategy	Implementation is "the means to achieving outcomes" (Fullan, 2001, p.52). implementation strategy is a plan for the change and operationalizing the strategy. A good implementation plan should flexible and open to revision (Kotter, 1996).

Description of the ADKAR change model

This section familiarises the reader with the ADKAR management model and exemplifies how it was employed in this research. The rationale for choosing the ADKAR model over several other models is because this model focuses on those individuals directly affected by the change rather than the whole organisation. This model was particularly useful as a diagnostic tool to assess the nature of transition within the context of Botswana.

ADKAR is an acronym for Awareness, Desire, Knowledge, Ability, and Reinforcement. The ADKAR change model was developed by Hiatt (2006) of PROSCI (2014) research to assist in determining if change management activities were having the desired results during organisational change (Hiatt and

Creasey, 2012). The premise of the PROSCI's ADKAR change model is that to move out of the current state, an individual needs Awareness of the need for change and Desire to participate and support the change. Successfully moving through the transition state requires Knowledge on how to change and the Ability to implement the required skills and behaviours. In the future state, that Ability is utilised and Reinforcement is required to sustain the change (Hiatt, 2006; Hiatt and Creasey, 2012).
Methodology

Research methodology

This section presents and discusses the conceptual framework which informed the design and methodology employed in this inquiry. The section then explains and justifies the rationale behind the design, the methods used for data collection and the techniques used for the analysis. The ethical procedures followed to conduct this research are explained and the limitations of the data collecting methods are also highlighted.

The ADKAR change model (PROSCI, 2014) already described in section 2.2 served as the theoretical framework to assess the nature of change. Insights gained were to identify gaps in the implementation and make proposals for more effective implementation in senior secondary schools. The study was principally a qualitative inquiry because most of the data collected were based on people's narratives and experiences with a new curriculum. In terms of data collection, a multi-method approach was adopted which included questionnaires, individual and group interviews as well as document review. The multi- method approach was driven firstly by the research questions to be answered, secondly the practicalities of the research context and finally for triangulation purposes (Neuman, 2011; Cohen et al., 2011). Creswell (1998, p.13) alludes to the notion that: *"audiences such as policy makers, practitioners, and others in applied areas need multiple forms of evidence to document and inform the research problems"*. The actual implementation started with a self-completion questionnaire for teachers; followed up with a group interview and ended with the individual interviews. Figure 1 exemplifies how the ADKAR change management framework was applied to the investigation.

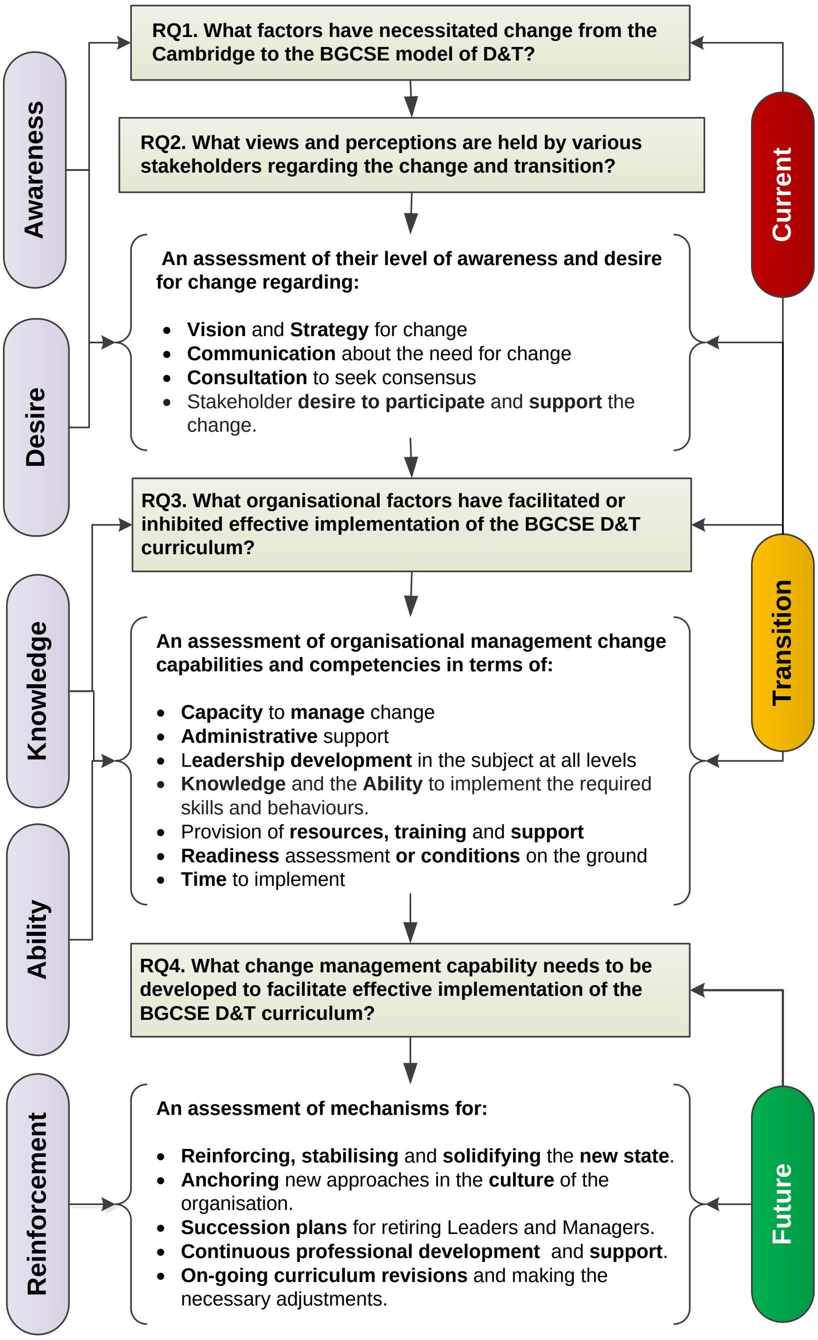

Figure 1: Application of the ADKAR change model as a diagnostic tool

Illustration adopted from: Ruele (2015:p.10)

Types of data collected

In terms of data collection, a multi-method approach was adopted which included questionnaires, individual interviews as well as document review. The bulk of the data were collected from in-service officers and teachers because of their role as change managers and implementers respectively; it was deemed that their knowledge and experience would help to illuminate the situation on the ground.

The teacher questionnaire

A questionnaire was deemed an appropriate instrument for collecting data from the teachers for two reasons: Firstly because the teachers represented a larger number of the respondents who participated in this study; Secondly the questionnaire enabled the researchers to gather data on one-shot basis and hence economical (Bryman, 2008; Cohen et al., 2011).

Administration of the questionnaire

The questionnaire was designed and piloted on a few practising teachers (n=10). The aim of piloting the questionnaire was to help identify errors before the actual implementation. The piloting also helped to collect baseline data which was used to measure the level of understanding and interpretation of the questions by the respondents. Furthermore, this piloting exercise helped to test the validity and reliability of the instruments used. Feedback obtained was then used to modify and/or make appropriate revisions to the instrument before administering it to the rest of the participants. The participants who took part in the pilot exercise were not involved in the final questionnaire. This was done to avoid them from influencing others. Table 2 provides a summary of the questionnaire used in this study.

Table 2: The structure and composition of a questionnaire for teachers

Part	Explanation	Objective
A	Introduction and instructions	• To facilitate clarity of instructions and to ensure that the participants appreciated the need to participate in the study
B	Personal details	• To capture teacher's demographic data
C	General questions	• To capture additional information
D	Measure of teacher's perceptions regarding the change; the degree of their participation in the change process	• To provide insight into their thoughts and opinions regarding change • To assess awareness; the level of participation and satisfaction with the roles played in the change process
E	Measure of the effects of change on practice	• To assess the level of satisfaction • To identify needs
F	Capacity for change; organizational conditions affecting change	• To identify facilitating and hindering factors needs; to assess the implementation capacity
G	measure of the state of the BGCSE D&T curriculum	• To gain further insights; generate contextual understanding
H	Change management strategies.	• To generate ideas; assess and identify appropriate intervention strategies.

Individual interviews

The interviews were semi-structured and were organised around conceptual issues which arose from change management literature. This was to allow the same interview schedule to be used across and also to make it easier to validate the responses against the literature findings. The interviews also allowed a variety of issues to be explored in greater depth than would be possible with a questionnaire. Table 3 below summarizes procedures used to conduct individual interviews.

Table 3: Procedures for individual interviews

	Procedures followed	How data were recorded
Individual interviews	Purposeful sampling procedures recommended by Miles and Huberman (1994) were used to identify key informants. Initial contact with senior officers was made by phone through the Enquiry Desk. The purpose of the study was explained and dates for the interview were proposed. Once the request was accepted, a formal letter was written with included an informed consent form and the interview schedule. The interview schedule contained questions to be asked in the interview. The documents were sent by email a month before the data collection exercise. The same interview schedule was used across to make it easier to validate the responses against the respondents. In terms of arrangements for interviews, a courtesy visit was made to the senior officers' offices to formalise the appointments and make all the necessary arrangements, including the venue for the interview.	The interview was recorded to minimise too much writing during the interview. However, the author jotted down a few notes. This was found useful in noting supplementary questions. In designing the interview schedule, procedures recommended by Bell (2005) were followed. The procedures require topics to be selected beforehand, questions devised, methods of analysis considered, and schedule prepared and piloted. An interview schedule was prepared with a list of questions and the order in which they would be asked (see Creswell, 1998: 24). The interviewees were asked the same questions. However, as already mentioned, there was provision for asking additional questions which had not been anticipated. The form was also found useful for transferring interview transcriptions. After the interview, the researcher verified that the device used to record the interview had worked throughout the interview. Reflection on the interview was done whilst issues were still fresh in the mind.

The study was conducted in the Northern and South central regions. The regions were chosen to achieve representativeness and to enable comparisons to be made.

Data analysis

Data analysis employed thematic approach for qualitative data while for quantitative data descriptive statistics were used. Each participant was assigned a unique identification code as follows: T = Teacher; ST = Senior Teacher; INSETOFF = In-service Officers; PEOFF = Principal Education

Officer. This coding also enabled the researcher to verify the responses against the individual participants.

Limitations of the study

These findings must be created with caution in terms of their generalisability (Robson, 2011). Cohen et al. (2011) advise that for qualitative study to be valid; it requires that all the checks and balances should be put in place. Due to limited time and resources it was not easy for the researchers to conduct a comprehensive empirical study which would have included other regions of Botswana. Owing to this constraint, the sample size used for the study was quite small, considering that Botswana is a vast country. Incorporating a broader sample could have enhanced the validity and generalisation of findings. Therefore, in view of these limitation, the findings should be viewed as contextually related and could be inductively applied elsewhere provided that context is closer to the one being investigated (Yin, 2009). Moreover, the methodological approach employed in this research, was chosen because they were deemed relevant to the specific demands and constraints of the research topic and to enable the researchers to elicit the optimum data and insight from the available sources. Most importantly, the findings have contributed to a greater understanding of the situation on the ground.

Presentation of selected findings

This section reports the findings of a small-scale pilot study which was designed to collect baseline data from various key stakeholders involved with the implementation of the BGCSE D&T curriculum. The data collected were used to provide insights into how the change was managed. Ultimately, the insights gained were to be used to inform a response action. The results reported here sought to capture views and perceptions of the respondents on the following issues:

1) Awareness of the need for curriculum change;
2) Administrative support;
3) Capacity for change; and
4) Teacher professional development

Awareness and desire for change

This question sought to establish the reasons for changing the curriculum. The question comprised three parts. The first part asked the participants to share their views in terms of their awareness about the government's decision to change the curriculum. The second part asked the participants to comment on how those decisions were communicated to them by the authorities. The last part assessed the role played by the various stakeholders in decisions about the change. The questions related to this part were open-ended even for the questionnaire. Document review was also done to validate the responses.

The awareness and desire for change were assessed across all the participants. The first part of the question asked the respondents to answer "Yes" or "No" to whether the change was necessary. A follow-up question asked the respondents to provide a justification for their answers. Figure 2 presents the findings in respect of teachers' perceptions about whether the change was necessary or not.

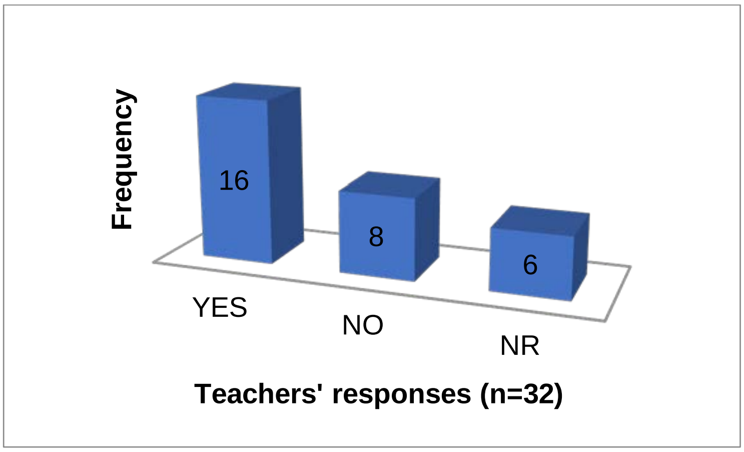

Figure 2: Teachers' perceptions of the need for change

Referring to Figure 2, sixteen (53%) teachers felt the change was necessary. This represents the majority. Eight (27%) felt the change was not necessary. The remainder did not respond (NR) to this question. In order to validate the responses from the questionnaire, the same question was asked to other participants in the individual interviews.

Interview results with senior teachers

Regarding the senior teachers it was found that many of them were new in their positions as such they could not ascertain the level of communication. Also they could not provide records of such communication. Based on this evidence it was concluded that communication was not clear. Similarly for teachers, it was noted from their responses that they had a mixed reaction about the level of awareness about the change. The following statements illustrate this mixed reaction:

> "I was not around at the time"
>
> "I was not at senior when it was changed"
>
> "Heard over the media about the transition"
>
> "Never informed; I was never consulted; Never took part in any"
>
> "About communication, I do not have information because I was still schooling"

Interview results with officials in the Ministry of Education

The remarks by the Permanent Secretary in the MOESD suggested that production of the BGCSE D&T curriculum was: "*the outcome of a great deal of professional consultation and collaboration*" (BGCSE D&T Teaching Syllabus, 2000, p.ii). However, the responses from the senior officers suggested that the communication regarding the change was not effective.

Results of document review

Document review was also done to validate the responses. For the validation, the main reference documents used were the report of the National Commission on Education (1993) and the RNPE (1994). The findings in terms of the review of government documents revealed that the decision by the government of Botswana to move away from Cambridge was a policy matter, which stemmed from the recommendation of the NCE. In 1992, a presidential commission was set up to identify an education system that is relevant and responsive to the socio-economic needs of the country. This commission led the production of an education policy document known as the RNPE (1994). Following the recommendation of the RNPE, D&T was identified as one of the key subjects needed for the country "to move away from the traditional agro-based economy to the more broadly based industrial economy the country" (Permanent Secretary, MOESD, 2000). It was recommended for all students from Junior to senior secondary school level (Republic of Botswana, 1994).

Capacity for change

The capacity for change was assessed in terms of the leadership at all levels, provision of resources (physical and funding) and teachers' profesional development. This part required participants to comment on the kinds of support they had received to prepare them for the change. It was focused mainly on the teachers by as the implementers. In the teacher questionnaire, a rating scale shown below was used to measure their perceptions.

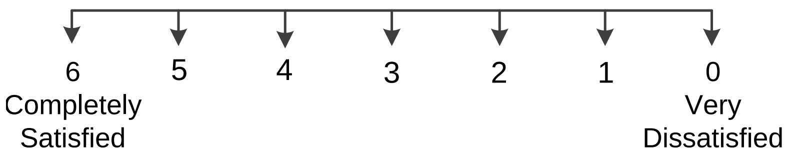

Figure 3 presents the findings based on teachers' perceptions.

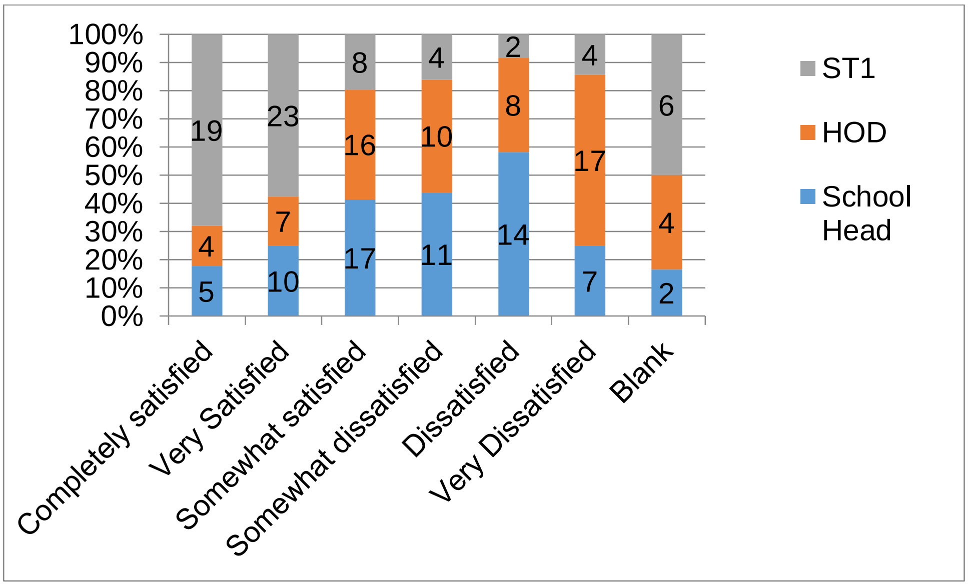

Figure 3: Teachers' perceptions of administrative support

The results showed that the majority (64%) of respondents reported *very satisfied to completely satisfied* with the support received from their senior teachers. While for the school heads and HODs, the results showed a fairly even spread and perhaps suggest that situations in schools are different.

A similar question asked the senior teachers to share their views on the level of support they received from their school heads. Figure 4 presents these findings.

"I don't think we are getting any support from anybody. I don't think they have the interest of the students at heart. The only time they talk to us is during results analysis" (ST1).

"Practical subjects are headed by a scientist. Though I would say it's not bad, sometimes you need someone with a similar background. Nobody understands the issues we are facing in the department" (ST2).

"I would say the current Head is very supportive" (ST3).

"There is really not enough support, so the support in short is really lacking. Regional support; there is not much support" (ST4).

"I would say the school head is trying; whenever we have a challenge, we get to him and he writes a letter to the Ministry. Regional office: There is no support at the moment" (ST5).

"There is some willingness" (ST6).

"I would say that I am really on my own, they are just confined to their offices in the administration" (ST7).

"Frankly speaking, I do not get support from the administration. I don't see them in the department; it doesn't only happen in D&T, it also happens in Home economics" (ST8).

Figure 4: Senior teachers' perceptions on administrative support

Regarding administrative support at school level, data collected from senior teachers showed a split reaction. The majority (5 out of 8) reported that school heads were less supportive (ST1; ST2; ST4, ST7; ST8). The remainder appreciated efforts made by their school heads (ST3; ST5; ST6). Overall the findings show varying experiences and indeed mixed feelings about administrative support at school level.

At regional level, the officers cited many challenges as follows:

"The support from management; they see D&T as a failing subject and yet expensive" (INSETOFF1).

"The reality is it is very difficult to get to higher offices. I think they are limited in knowing what is happening in the D&T department. We have recommended such things as in-service training, but that has not happened" (INSETOFF2).

"I'm really having it tough, I'm not making any breakthrough" (INSETOFF 4).

In terms of their working relationship with their superiors in the regions, the findings suggest a rather gloomy picture. The officers decried the lack of support from their superiors. Whereas, in terms of funding for the subject, the officers attributed limited funding for D&T to lack of knowledge by the authorities in terms of what the subject entailed. They also accused the management for lack of action on their recommendations. Another reason advanced was that the management could not justify spending more money on a subject which was perceived to be producing poor results (PEOFF1; PEOFF2).

Provision of in-service support to the teachers

The next section presents the findings in respect of the effectiveness of the current teacher support system. The question was addressed to all the participants with some slight alterations to suit their context. A scale similar to the one show is section 4.5 was used. Figure 8 summaries teachers' perception regarding the current in-service support system.

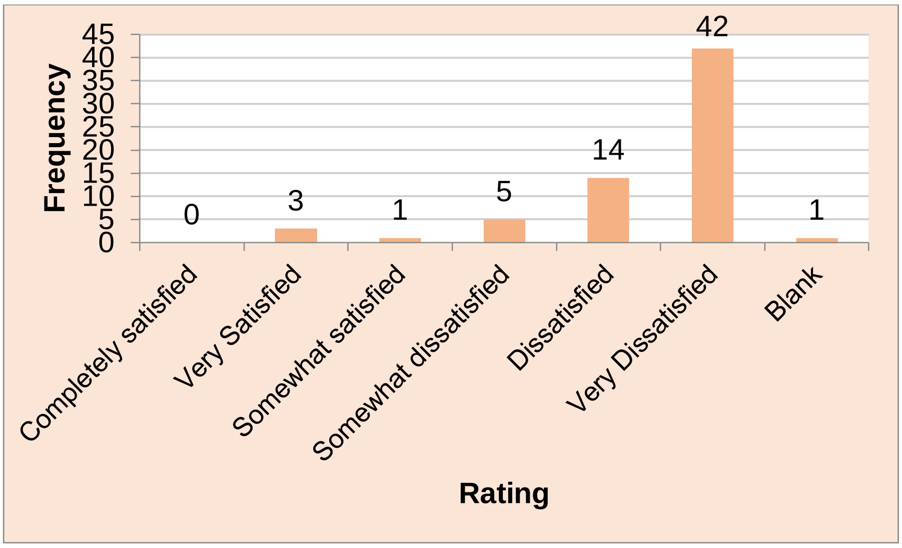

Figure 5: Level of satisfaction with provision of INSET support

According to the scale used the results show that forty-two (64%) of respondents were *very dissatisfied* with the current teacher support system. A combined total of *somewhat dissatisfied* and *dissatisfied* is nineteen (19), this represent 29%. The remainder (6%) reported *somewhat satisfied* and *very satisfied* with the system respectively. Missing in the data are those *completely satisfied.* An overall the majority of the respondents (93%) were very dissatisfied with the current teacher support system.

A similar question was addressed to in-service officers. The following extracts illustrate their perceptions. Figure 6 captures the perceptions of in-service support to the teachers.

> *"We try to support teachers, unfortunately when they get back to schools, they don't have materials try with and engage students. I also do research on how we can simplify things for them. I'm not competent in all the areas"* (INSETOFF1).
>
> *"I'm sorry to say for the 3 years that I have been in the office, we have carried out school inspection, we have recommended such things as in-service training, but that has not happened. In our schedule, there isn't much time to find a slot to conduct a workshop. We have had a workshop, but we haven't had any follow-up. I think that is the part that is lacking"* (INSETOFF2).
>
> *"It's not that effective, looking at the area, the size. The region is wide and the schools are far apart.. Some schools are not easy to reach"* (INSETOFF3).
>
> *"Schools are playing a minor role in staff development. We should be getting support from staff development officers, but of late focusing more on PMS. There are follow-ups, though we are hampered by lack of transport. We haven't conducted a workshop that goes into 2 weeks. One week is not enough because it forces me to run through issues"* (INSETOFF4).

Figure 6: In-service officers' perspectives about the level of support to teachers

Discussion

In this section we discuss a summary of the major findings and of the principal issues and suggestions which have arisen from this study and literature review.

After three decades of following the British education system, a need was felt to localise the secondary education curriculum, with the aim of making it more relevant to Botswana's strategic vision for human resource development and economic growth. In terms of Botswana's vision for technology education, the underpinning philosophy for the development of this curriculum was to prepare children, who are the future work force for transformation from an agro-based economy to an industrial economy consistent with technological and global changes (Republic of Botswana, 1994; Republic of Botswana, 2009). With this vision in mind, when the D&T curriculum was being developed attempts were made to include new learning areas such as electronics, pneumatics, CAD/CAM and ICT. However, upon implementation a number of challenges were encountered. The next sections will outline some of the challenges which impeded the implementation of the BGCSE D&T curriculum.

Implementation strategy

In localising technology education curriculum in Botswana, teachers grappled with the benefits it brought, and faced some challenges in the delivery of the curriculum. The benefits included the contextualised setups and content which enabled teachers to relate the curriculum to their local environment.

When embarking on large scale reforms like the localization of a national curriculum, it is recommended that the change be broken down and piloted before full implementation (Kotter, 1996). Piloting helps to identify problems on a scale and enables corrective measures to be put in place before full scale implementation (Fullan, 1993; Fullan, 2001). However, in terms of the implementation of the BGCSE D&T curriculum we observed that unlike the Cambridge which was piloted in five schools before full implementation, the BGCSE one was implemented fully from the start.

Communication strategy

The communication is problematic issue when one considers that most organisational structures, particularly those in education, tend to operate within a pyramidal management system (Tabulawa, 2009). For example, Bush and Middlewood (2005) observed that this management style can hinder effective communication. In a similar way, Fullan (2001) notes that often such pyramidal structures act as impediments to change.

Additionally, outside consultants or collaborators can be brought in to add mirror to the discussion and highlight the necessity for change to occur. This will establish a sense of urgency within the organisation and create a consensus.

Leadership and administrative support

Studies have shown that the context in which the change takes place, combined with limited implementation capability, employee resistance and limited resources often act as barriers to change (Hiatt and Creasey, 2012; Hiatt, 2006; Fullan, 2001; Kotter, 1996). To succeed in this kind of environment requires organisations to build the necessary change management capability which would enable them to drive these reforms forward. However, it has been observed that often change initiatives are poorly managed, not well resourced and not seen through by the sponsor (ibid).

In terms of administrative support a major constraint cited in the data was that of provision of resources to enable teachers to deliver new content areas. It was reported that the government committed to providing mainly the physical infrastructure, but there were delays providing the necessary equipment. In some cases equipment was supplied but was not commissioned. In other instances, equipment was supplied especially CAD/CAM equipment, unfortunately, in all the schools that participated in this research, the equipment was lying idle. When investigating reasons why the machines were not being used, the teachers claimed that the software that operated the machines was not user-friendly. The other challenge cited was that the machines had some electrical wiring problems. This finding suggests that because of limited teacher expertise in CAD/CAM and lack of equipment for pneumatics, these content areas were not widely taught in secondary schools.

Teacher capability

From this research, we observed that many of the implementation challenges identified were related to *knowledge* and *ability* elements of the ADKAR change model. According to the ADKAR model, if *knowledge* is the area identified as a barrier to change, then education and training are recommended to help develop the skills and behaviours needed by the change (Hiatt, 2006; Hiatt and Creasey, 2012). Likewise, if the area identified is *ability*, it is recommended that ongoing coaching and support will be needed as well as time to develop new abilities. The technology area seems to be a threat to many teachers who lacked competency in some new content areas such as electronics, pneumatics and CAD/CAM.

Teacher support system

In the case of Botswana, limited knowledge and ability to deliver the curriculum can be attributed to gaps in initial teacher training, ineffective in-service support system and inadequate provision of teaching and learning resources in schools. This limited capacity to implement leads us to the conclusion that the way the existing curriculum is delivered in schools provides little scope for developing student technological knowledge and capabilities as espoused in the RNPE. This situation suggests that this curriculum remains rooted in its former CDT status.

Sustainability of change

To ensure that change is sustained, mechanisms must be put in place to consolidate the effort (Fullan, 2001; Hiatt and Creasey, 2012). Some writers (e.g. Hiatt and Creasey, 2012; Hiatt, 2006; Fullan, 2005) have argued that employee training and provision of resources can help increase organisational capacity to handle new change. Others (see Kotter, 2012; Morrison, 1998) suggest that one way of ensuring that change is sustained is by developing a succession plan such that change agents and leaders would be regularly added to organisation's change coalition. In Botswana it was observed that some officers retired from the service and it took a long time for their positions to be filled. This created a leadership vacuum in the system. However, those efforts alone will not suffice; unless measures are instituted to ensure that change is entrenched into the organisational culture. Additionally, periodic reviews would help to identify problems in the change process as they occur (Kotter, 1996).

Teacher professional development support

One of the mechanisms for sustaining change is through continuous teacher professional development (TPD). The goal of TPD is to *"prepare teachers to enact the curriculum appropriately for its design in their classrooms"* (Fishman et al, 2003, p.5). Petrie (2012) indicates that "professional development for teachers is recognised as a key vehicle through which to improve teaching which in turn will help improve student achievement. OECD[8] (2005) emphasised that effective professional development *"is*

[8] Organisation for Economic Cooperation and Development (OECD)

on-going, includes training, practice and feedback, and provides adequate time and follow-up support" (p.49).

A large and growing body of literature has underscored the notion that teachers are an integral part curriculum change because of their role as implementers (Fullan, 1993; Morrison, 1998; Whitaker, 1993; Morrision, 1998; Fullan, 2001; Durrant and Holden, 2006; Welch and Mueller, 2003; Villegas-Reimers, 2003). As such they are an essential part of the implementation strategy. Unfortunately as Canavan and Doherty (2007, p.292) observed that *"curriculum development has not always been matched with appropriate support through staff development or rigorous consultation with stakeholders"*. At school level, Bennett et al (1992) notes that the principal has a strong influence in terms of *"whether a change is to be taken seriously by supporting teachers both psychologically and with the resources"* (p.117).

Regular and timely teacher professional development support would ensure that people do not return to their old ways of doing things. This view is also supported by Bourne and Bourne (2012) who write that: *"most change efforts fail because people revert to their old ways rather than get stuck in the new ways"* (p.13).

In the case of Botswana, the lack of continuous teacher professional development was reported as one of the factors that has contributed to the teachers' deficiency in delivering the localised curriculum. For example, it was reported that there were only four in-service officers operating in a total of ten regions. This limited number of in-service officers on the ground suggests that some regions did not have any have in-service officer. In some cases, it was reported that some regions were too large to be managed by one officer.

Conclusions and Recommendations

Change is a constant feature in any organisation because the driving forces that influence an organisation's operations are continually and inevitably changing. Any change regardless of size and scope, requires a clear vision; implementation strategy; sustained administrative support and a powerful guiding coalition to drive it forward. It has been found that, if empowered with knowledge and resources, individuals in an organisation are a vital resource and change agents (Hiatt and Creasey, 2012; Hiatt, 2006). In the case of curriculum change, it has been found that it is only when teachers, who are the implementers, accept change in the first place and get involved personally from the start that effective change will be achieved (Hargreaves, 2005; Fullan, 2001; Lachiver and Tardif, 2002). This underscores the notion that teacher participation in the curriculum reform process and their teacher professional development should never be overlooked.

ADKAR change model used in this research possesses great potential as a measurement instrument. Since the model describes the required elements for a successful change, it can be a powerful measuring stick to evaluate if change management activities are having the desired results. In this manner, ADKAR provides a lens through which an organisation can diagnose the barrier points in change management. Indeed, it aligned well with the objectives of this research which sought to identify and validate key factors affecting the implementation of the BGCSE D&T curriculum.

Finally, it has been observed that great changes require a powerful arm of the government working in collaboration with other key stakeholders to push them forward. Therefore, what is needed going forward in terms of future curriculum reforms is a sponsor road map. This road map is an outline of the specific actions that the government will undertake to sponsor the change. The government's role should not be seen as just signing cheques. Rather the government should be the face and voice of change through active and visible participation throughout the change process. Otherwise as observed by Kotter (2012) that: "new initiatives fail far too often when employees, even though they embrace a new vision, feel disempowered by huge obstacles in their paths" (p.10).

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Beyond Enquiry: Towards an Explicitly Creative STEM

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Abstract

Creativity is identified as a key economic driver and STEM education is increasingly looked upon for providing the fuel. STEM and creativity are often paired together as a matter of course, but this assumption needs checking. A common model for teaching STEM is inquiry-based learning, and it is often assumed that it encourages creativity. A *creative* STEM however needs to go beyond enquiry as a mode of learning and engage students in conjectural learning. To put creativity on the agenda, consideration also needs to be given to whether it is even teachable given the idea that it may just be innate. Here it is helpful to understand creativity as attitudinal. This paper explores the teachability of creativity and questions the capacity for enquiry based learning to deliver an explicitly creative STEM.

This is about creativity, how it may be taught, and how it can have a good home in STEM. By STEM I mean the grouping of science, technology, engineering and mathematics as integrated disciplines working together in project based work in a secondary education setting. Subject specific content is called upon as needed to build knowledge around the completion of a project. The success of STEM is in how powerfully content is contextualised. STEM has a number of variants and part of the effect of it being multidisciplinary is that there are many different approaches. Even with the range of approaches, creativity should be on the agenda.

STEM, the new opportunity for creativity

The word ‘creativity’ is finding currency in some unexpected places. Twenty years ago creativity did not have such a high profile. But now even for industries like finance, investment, scientific research, law and retail, it is no longer a fringe concept. Creativity is now seen as necessary for competitive advantage and, on a larger scale, a key economic driver. Now we even aspire to be a ‘creative economy’. And like most OECD countries we are actually doing it. From 2006 to 2011 the growth in creative jobs in Australia was 40% higher than the workforce average (ARC Centre of Excellence for Creative Industries and Innovation, 2013).

Digging deeper into the data there is a more interesting story. In this report creative jobs were divided into those involved in ‘cultural production’ (traditional art products, books, music etc.), and those in creative services industries (product design, IT solutions, digital technologies etc.). Notably, jobs in cultural production actually lagged behind the workforce average - it was the creative services industries that really drove the growth in creative jobs. And these are the jobs most closely linked with STEM education, which accounts for all the attention STEM is getting.

It is fascinating and heartening to see the new premium placed on creativity as it finds a home across a range of industries that want to be part of the ‘creative economy’. And now STEM education is seen as a strategic player. This is exciting, but it is something of a large burden to carry – to provide the creative workers of the future.

What premium do we place on creativity in secondary education? We know that the best time to flex your creativity is in childhood as attested by the value we place on subjects like art, music and performing arts. However for the economic rationalist, the real jobs growth is in the creative jobs with a STEM base. STEM is the new opportunity for creativity.

Enquiry based learning and STEM

We should expect creativity to find an easy home in STEM and the link is often extended so that STEM is assumed to be creative by definition. This is a mistake easily made in the excitement that comes with 'cool technology'. Giving students great technology to work with is an indicator that something creative might be happening, but it is not the same as creativity itself. And there is a second subtler mistake. Delivering a creative lesson means that the teacher has been creative, but it doesn't necessarily equate to creative student outcomes. This is why enquiry based learning appears to fit the bill for STEM. It requires a creative delivery, it has the right look.

Enquiry based learning has its home in science whose main concern is to understand the world. Students are encouraged to be open to wonder, building their own knowledge of their world. It is a very natural way of learning, and the teacher becomes more of a guide.

> The tutor establishes the task and supports or facilitates the process, but the students pursue their own lines of enquiry, draw on their existing knowledge and identify the consequent learning needs. They seek evidence to support their ideas and take responsibility for analysing and presenting this appropriately (Kahn & O'Rourke, 2004)

Enquiry based learning is attractive because of what it is replacing. The directed learning model so effective in the education revolution of the 1800s required students to listen, absorb and repeat information. This has been the default mode of teaching for 200 years and most of us know it well. On the whole it has limited applicability for STEM. The antidote is inquiry-based learning. Rather than students learn what someone *else* has found out, they engage with the real world to find it out for themselves. This is a refreshing leap forward with profound consequences on how classes are taught. Inquiry based learning now has a significant presence, nevertheless we should be unafraid to ask: is it the best model for teaching creativity?

If we want *creative* STEM, then we need to go beyond enquiry. Enquiry based learning is good at firing up curiosity and engagement, but the best way to model and nurture creative attitudes is through what I call conjectural learning. Where enquiry is about learning how the world is, conjecture asks what the world *could* be like. Where enquiry is about learning through interacting directly with the physical world, conjectural learning asks that students *do* something with what they have found out.

And by *doing something,* I refer to solving problems by designing and making. The richness of the making experience is the litmus test for creativity in STEM.

Directed learning is efficient, enquiry-based learning is engaging, but neither asks enough if our goal is student creativity. Here we should not shy away from the notion of teaching creativity.

Creativity

We tend to believe in an innate human creative ability, and for good reason: creativity has made our species incredibly successful. We are the builders, the dreamers, the tool-makers. Creativity is our species most defining trait. This is thanks to our outstanding prefrontal cortex, the part of the brain that helps us wonder what might happen if…. It is how we can imagine different futures. If creativity is innate, that is genetically hard wired, then the notion of teaching creativity becomes interesting.

It turns out that innateness is not as readily accepted as a stand-alone concept as it once was. Consider the difference between early anatomically modern human and the current behaviorally modern human dramatic. There has been a profound transformation, albeit not physical. While there is no genetic change the difference is accounted for by cultural transmission where each generation builds on the cultural learning of the previous one. This is described as the 'cultural ratchet' effect (Brockman, 2015). It's through cultural transmission that our most valued human characteristics have been built. This brings into question the idea of innateness.

Epigenetics muddies the waters further. The concept of innateness is based on the primacy of the genome, but now that the epigenome is better understood this is in question. It is the epigenome which determines gene *expression,* and this is what ultimately leads to traits (Weaver, 2004). So, while creativity may be somehow genetic, it is genetic expression that plays a bigger role. The big news is that the epigenome is not fixed, it can be affected by the environment. This has to inform our understanding of what we consider an innate ability.

So here I make a distinction between capacity and ability. Whilst there may well be overall innate capacity for creativity within each of us, it may be unrealized, expressed merely as a tendency. Creative *ability* needs to be fired up. We have not lost our creative capacity, it's just that our creative ability is not being stretched like it once was.

To explain: The world we live in now is very different to the world our species became successful in. For most of human history our species survived in a world where there wasn't TV, internet, economic meltdowns, or fake news. There was just one thing – survival. This was what our psychologies evolved for.

It was our social interaction and our creativity that made our species successful and brought us to where we are today. But once where creativity was a survival trait it has now become something different - an advancement trait. We are using it for a different purpose. Advancement does not necessarily compel creativity like survival once did. And so we haven't lost our creativity, it is still within us, but it just isn't being put to the ultimate test that is survival.

We hear a lot about food in this survivalist context. Thousands of years ago it was a good idea to eat as much sugar and carbohydrates as possible because you did not know when the opportunity would come again. It was a matter of survival. This food is now plentiful, as evidenced in the fast food phenomenon, but we have not suppressed our natural cravings, which incidentally no longer serve us so well anymore. Just as our appetite is piqued by the smell of French fries in an atavistic survival response, we are also tuned to enjoy being creative. As a teacher there were times that my younger classes would give up recess time to try to get into class earlier. This was also an atavistic response, the pull of the creative opportunity – they could (metaphorically) smell the French fries.

Teaching creativity

Creativity arguably does need to be taught, but it is a different beast to any content.

Birds fly, we think of this as an innate ability. Do they learn it? Maybe not, but they do need to be encouraged. They see their parents fly, so they get a fair idea of what is required of them. Flying is modeled, and by inference expected. Then at the right time it is required. Reluctant birds may even get pushed out of the nest. On its first flight from the nest, the young wandering albatross does not touch land for two years. However some birds' first flight is not as successful, and yet once they have the hang of it, we say they have an innate ability.

There are lessons we can learn from the bird in how we teach what is an innate capacity.

Firstly it needs to be modeled. Modeling is the most powerful teaching strategy in our tool kit. How we engage with the subject will become how our students engage with the subject. If we model curiosity, our students will be curious. If we are solving problems by making things then our students will do that too. When Design and Technology teachers make their own projects, they are modeling. This is the kind of authenticity that students crave. The second lesson from the bird is that, we should explicitly expect creativity, and sometimes we even need to give students a push. The last lesson is that there will be failures, but we accept this as a necessary part of the journey to success.

So even though creativity may to some extent innate, we *can* teach it. Not in a content specific way - it can never be a chapter in a book. We could treat it as a skill to methodically develop, but this would kill it. I propose understanding creativity as a group of attitudes.

A creative attitude

On a recent visit to Ulaanbaatar (Mongolia), I was struck at how differently people lived, and this was manifested in their built environment (I didn't expect to see yurts in suburbia). It was all foreign to me, but completely normal to the locals. This is the joy and challenge of travel – you get to see someone else's normal and by this compelled to ask questions of myself and of the world around me. My attitudes change as I rethink my idea of what is normal.

This is an interesting position to be in – to have your idea of *normal* questioned. When we allow ourselves to question the unquestioned, to let go of normal, then this is where we will have our most creative insights into what the world *could* be like. The question of 'why' extends to a question of 'how'. Why is the world like this? - How could it be different? Isn't this what we want from our students – to ask these exact questions? It resonates with the goals of Design and Technology and STEM education: to help students envisage and create the future.

So perhaps one of the key ways to teach creativity is to metaphorically 'land students in foreign places'. Just as I am challenged and stimulated when I visit another country, teachers need to expose their students to alternative 'normals'.

Give a student a pen and paper and ask them to design a table lamp they usually draw a lamp they have at home. Even though asked for *their* design, they are trapped by their own notion of normality. It is this patterned thinking that teachers can challenge by exposing their students to examples of lamp designs that are far from their normal, to 'take them to a foreign land'. Students need to re-learn what a lamp *could* be.

We do not have to travel, but our job as teachers is to take students on a journey, to make the world a bigger place, to expose them to ideas that lie beyond their normal. That is when students ask good questions, like *why?* and *how*?

This is one example of an attitude of creativity. My bigger list is:

- Looking at the world in a different way,
- Curiosity
- Being prepared to challenge what is normal
- A belief that there is no such thing as useless information.
- Asking questions (why, what if, and how)
- Never really being satisfied
- Embracing change, wanting to be an agent of change
- Entrepreneurship
- Readiness to learn new skills. Saying: "I can give that a go"
- Accepting that it is OK not to fully understand a concept for it to be of value – sometimes it is OK just to know *about* concepts.
- Accepting failure as necessary for success

Attitudes are the unsung hero of education. We tend not to talk about attitudes much – they are too easily eclipsed by our concern with skills. Attitudes can't be taught in a programmed way, there is no chapter to turn to. They are not examinable – too hard to put a number next to, and for the reductivist, if it's not measurable then it's not valued. But they are possibly an education's most enduring endowment.

At school I did a reasonably high level of maths – I was good at it. I didn't enjoy it and I didn't really stop to think if it was doing me any good. Years later I look back at the maths I used to do, and I have no idea now how I was able to do most of it. It is beyond my present ability. I have lost my maths because I don't use it – nothing over a year 9 level on a daily basis. This is probably true for most people, and yet almost everyone does maths at school. Why? Because we somehow know that it is good for us, even though its relevance is not always clear. In fact the best case for maths is often the getting of marks. We are told that maths is good for us and that is enough – and they are right. The maths I no longer use, although of questionable relevance, I now strongly believe was good for me.

It turns out that even though I don't use a lot of maths – I love it. I'm not that good at it, but I love what it can do, how it matches reality, how it is true for all time – there is a kind of beauty to it. I read books on popular mathematics. Many concepts I don't understand, but I don't let that stop me from enjoying the worlds other people have insights to. My maths education left me with few enduring skills, but what it really did was help me look at the world in a certain way. It gave me an attitude that made me receptive to mathematical ideas. And so now I look at the beauty of a tree and think fractals, the functionality of a bridge and think forces, traffic flow and think phases of matter, not to mention the mysteries of prime numbers. Maths has changed the way I think, it has made the world a more interesting place and it has enriched my life. Well done maths.

Of course this phenomenon is not special to maths, the same must be able to be said of every subject including Design and Technology subjects – that it changes the way students think, that it helps students to look at the world a certain way, and in doing so it enriches their lives. Here we see cultural transmission at work and it is not a process of knowledge transfer, but of attitudes. Attitudes just slip in, usually taught by default. But attitudes are a 'slow burner'. Skills will need to be updated. Knowledge is harder to grasp as information becomes too vast to remember. Then there is attitude. Attitudes are global, enduring, transportable, and ultimately enriching. It is attitude that actually solves the problem of obsolete knowledge and outdated skills. Employers know this well when they say: "hire for attitude, train for skills".

In STEM education the knowledge and skills we impart have obvious usefulness and so we tend to play this as our trump card, it's what makes us relevant, even our reason for existing. But in our desire to prepare students for the 'jobs of the future' remember that job fluidity requires workers to be nimble as their careers span different industries. The effect is that precise knowledge and skills are going to be less important. The relevance of STEM therefore is not merely in knowledge and skills – attitudes will play a big role.

To teach students creativity is to teach attitudes and the most powerful method is by modeling. The way we teach our subject says a lot about how we value it and in turn this will impact the way students respond to the subject. Reflecting on my own teaching practice, I know that some of my attitudes have transferred to my students. I hope this is what they experienced in my classroom:

- failure valued as part of the creative process;
- that there is no information not worth knowing;
- you don't need to fully understand a concept for it to be worth knowing about;
- ideas from many disciplines can blend together;
- outcomes measured not by a final mark, but by the process used;
- there is no such thing as irrelevant information;
- the teacher does not always know the answer;
- whatever is *normal* is challenged.

In a perfect world it would be good for every classroom to be like this, where the free inquiring mind is valued over the rigid requirement of getting the right answers. It's not going to happen, but each school should have one classroom like this, and may it be a STEM classroom.

Conclusion

Creativity is not completely innate, it can be taught. Not as a skill, rather as a set of attitudes. Although rarely assessed, attitudes are powerful in shaping the individual student. Teachers are constantly modeling attitudes, so it is worthwhile for them to reflect on the kinds of attitudes they propagate, certainly if their aim is to teach a creative STEM.

Further to the question of how creativity can be taught in STEM is the way it is delivered. We should question the assumption that enquiry based learning provides a complete solution to teaching a STEM that claims creativity as a key student outcome. For STEM, inquiry based learning is a powerful model ticking a lot of boxes, but it is not explicitly creative. There is value in defining a model that is. I call it conjectural learning whereby problems are addressed by making (or producing) solutions through a process of proposing and testing ideas. There is nothing new here, but in the STEM world we need to give it definition so that creativity is not lost as an optional extra in enquiry based learning. Students need to wonder, solve, test and create, according with the highest goal of STEM, that is: equipping and inspiring students to change their world. Enquiry on its own looks somehow unambitious, missing the opportunity to stir creative capacity into creative ability.

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An Analysis of Students' Point of View and Criteria for Evaluation of Social Impact of Technology

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Abstract

This study aims to shed light on the evaluation perspectives and judgment criteria that junior high school students use when evaluating technologies. The question of how to cultivate junior high school students' technological literacy is important in technology education. In order to cultivate junior high school students' ability to evaluate technologies, teachers need to understand how students comprehend and judge the technologies that support our society. This study asked junior high school students to evaluate technologies that have been actively discussed in society. We then attempted to elucidate the students' point of view and judgment criteria for evaluation of technology. Our results revealed that junior high school students make decisions differently according to the technology being evaluated. Regarding their decision-making concerning a certain technology, students who answered "approval" paid attention to technological aspects, such as "Technological purpose" and "Technological vision." In contrast, students who answered "disapproval" paid attention to social aspects, such as "Economic effect on the industry" and "Resources and materials."

Keywords: Techonology Education, Evaluation of Social Impact of Technology, Point of View, Criteria, Junior High School Students, Japan

Introduction

Technology has markedly advanced in recent years, and its two-sidedness (advantages and disadvantages) has become diversified. For example, nuclear power generation and artificial intelligence possess both advantages and disadvantages. To cope with these technologies, we must be able to appropriately examine, evaluate, and use them.

In 2000, the International Technology and Engineering Educators Association defined technological literacy as the ability to understand, use, and manage the technologies that support our society (Technology for All Americans, 2000). The organization regards technological literacy as the purpose of democracy-based technology education. This idea has influenced countries around the world. Japan's national curriculum for technology education states that technology education's purpose is to cultivate the "ability and attitude of students to appropriately evaluate and use technology (MEXT, 2008)."

The learning contents of Japan's technology education include "Materials and processing," "Energy conversion," "Biology-related technology," and "Information technology." The purpose of technology education is to cultivate students' technological literacy through practical activities related to each learning content. School lessons have adopted many approaches to technological evaluation. For example, some require students to evaluate goods produced by others and to debate current technologies.

To incorporate technological evaluation as a learning activity, teachers need to understand how students comprehend and judge the technologies that support our society. Teachers must inform students of technology's two-sidedness and ask them to make decisions based on certain evaluation and judgment criteria. Regarding teachers' awareness of technology's two-sidedness, Lung-Sheng Lee and Hsiu-Chuan Yang et al. examined technology teachers' anxiety about nuclear power generation and the effect of technology's two-sidedness on technology education (Lee, L. et al, 2013). Behnam Taebi reported the importance of knowing technology's risks in order to appropriately evaluate technology (Tebi, B, 2016). These studies investigated teachers and nuclear power generation. However, no study has sufficiently investigated students' perspectives on technological evaluation and judgment criteria.

To elucidate the teaching methods used to cultivate students' ability to evaluate technologies, this study asked junior high school students to evaluate technologies that have been actively discussed in society. We attempt to elaborate on the points of view and judgment criteria on which they focus.

Methods

Subjects

This study investigated 1,893 junior high school students in Japan, securing valid responses from 1,730 students (91.4%).

Instruments

For its measurement instruments, this study used (1) items used to comprehend decision-making with regard to technology and (2) items used to comprehend students' technological evaluation points of view. In addition, we created four technological themes: Technology of utilizing wood resources, Nuclear power generation, Genetic recombination technology, andSsocial networking service (SNS). We gave one of these four themes to each subject.

Items used to comprehend decision-making with regard to technology

(1) Technology of utilizing wood resources

(2) Nuclear power generation

(3) Genetic recombination technology

(4) Social networking service

We set the "social role," "advantages and disadvantages," and "approval and disapproval in public opinion" criteria for these technologies and asked the subjects, "What do you think about the future use of this technology?" For the answers, we provided six options: "immediately stop using," "gradually reduce using," "gradually increase using," "rapidly increase using," "conflicted," and "undetermined."

Items used to comprehend the technological evaluation point of view

To comprehend students' evaluation point of view when making a decision about technology, we used the technological evaluation point of view created by Moriyama et al (Moriyama, J. et al, 2004). This point of view consists of the following items: Scientific principle, Background of science's history, Technological purpose, Operational restrictions, Alternative technology, Background in technology's history, Technological vision, Controllability by humans, Resources and materials, Accident risks and cases, Needs, Public opinion, Economic effect on the industry, Legal regulations and guidelines, Involvement in environmental issues, and Effect on the production, Distribution, and Consumption systems. The students were asked to select one of four options when they made a decision about a technology, which had been given to them as the theme. The four options were: "4: I considered it a lot," "3: I considered it a little," "2: I barely considered it," and "1: I did not consider it at all."

Procedures

After the investigation was completed, we calculated the decision-making ratio for each technology, as well as the mean value and standard deviation (SD) of each item in the technological evaluation point of view. To compare each item's mean value according to decision-making type (approval, disapproval, and conflicted), we performed analysis of variance (ANOVA).

Results

Ratios for the decision-making types

Table 1 shows the ratios of students who answered "approval," "conflicted," "disapproval," and "undetermined" for each item of the technological evaluation point of view.

Table 1. The ratios of "approval," "conflicted," "disapproval"

	Approval (n=363)		Conflicted (n=364)		Disapproval (n=966)		Undetermined (n=37)		Total (n=1730)	
	total	ratio	total	ratio	total	ratio	total	ratio	total	ratio
Technology of utilizing wood resources	40	9.5%(-)	46	10.9%(-)	332	78.9%(+)	3	0.70%	421	100.00%
Nuclear power generation	76	16.5%(-)	56	12.2%(-)	312	67.8%(+)	16	3.50%	460	100.00%
Genetic recombination technology	135	31.0%(+)	77	17.7%	212	48.6%(-)	12	2.80%	436	100.00%
Social networking service	112	27.1%(+)	185	44.8%(+)	110	26.6%(-)	6	1.50%	413	100.00%
Total	363	21.0%	364	21.0%	966	55.8%	37	2.10%	1730	100.00%

$\chi^2_{(9)}$=338.18**

(+)In the residual analysis results, significantly high frequency occurs at the level below 1%.

(-)In the residual analysis results, significantly low frequency occurs at the level below 1%.

As Table 1 shows, for "Technology of utilizing wood resources," the ratios of students who answered "approval," "conflicted," "disapproval," and "undetermined" were 9.5%, 10.9%, 78.9%, and 0.7%, respectively. For "Nuclear power generation," the ratios were 16.5%, 12.2%, 67.8%, and 3.5%, respectively. For "Genetic recombination technology," the ratios were 31.0%, 17.7%, 48.6%, and 2.8%, respectively. For "Social networking service," the ratios were 27.1%, 44.8%, 26.6%, and 1.5%, respectively.

The chi-square test revealed significant bias in the ratio of each decision-making type among the items of the technological evaluation points of view ($\chi^2_{(9)} = 338.18$, $p < .05$). The residual analysis revealed that the ratio of students who answered "approval" was highest in Genetic recombination technology, while the ratio of those who answered "disapproval" was highest in Technology of utilizing wood resources. The ratio of students who answered "conflicted" was highest in Social networking service.

Students can purchase crops produced using Genetic recombination technology at supermarkets and other places. Students also use Social networking service. However, students have difficulty judging the usefulness of Nuclear power generation and Technology of utilizing wood resources, with which they have little or no experience. Therefore, we expected students' decision-making to vary according to the evaluated technology's characteristics and purpose. In the next section, we will examine the technological evaluation point of view that affects the types of decision-making (approval, conflicted, and disapproval).

Comparison of the technological evaluation points of view among students who answered "approval," "conflicted," and "disapproval."

We calculated the mean value and SD of each item of the technological evaluation points of view, which are shown in Figure 1. The mean values of "Technological purpose" and "Operational restrictions," were the highest (3.29), whereas those of "Background of science's history" and "Background in technology's history" were the lowest (2.06). To compare each item's mean value among students with different decision-making types, we performed ANOVA and Tukey's multiple comparison test. In this study, students who answered "approval" were referred to as the approval group, students who answered "conflicted" were referred to as the conflicted group, and students who answered "disapproval" were referred to as the disapproval group.

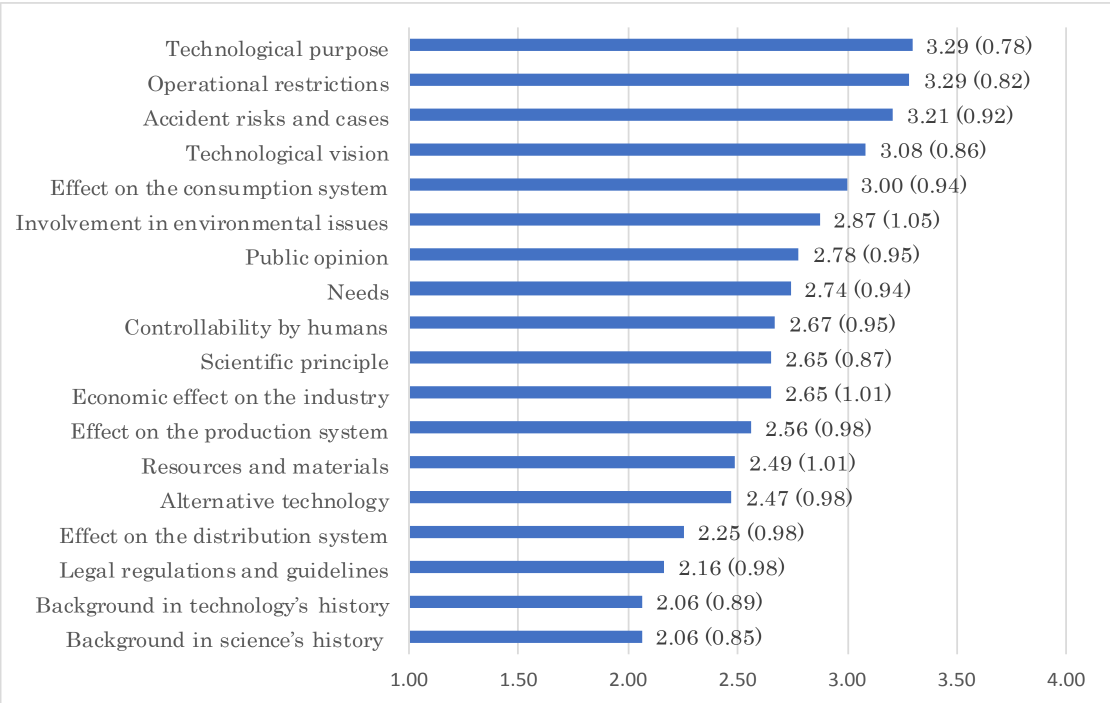
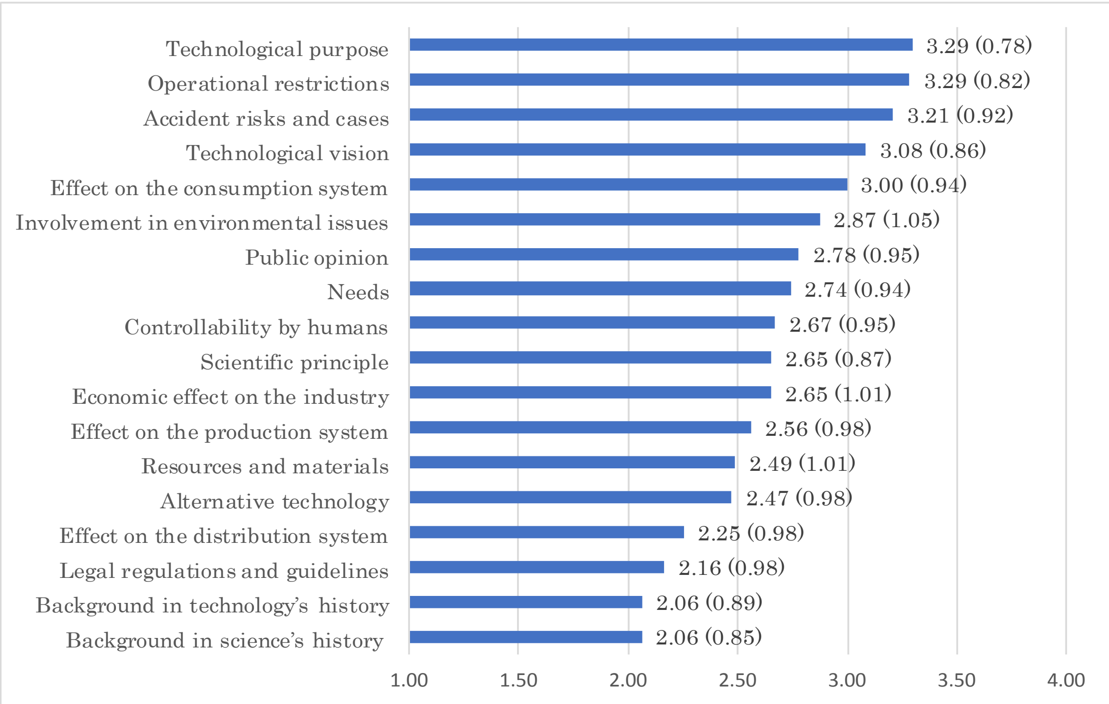


Figure 1. Mean value (SD) of each item if the technological evaluation points of view

Table 2 shows the comparison results. Significant differences were observed in 11 of the 18 items. These items were: “Scientific principle,” “Background of science’s history,” “Technological purpose,” “Alternative technology,” “Background in technology’s history,”

Table 2. Results of ANOVA



Technological evaluation points of view	Approval (n=363)		Conflicted (n=364)		Disapproval (n=966)		ANOVA		Tukey
	Mean	SD	Mean	SD	Mean	SD			
Scientific principle	2.76	0.88	2.66	0.85	2.54	0.89	$F_{(2,1690)}$= 5.54	**	B<A
Background in science's history	2.17	0.91	2.10	0.85	1.92	0.80	$F_{(2,1690)}$= 8.65	**	B<A=C
Technological purpose	3.38	0.78	3.19	0.79	3.30	0.78	$F_{(2,1690)}$= 8.44	**	C<A
Operational restrictions	3.29	0.86	3.26	0.82	3.30	0.78	$F_{(2,1690)}$= 0.49	ns	
Alternative technology	2.37	0.96	2.67	1.01	2.39	0.97	$F_{(2,1690)}$= 17.8	**	B=A<C
Background in technology's history	2.15	0.97	2.08	0.87	1.96	0.82	$F_{(2,1690)}$= 4.41	*	B<A
Technological vision	3.23	0.87	3.05	0.87	2.98	0.85	$F_{(2,1690)}$= 8.19	**	B=C<A
Controllability by humans	2.73	1.02	2.68	0.94	2.60	0.90	$F_{(2,1690)}$= 1.58	ns	
Resources and materials	2.43	1.02	2.73	1.00	2.30	1.01	$F_{(2,1690)}$= 29.6	**	B=A<C
Accident risks and cases	3.19	0.91	3.16	0.94	3.27	0.92	$F_{(2,1690)}$= 1.62	ns	
Needs	2.82	0.93	2.67	0.93	2.73	0.97	$F_{(2,1690)}$= 3.05	*	C<A
Public opinion	2.75	0.99	2.76	0.98	2.84	0.90	$F_{(2,1690)}$= 1.10	ns	
Economic effect on the industry	2.70	1.07	2.72	0.97	2.54	0.99	$F_{(2,1690)}$= 4.47	*	B<C
Legal regulations and guidelines	2.20	1.04	2.13	0.94	2.16	0.96	$F_{(2,1690)}$= 0.83	ns	
Involvement in environmental issue	2.78	1.13	3.22	0.94	2.61	1.08	$F_{(2,1690)}$= 59.4	**	B=A<C
Effect on the production system	2.56	1.03	2.65	0.98	2.47	0.95	$F_{(2,1690)}$= 4.82	**	B<C
Effect on the distribution system	2.28	0.97	2.29	0.94	2.19	1.02	$F_{(2,1690)}$= 1.40	ns	
Effect on the consumption system	3.04	0.94	3.03	0.93	2.93	0.95	$F_{(2,1690)}$= 1.74	ns	

p <.01** p <.05*

A:Approval B:Conflicted C:Disapproval

Figure 1. Mean value (SD) of each item if the technological evaluation points of view

"Technological vision," "Resources and materials," "Needs," "Economic effect on the industry," "Involvement in environmental issues," and "Effect on the production system." Of these 11 items, the mean values of 9 items—excluding "Technological purpose" and "Needs"—were lower in the approval group than in the conflicted and disapproval groups. The mean values of "Scientific principle," "Background of science's history," "Technological purpose," "Background in technology's history," "Needs," and "Technological vision" were higher in the approval group than in the conflicted and disapproval groups. The mean values of "Background of science's history," "Economic effect on the industry," "Alternative technology," "Resources and materials," "Involvement in environmental issues," and "Effect on the production system" were higher in the disapproval group than in the conflicted and approval groups.

Discussion

Table 3 shows the aforementioned results. As this table shows, no item had a significantly higher mean value in the conflicted group than in the approval or disapproval groups. In other words, students who paid special attention to the technological evaluation point of view belonged to the approval or disapproval groups. The mean values of “Scientific principle” and “Technological purpose” were significantly higher in the approval group than in the other two groups. Since these two items were related to technological principle and developmental perspectives, this means that the approval group tended to pay attention to technological aspects. The mean values of “Economic effect on the industry,” “Resources and materials,” and “Involvement in environmental issues” were significantly higher in the disapproval group than in the other two groups. Since these items were related to economy, resources, and environment, this means that the disapproval group tended to pay attention to social aspects.

Table 3. Point of view affecting decision-making

Point of view affecting approval	Point of view affecting conflicted	Point of view affecting disapproval
Scientific principle		Background in science’s history
Background in science’s history		Alternative technology
Technological purpose		Resources and materials
Background in technology’s history		Economic effect on the industry
Needs		Involvement in environmental issues
Technological vision		Effect on the production system

Based on these results, when technological evaluation is introduced into technology classes as a learning activity, both the “technological aspects” noticed by the approval group and the “social aspects” noticed by the disapproval group must be incorporated in order for students to evaluate technologies based on their advantages and disadvantages. For example, when students hold a debate on future usage of a certain technology, teachers should ensure the students understand both the technological and social aspects of the issue. Consequently, the students can broaden their decision-making horizons. Conversely, if teachers provide students with a particular aspect of technology, the students’ decision-making can be biased. When students consider an issue that lacks social consensus, it is important that teachers provide the issue’s technological advantages and disadvantages. As a result, the teachers will be asking students to make decisions based on rational grounds and to think deeply about the future image of technology, resulting in the cultivation of technological literacy.

Conclusion and Future Tasks

This study asked junior high school students in Japan to evaluate technologies that have been actively discussed in our society. We then attempted to elucidate their evaluation points of view and judgment criteria. The results can be summarized as follows:

1) This study asked junior high school students to evaluate Technology of utilizing wood resources, Nuclear power generation, Genetic recombination technology, and Social networking service. Regarding future use, the ratios of students who answered “approval,” “disapproval,” and “conflicted” were highest in Genetic recombination technology, Technology of utilizing wood resources, and Social networking service, respectively. This suggests that the students’ decision-making varied according to the evaluated technology’s characteristics and purpose.
2) Regarding their decision-making concerning a certain technology, the approval group tended to pay attention to technological aspects, such as “Technological purpose” and “Technological vision” Conversely, the disapproval group tended to pay attention to social aspects, such as “Involvement in environmental issues” and “Resources and materials.”

3) Based on these results, when technological evaluation is introduced into technology classes as a learning activity, it is important that teachers provide their students with the issue’s technological advantages and disadvantages.

In the future, we will examine in detail the type and aspects of technology that are evaluated, as these affect decision-making. We will also examine how to set appropriate themes for students and measures to support teachers.

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Study of Systematization for the Methods and Contents of Technology Education

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Abstract

Purpose: The purpose of this research is to select and systemize the essential elements of technology education in foreign countries and Japan.

Method: We emphasize the relationship between self and others, design and manufacturing or production, elements and whole, concreteness and abstraction, place and time, reason and sensibility, human growth and development, and others as a systemization of technology and information education. The learning of technology bases on processing as concept → design → production →evaluation and improvement. At this time, those processes repeated evaluation and modification. Theories of Jackson's Mill, Savage et al, and Standards from 1980s to 2000s in the United States are very useful to understand the concept of technology education systematically. We compare our results and these approaches from the viewpoint of technology education.

***Findings and discussion*:** Theories of these approaches has been shown the classification of the internal and external human activity as the model for the technology education curriculum. These conceptual frameworks especially consists of relationships between input and output for human processing. In addition, the methods and contents for technology education include human society with nature, learning of technology, system study of the learning process, academic progress and learning area. Those mean human activities of information processing in spiral resources utilize in problem-solving. We classify those relationships systematically.

Keywords: Systematization, Methods, Contents, Technology Education, Japan

Purpose of Technology Education

When humans want to produce things for the target, they will be to process various natural materials through actions such as processing, cultivating and building according to the law of nature. The human has been trained to follow the law of nature for a long time. Moreover, this accumulation of technological production has become the cornerstone of an idea of scientific things such as the law of nature. Thoughts which human has generated are considered to be natural objects as well. Nature thinks through human nature. Human exist as a medium of natural thinking. If we consider the existence of human as a system, we can see that human depends on two large systems, one is the external system such as nature or an artifact, and the other is human recognition system (Vries 2005).

The system consists of the elements that interact each other. The system has a hierarchical structure in both cases where an element included therein is a subsystem or where its own system itself is made as a larger system element.

The system of nature or the artifact is the system which processes physical events that are the movement of substances or energy. The recognition system treats the mental event which is an information aspect of a mental phenomenon. Human can be regarded as a natural recognition system which is an integrated body of these two systems. Attributes of these elements interact among the elements, thereby attributes of the system generate. The sum of the relationship between the attributes and elements element creates the system structure. Modern society is mostly manufactured as industrial products, from the agriculture or fishery industry that secures food for people, from various kinds of daily necessities such as clothing and other items to construction or transportation (Mitcham 1994).

Understanding of modern society, we have to grasp the things for the system. The greatest feature of human beings is their ability to have intelligence and to change the surrounding environment as their needed. One of the major objectives of technology education is the human development with the ability to make things. To make things is often used interchangeably with technology. In this case, not only processing of the materials or assembly of parts, but also manipulation of the symbols is included. If we classify two types of technology of human beings, it may be roughly divided into technology for product or technology for use. In other words, it may be called technology to create and operate a system (Mccormick 1992).

In this research, we consider the purpose of technology education as human development of ability to grasp systematically for various generation and change of things, and then we consider the methods and contents of technology education systematically (Sumi 2014).

Systematization of method of technology education

The PISA academic ability started in 2000(Ministry of Education 2015) is an indicator of new teaching methods to foster people supporting rapid technological innovation. In this survey, the children having problems are reading comprehension or the ability for descriptive problem for examining question about thinking ability, judgment ability, expressive ability and so on, and students are not able to solve problems on utilization, and improving their ability to solve problems in school education is an urgent task. In particular, this survey lists issues related to "utilization", and also "competency (as skill)" required by OECD required to utilizing not only "knowledge" and "skill" but also various psychological or social resources including skills and attitudes as well as the ability to respond to complicated requirements (as tasks) within a specific context.

The ability to respond to such requested tasks is not only ability to comprehend the reading ability, mathematical literacy, and scientific literacy which are questioned in the PISA academic achievement survey, but also ability to solve problems as a performance evaluation in a situation closer to reality. The learning to improve abilities for problem solving is rather than an exploration-type problem solving learning in science, it is instead to develop ability to solve problems according to technological literacy such as innovation or technological governance which are able to utilize in real society in order to deepen the utilization power required for mathematical literacy and scientific literacy.

We consider some of the systematic considerations for technology education of the United States of America or Japan.

2.1 Historical transition of technology education comparing Japan and U.S.A.

We will examine the method and the significance of systematic approach of technology education by comparing several examples about the historical change of technology education between Japan and U.S.A.

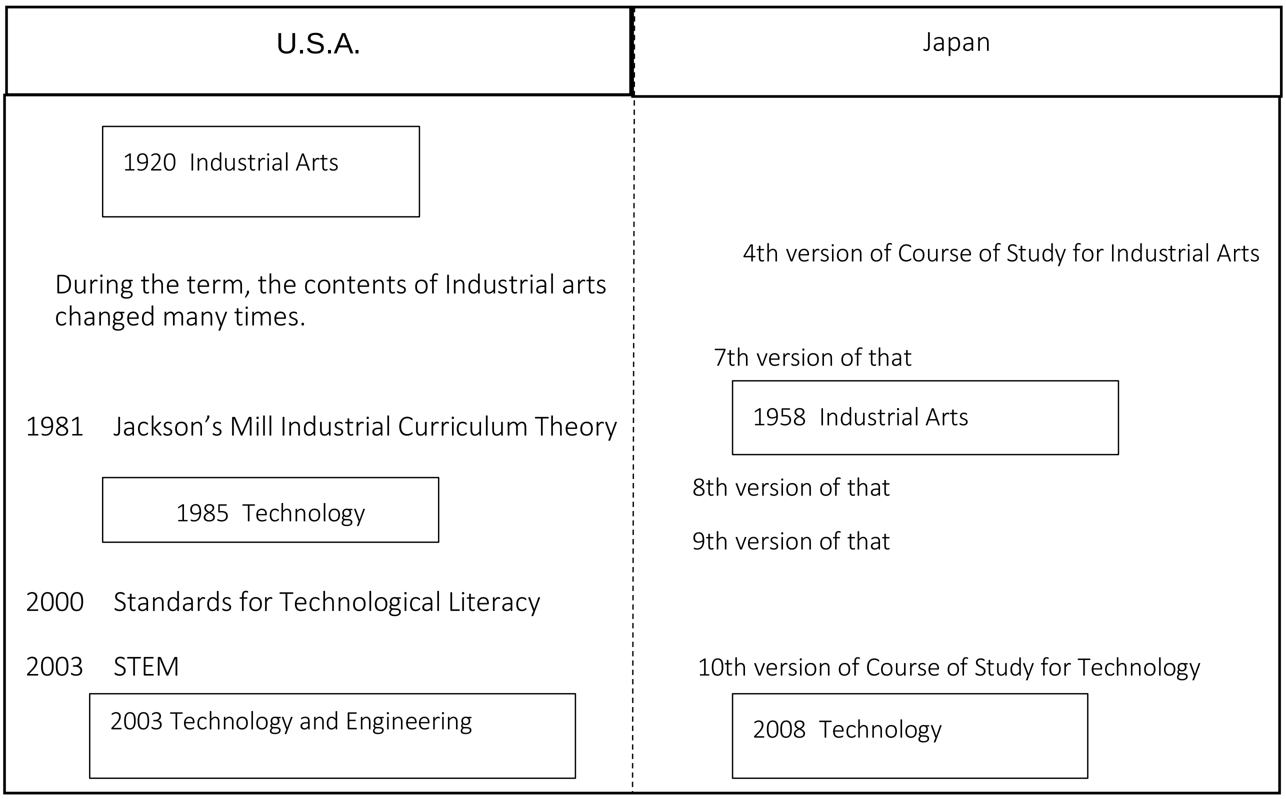

Figure 1: Historical transition of technology education comparing Japan and U.S.A.

Structure of learning conscious of production concept

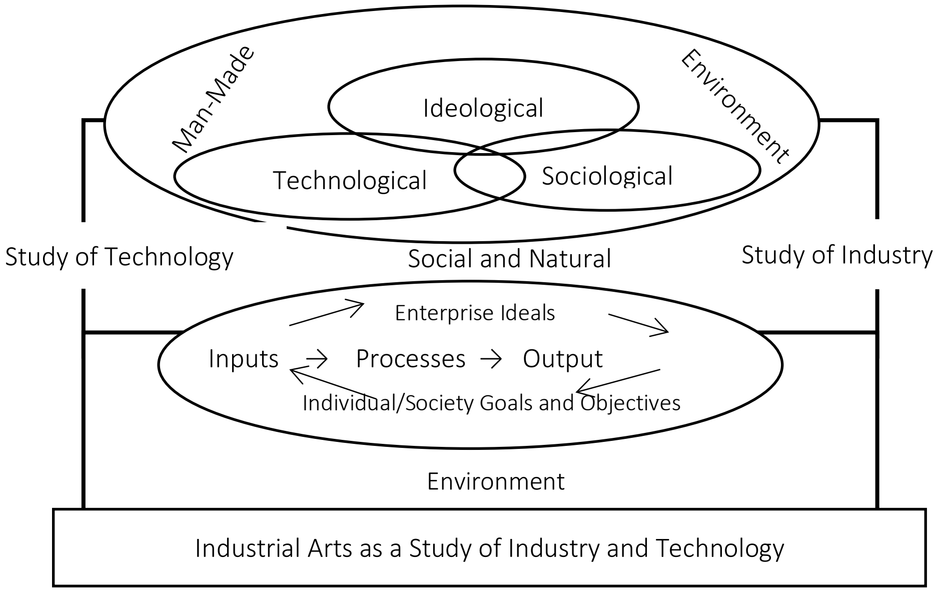

Figure 2: Jackson's Mill Industrial Curriculum Theory

Figure 1 shows U.S.A. proceeded to emphasize science and technology education as a whole in education after the sputnik crisis in 1957. The contents of technology education as if they were based on industrial education focusing on science and technology changed from vocational preparation in both countries (Herschbach 2009).

Figure 2 shows "Jackson's Mill Industrial Curriculum Theory" submitted in 1980 showing the learning structure aware of production concept (Snyder et al. 1986). A model of technology education as indicated the subtitle is a model that overlooks the entire inner world of human beings or the outer world surrounding human beings, which is indicated the position of technology learning. Moreover, the corporate philosophy, and personal or social goals circulate in a spiral of "input ---> processing ---> output" in the environment.

Structure of human perception and activity in technology education

Figure 3 shows the structure of human perception and activity in technology education by "A Conceptual Framework for Technology Education" submitted in 1990 (Savage et al. 1990).

A model of technology education as described in the subtitle, it shows the relationship between input and output in human processing, and it is based on information processing model.

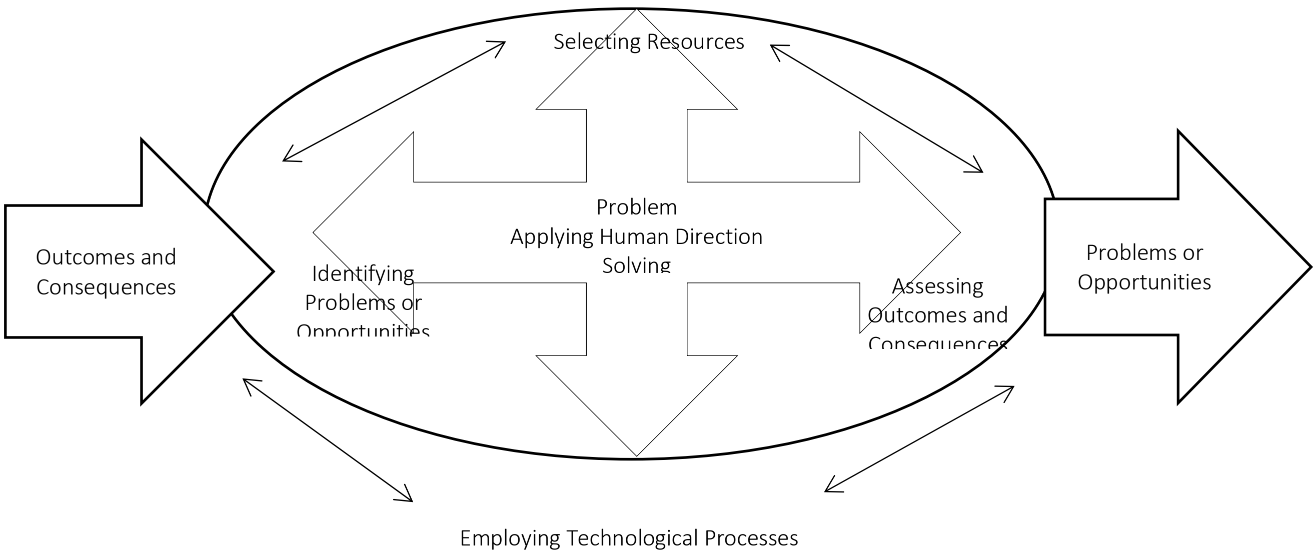

Figure 3: A Conceptual framework for technology education

Necessity of self-actualization as a member of society and contribution to industrial society

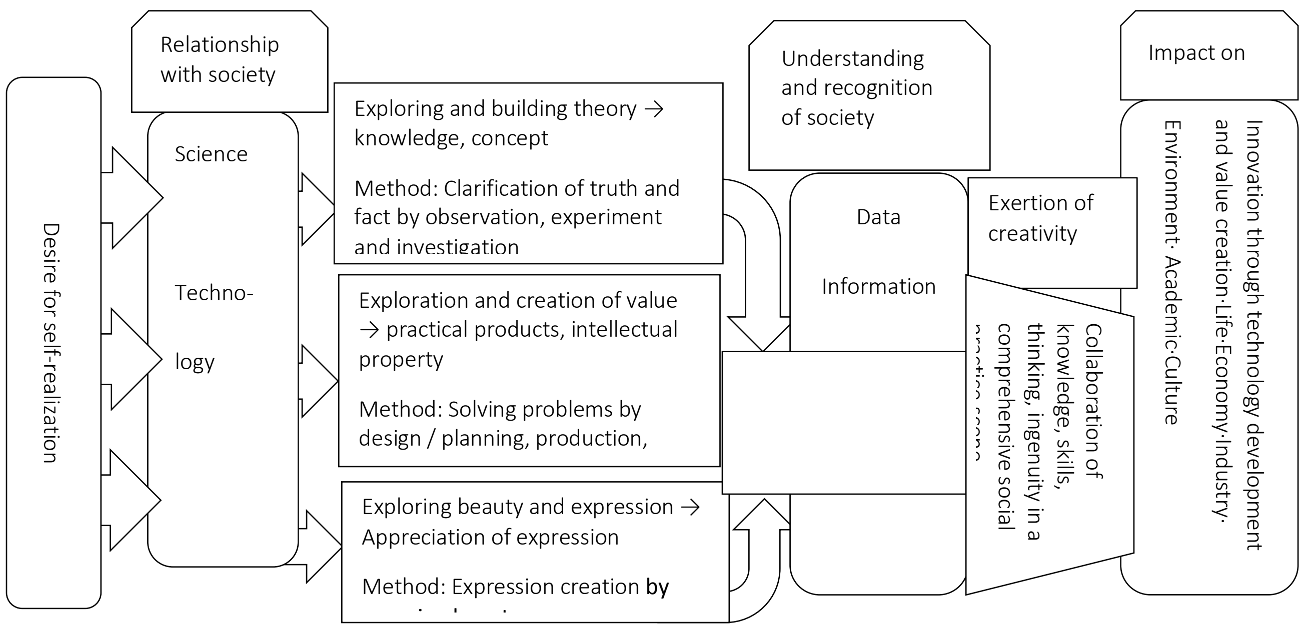

Figure 4: Examples of targets for technology education in Japan

Figure 4 shows the goals of technology education which shows the desire of self-actualization as a member of society and contribution to the industrial society. From the left to the right of figure, the desire of self-realization of individuals advances to explore and construct the theory, to explore and create value, to explore beauty and expressions to through the relationship with society through science, technology and art. It also explains the process by which they are integrated to produce various creative values.

The characteristics of learning activities of technology education are related to solving technological problems, challenging the designing and planning and production, production and training of practical items, and developing creativity to lead innovation through technology development and value creation throughout lifelong learning

Segmentation of learning flow of technology education as a system

Figure 5 shows the segmentation of learning flow of technology education as a system. As an inherent methodology of technology education, it shows how the learning process of the learner traces the basic process of concept ---> design ---> production ---> evaluation with the objective of producing material and symbols.

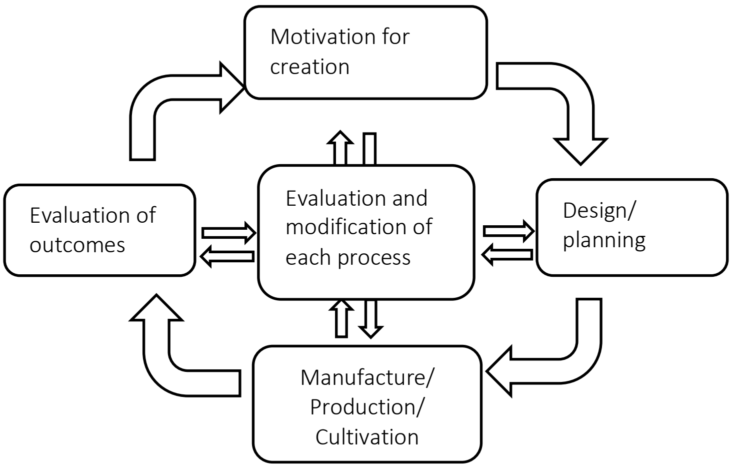

Figure 5: Specific method of Japanese technological education (JSTE) (JISTES 2012)

The system diagrams of the technology education of Japan and U.S.A. have been shown, and segmentation of learning flow of technology education in the preceding research is recognized as the structure of learning conscious of production concept, which includes the structure of human recognition and activity in technology education, the desire of self-realization as a member of society, and contribution to the industrial society. Based on these contents, we will look at the new perspective of the latest Japanese middle school teaching guidelines technology education in the next section.

Contents of course of study of technology education of junior high school in Japan

On February 14, 2017, the new course of study for junior high school in Japan was proposed (Ministry of Education 2017). The aim of technology education is to nurture the following qualities and abilities to realize a better life and build a sustainable society. The goal of the technology field is to "set the qualities and abilities to build better life and sustainable society through technology through practical and experiential activities related to technologies such as working with technology viewpoints and ideas, We aim to cultivate as follows", and for this purpose, it sets three objectives.

(1) To understand the relationship between technology and life, society, and the environment through the basic understanding for technology such as materials and processing, nurturing organisms, energy conversion and information technology with mastering basic skills.

(2) To improve the ability to solve problems, such as finding problems related to technology, designing solutions, planning solutions, expressing them in production figures, etc., making concrete through prototyping etc., evaluating and improving practices.

(3) To improve a practical attitude to devise and create technology in an appropriate and honest manner to realize a better life and build a sustainable society.

Table 1 shows the segmentation of knowledge acquisition, knowledge creation and skill acquisition based on the content of technology education of junior high school.

Table 1 Contents of the course of study

	Materials & processing	Nurturing organisms	Energy conversion	Information technology
Under-standing	Principle/law such as material and processing characteristics etc. Basic mechanism structure such as material manufacturing /processing method	Principles/laws of biological growth, characteristics of ecology, etc. Fundamental technological system such as how to adjust the biological cultivation environment	Principles/laws such as the characteristics of electricity, movement, heat Conversion and transmission of energy etc. Basic technical structure and necessity of maintenance inspection	Principles/laws of information representation, recording, calculation, communication characteristics etc. Basic structure of technology related to digitalization of information, automation of processing, systemization, information security, etc. Necessity of information ethics Construction of information communication network Basic mechanism for using information Mechanism and control system structure
	• Basic technology structure, Concept of technology			
Thinking	Devices for problem solving	Evaluation, improvement and correction of processes and	Idea and design by concept of electric circuit	Devices for solving problems How to set issues and composite media to use

	included in technology	results of cultivation or breeding	or mechanical mechanism	To embody information processing procedures Flow of input and output data Conceive measurement and control system and materialize information processing procedure Production process and results evaluation, improvement and correction
	• Production process and results evaluation, improvement and correction • Evaluating technology, appropriate selection, management and operation methods • Improvements and applications based on new ideas			
Acquirin g	Set issues and materialize the design by designing materials selection and molding method etc.			Production of safe and appropriate programs, confirmation of operation and debugging
	• Safe · Proper production, inspection, inspection etc.			

Table 1 shows that the viewpoint of learning is roughly divided into "understanding", "thinking", and "Acquiring ". "Understanding" is focused on learning the basic principles of natural science, engineering, information science, and the concepts of laws and technologies. "Thinking" is focus on the problem solving or ingenuity in the process from concept to design and production. "Acquiring" is focused on safety, inspection, inspection or adjustment.

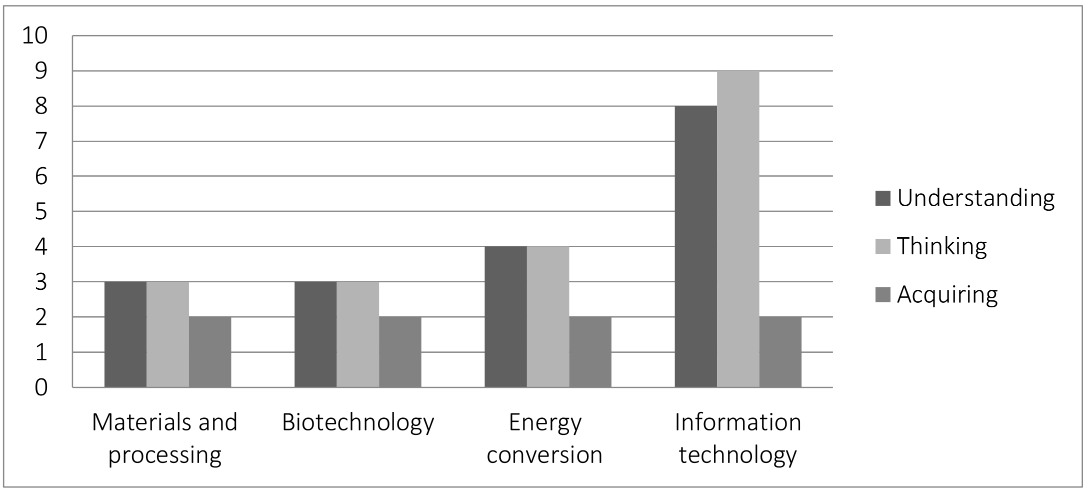

Figure 6: Comparison of the number of items in the course of study

Table 2: Handling of the content of the course of study (2017)

	Materials & processing	Biological breeding	Energy conversion	Information technology
To notice	1. Traditional technology of our country 2. Techniques for precision manufacturing			
	• · Technology has been optimized focusing on requirements from society, safety, environmental burden and economic efficiency			
Handling	Isometric drawing and projection by third angle method	Cultivation of crops, rearing of animals and fisheries · cultivation of living things	Safe use of products and systems used in daily life such as electrical equipment and indoor wiring	1. Cultivation of crops, rearing of animals and fisheries · cultivation of living things 2. Safe use of products and systems used in daily life such as electrical equipment and indoor wiring 3. How to digitize information and amount of information, intellectual property rights including copyright, responsibility for transmitted information, and cyber security in society 4. Basic features of various media used for contents and necessity of protection of personal information
	1. Technology contributes to improvement of living, inheritance and development of industry, effective use of resources and energy, conservation of natural environment and so on. 2. Select tools, equipment, materials, etc. to be used in the production, production, and training scene in consideration of safety and health			
To comply	Considerations to unaffect regional ecosystem Standards and precautions for use of chemicals			
To conceive	By finding problems by way of thinking and way of thinking, setting up assignment, solving			
Fostering attitudes	1. Attitude to create, protect and utilize intellectual property, 2. Attitudes to advance things persistently in cooperation with others in ethics concerning technology			
Collaboration with	• Principles and laws to take up			

related subjects	

Figure 6 shows the ratio of knowledge acquisition, knowledge creation and skill acquisition for "material and processing", "nurturing organisms", "energy conversion", and "information technology" of technology education. When comparing the items of each technology, the number of content items related to information technology is approximately doubled by "understanding" and "thinking" with respect to other technological contents. It can be seen that there are many items related to information technology among the four contents.

Table 2 segmented six terms for the viewpoints of introduction, contents, attention, creation, attitudes and related knowledge of technology education.

Discussion

We discuss how to relate those components from the viewpoint of curriculum composition, lesson practice, and class evaluation about methods and contents of technology education. New Japanese course of study showed in the previous section, from the viewpoint of learning of technology education in junior high school is summarized from "understanding", "thinking", and "acquiring". The handling of these contents also was found that it was segmented from the perspective of introduction, contents, attention, creation, attitude and related knowledge.

We discuss the technology education as a system, which treats the elements of the lesson, namely "time", "space", "interrelationship among humans", "learning possibility", "elements of class content", "development teaching material use", "learning evaluation", and so on. We will develop not only the contents described in the current guidelines for teaching with the concept, design, manufacture and evaluation of objects, but also the viewpoint of learning the way for problem solving with the fundamental technology education. We also consider the necessity of re-thinking in perspective. Therefore, based on the ability of the learner obtained by practicing new technology education, we propose the following paradigm shift of contents of technology education (Kikuchi 2013) (Kikuchi et al.,2013).

(1) Mutual relationship between one person and others as an influence of self-reflection and the opponent including education/learning activities

・Flow of mutual evaluation from self-evaluation of manufacturing/production/nurturing

・Activities aware of collaboration

(2) Mutual (element) and composite (whole) as a relation between material and finished material in learning including work

· Production flow from training of compound production to manufacturing/production/nurturing to production and training

· Development from single body to complex and new creation

(3) Theory and practice and interrelationship between conception and manufacturing/production

· Objective setting from analysis of materials to manufacturing, production and nurturing

· Organization of concept

· Design of objects to be manufacturing/production/nurturing

· Specific work

· Evaluation

· Improvement

(4) Interrelationship between concrete and abstract that treats objects as "things" (material and composition) and "things" (ideas and creations)

· (Example) Measurement and Control teaching/learning material

· Develop from hardware production to software production

(5) Interrelationship of the influence of place and content as a way of grasping things and information exchange through logistics and communication

· Flow from production or nurturing to logistics

· Flow from production to communication flow

(6) Temporal interrelationships of past, present and future, including human development and growth as a way of living a mentally rich life in the future

· Purpose and setting work: Evaluation of current production, production and training

· Tool usage and problem: Setting according to physical growth

· Objective setting work: Evaluation of production, production and training that assumed the point of time to start appearing in society

· Purpose and setting work: Evaluation of production/production/training that assumes the period of active in society from 20 to 30 years old (Adaptation to a sustainable society)

The studies on systematization of work process are progressing for technology education in Japan, but the examination of systematization of thought process at learning was insufficient. In this research, we discussed the importance of systematization of thought process at learning and presented the direction of technology education for the future.

Conclusion and perspectives

In this research, we considered the purpose of technology education as fostering the ability to catch various generations and change of things systematically, and examined the method and contents of the system. For research purposes, we presented the concept of general systems and cited it as a way to capture the system in technology education. In the following comparison of system diagrams of technology education between Japan and U.S.A., the structure of learning conscious of production concept, the structure of human recognition and activity in technology education, desire to self-realization as a member of society and contribution to industrial society, and it was a segmentation of the learning flow of technology education. Furthermore, in Section 3, we investigated new perspectives of the latest Japanese course study of technology education in junior high school. Based on these, the following elements that compose the class, namely "time", "space", "mutual relationship between humans", "learning possibility", "element of class content", "development teaching material utilization", "learning evaluation" from a viewpoint of system. In the technology education, it is important to develop systematic thinking of learners by arranging systematical learning materials for each lesson contents.

In the future work, we reconsider the composition of the subjects to foster the students' ability to capture the various objectives and changes systematically. We develop systematic thinking to capture complex events of human society, and step further into design thought for creation and continuation of new society. We will extend subjects to more universal educational methods and contents for technology education.

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Challenges of Teaching Technology in the Preschool

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Abstract

In many countries over the last decade early childhood education (ECE) has leaned towards a more learning-oriented pedagogy. This is also the case in the Swedish preschool. Preschool staff in Sweden are now commissioned to teach specific subjects, including technology. Previous research has shown that collectively, preschool staff have a broad and diverse view of what technology education is or should be. At the same time, other studies show that what is actually taught appears to be much less. Thus, something seems to be preventing educators from providing the technology education they regard as essential. The research question is: What challenges exist for the teaching and learning of technology in the Swedish preschool? The statements made by seven preschool staff are used to illustrate these challenges. The statements are analysed using a qualitative content analysis, which results in a set of categories. One of the challenges to the teaching of technology is educators' lack competence in the subject. This obstacle includes a view of technology as a means for learning rather than the object of learning. Another obstacle is a traditional view of the preschool and learning, namely that children should explore things on their own and that it is more important to follow their interests than the pedagogical plan. In order for teaching to happen in preschool the commission of the preschool along with its inclusion of subject teaching must be clear to all preschool staff. In order for teaching to happen in accordance with the curriculum in-service and pre-service training that focus on how subject teaching that allows children's participation and influence is performed need to be provided. And finally, in order for technology teaching to happen all preschool staff need adequate training in technology. In-service training for a few is not enough.

Key words: technology education, early childhood education, preschool, preschool staff, challenges

Background and aim

Since becoming a school subject, technology has often struggled to find its place on the compulsory school sector schedule (Hagberg & Hultén, 2005; Jones, Buntting & de Vries, 2013). Also, technology education has often been regarded as insufficient (see e.g. Jones, Buntting, & de Vries, 2013; Jones & Moreland, 2004; Swedish Schools Inspectorate, 2014). In early childhood education (ECE), it has been found that staff lack the confidence to teach the subject and that the ambitions expressed in curricula have yet to be implemented (Benson & Trevelen, 2010; Campbell, 2010: Hellberg &

Elvstrand, 2013; Swedish Schools Inspectorate, 2012, 2016; Turja, Endepohls-Ulpe & Chatoney, 2009). Turja et al. (2009) connect this to the fact that in many countries the teaching of technology in ECE is still a relatively new idea. Even now in Sweden, six years after technology as a content area was explicitly included in the learning objectives for the preschool (National Agency for Education, 2010), the Swedish Schools Inspectorate (2016) still reports that very little technology is taught in the preschool. However, a recent study has shown that preschool staff collectively address many technological aspects when describing preschool technology education, but that their individual descriptions vary considerably (Sundqvist & Nilsson, 2016). This indicates that the staff have ideas of what preschool technology education should be, some having more developed ideas than others. Also research has found that preschool teachers appreciate the curriculum and report that it have had a positive impact on how they work with children’s learning (Brodin & Renblad, 2015). Despite this, when it comes to technology something seems to prevent staff from providing the kind of technology education envisaged in the curriculum. As mentioned earlier, teachers’ subject knowledge in technology has often been found lacking or insufficient (Benson & Trevelen, 2011; Campbell, 2010; Lachapalle, Cunningham & Lindgren-Streicher, 2006; Robbins, Babaeff & Bartlett, 2010). Of course this may cause difficulties for presenting a sufficient technology education. Other aspects previously found and interpreted as hindering technology education in ECE is teacher direction, such as teachers either directing activities very strongly (Ehrlin, Insulander & Sandberg 2015), or not directing at all, thinking that children learn when they discover on their own (Campbell & Jobling, 2008; Hallström, Elvstrand & Hellberg, 2014), and rescources such as low staff-child ratio (Hellberg & Elvstrand, 2013) and lack of adequate materails (Hellberg & Elvstrand, 2013; Mawson 2007).

In order to contribute to, and perhaps widening, the knowledge of the challenges for technology education, this study uses the statements made by seven preschool staff to investigate the research question *What challenges exist for the teaching and learning of technology in the Swedish preschool?*

Swedish preschool and its development

In many countries, including Sweden, ECE have become more learning orientated (OECD, 2006; OECD 2012). In Sweden, this has meant moving somewhat away from the social pedagogic approach and towards the pre-primary approach, which has resulted in a stronger emphasis on cognitive ability and subject learning (Bennett, 2005; Jönsson, Sandell & Tallberg Broman, 2012). This development began with the first curriculum in 1998 (National Agency for Education, 1998) and was further enhanced with the 2010 and 2016 revisions (National Agency for Education, 2010, 2016). These revisions pay greater attention to technology as content area to the extent that the curriculum now states two specific technology goals, namely that the preschool should strive to ensure that each child develops its ability to 1) “build, create and construct using different techniques, materials and tools” and 2) “identify technology in everyday life, and explore how simple technology works” (National Agency for Education, 2016, p. 10). Learning, care and personal development are now equally emphasised and learning is expected to be based on children’s interests and experiences. The curriculum also highlights the child’s right to participation and influence on the approach and content of the daily practice (National Agency for Education, 2016).

According to Sundberg et al. (2015), the pedagogical approach described in the revised curriculum gives what can be understood as conflicting messages, in that the traditional preschool pedagogy now meets the school’s subject orientation, which poses a challenge for the preschool staff. This was noted after the implementation of the first curriculum by Pramling Samuelsson and Sheridan (2004). They found that traditional attitudes and ways of working still predominated. Later studies have confirmed that this is still the case (Melker & Rydberg, 2012; Sundberg et al., 2015). Doverborg, Pramling and Pramling Samuelsson (2013) argue that if preschool teachers are to work towards the learning objectives and at the same time encourage children’s participation and influence, they need adequate knowledge about the learning object, clarity about what the children are supposed to learn and be able to actively inspire them. Having adequate knowledge about the learning object means preschool teachers will be able to identify opportunities in children’s interests, respond to any spontaneous situations that may occur and connect them to the learning object.

Method

As learning is regarded as situated and develops in cultural and social practices, the study takes a sociocultural perspective (Säljö, 2014). Striving to understand the participants’ situations and the challenges involved in the teaching and learning of technology in preschool the study used semi-structured interviews for data collection (Kvale & Brinkmann, 2009). Seven early childhood educators – two men and five women – from six different preschools in one Swedish municipality were interviewed. The participants were selected from a previous questionnaire study, including preschool staff with varying background variables, such as age, gender, working years and academic qualifications as recommended by Graneheim and Lundman (2004) in order to contribute to a richer variation of the investigated phenomenon. Of the seven participants, five were preschool teachers and two child-care attendants[9]. Their ages varied from 26 to 58 and their experiences ranged from being new to the profession to almost 30 years of service. The interviews were held at their respective workplaces and were audio recorded. An interview guide was formed to capture both positive and

[9] There are two professional categories of Swedish preschool staff: the university educated preschool teacher and the non-university educated child-care attendant with a care certificate or diploma from upper secondary school. In this article, when they are referred to jointly, they are described as preschool staff.

negative descriptions and what the participants perceived as being most central to technology education.

In order to identify the possible challenges to the teaching and learning of technology a qualitative content analysis focusing on the manifest content, inspired by Graneheim and Lundman (2004), was performed in four steps to inductively create categories describing these challenges. After thorough readings of the interview data, all the statements in the interviews that could be interpreted as challenges to the teaching and learning of technology were extracted from each transcript and compiled in one text, which constituted the unit of analysis. The unit of analysis was divided into meaning units and labelled with codes. Codes that were similar were merged into sub-categories, which were then merged into categories. This was conducted in an iterative process, in which the meanings and understandings of the statements were sought by going back and forth between the literature background, the transcripts as whole, the meaning units and the categories as they were formed. Hseih and Shannon (2005) call this type of qualitative content analysis *conventional content analysis* and they describe it as the type of qualitative content analysis best suited for seeking a rich understanding of a phenomenon.

Ethical considerations

The study was designed to meet the ethical considerations of the Swedish Research Council (2011). In accordance with this, the participants were informed about the aim, their voluntary participation and the confidential handling of material and personal data.

Result

The result of the analysis is presented below as four categories encompassing eight sub-categories.

View of and competence in technology and the teaching of it

Insecurity about what the content area of technology includes

There is an insecurity about what technology is in general and with what the area should include in the preschool. This includes a view of technology as something that is difficult and what can be described as a narrow or undeveloped understanding of the subject, such as including natural science in the technology education content or viewing technology as a means or method for learning other content (e.g. natural science or social skills), rather than being a learning object in itself.

> Electronics…things I'm not that familiar with. No but it is electrical stuff, or, I don't know. Maybe that's wrong…technology…well. No, I don't know what I'm thinking about. I'm thinking about electronics, electrical stuff, that's what I think about.

Insecurity about how to teach technology

This sub-category shows an insecurity about how to teach technology to preschool children. This is related to the former category, in that pedagogical content knowledge, which is the issue in focus here, is related to subject knowledge (Rohaan, Taconis, & Jochems, 2012). Thus, if the subject knowledge is limited, the teaching of that subject will naturally be difficult. There seems to be an opinion that it is easier to teach technology to older children in school than to younger children in the preschool.

Technology is less important than other areas in the preschool

Technology is compared to other areas in the preschool and in this respect is viewed as less important. Areas like mathematics and the Swedish language are viewed as more important.

View of the direction of children's learning and activities

Preschool children should not be taught

There is a belief that children in preschool should be allowed to explore on their own and learn from their own chosen activities. Preschool staff can sometimes interact with children in their chosen activities to develop their thinking about what they are currently occupied with, but they should not try to direct what children do. What is important here is that the preschool staff can see that children do technology on their own and know that they are addressing the curriculum without actually being taught.

> No, but about the curriculum, we have said this many times, I mean, we have read it again and again. I mean, everything we do, it's so much in a day. We work a little with the Lotus diagram [a document where they can highlight which curriculum goals have been covered in a specific activity] […]. We cover almost everything in the activities we've looked at. So we say we cover the whole curriculum every day. It's more about them discovering and exploring rather than us teaching them.

Children's interests guide the way

What children show an interest in is used as the basis for long-term planning and can change or halt ongoing projects and activities. There is a belief that children can focus for longer periods and learn better if they are interested in and like what is taught and how it is taught. The curriculum's formulations on children's participation seem to be interpreted as following children's interests.

> Then if the children get tired of animals […] then we will have to rethink and, well what do they like now, and try to form a theme around that.

Lack of resources

The existing resources are not sufficient

It is considered that the existing resources of time, staff, space and material are not sufficient to give children the education that is required or desired. Time and staff are interrelated, in that if there are few staff members each person has less time to do the same work. This results in the staff being unable to develop the practice to enhance the quality of the preschool education. A lack of each of the mentioned resources is considered problematic in the everyday work, because it limits the number of activities that can be offered.

> No, now we are changing staff again […] so we haven't really come so far with that [how to integrate technology learning in the practice]. […] right now there's only room for the everyday issues, so no we haven't talked about that.

Time for in-service training

Too little time for in-service training, and for staff to learn from each other, are regarded as problems. Time is allocated for some staff members to take part in groups where in-service training is provided, although these staff members are not given enough time to share what they have learned with colleagues. This is a problem, because sometimes the teaching is organised in a way that requires all the staff to have knowledge about the content, hence content not known to all the staff in a work team is excluded.

Unpredictable incidents hinder a planned learning situation

Children become ill

Young children can become ill very quickly, in any situation. This may happen during an activity, which results in either the activity being stopped or children only remembering the incident and not the planned learning content.

Discussion

The study reveals several challenges, both specific to the content area of technology and for teaching a content in general in the preschool. Concerning the challenges that are specific to technology, the study finds that some preschool staff feel unconfident in the subject. This has been reported in previous studies (see e.g. Campbell, 2010; Hellberg & Elvstrand, 2013; Robbins, Babaeff & Bartlett, 2010) The study also reveals that some staff regard this content area as less important than other areas and that there is a view of technology as a means for learning rather than the goal (as presented in category A).

With regard to the more general challenges for teaching a content, category B describes a view that children should direct their own activities and learning, similar to the findings of Campbell and Jobling (2008) and Hallström, Elvstrand and Hellberg (2014). Among the participants there may also exist opinions that the teacher should engage more in teaching the children. However, from a sociocultural perspective (Säljö, 2014), the views described in category B stand out as problematic when it comes to children's learning, because they imply a passive teacher who does little to scaffold children's learning. The attitude described in this category (B1), that preschoolers should not be taught at all, could explain why there is so little technology education in the preschool, even though some staff have well-developed ideas of what technology education in the preschool should be like (Sundqvist & Nilsson, 2016). Taken to extreme, this could imply that the staff's subject knowledge is irrelevant because they do not want to teach the children anyway. As an example of this idea, subcategory B1 addresses the important issue of the staff's approach to the curriculum. The way of working with the curriculum indicated in the quote in the subcategory is problematic, because it means that there is no plan to actually *develop* children's knowledge in accordance with the curriculum (Doverborg et al. 2013). Instead, the curriculum goals are "checked off" after the staff have identified the areas of the curriculum in the children's activities. Subcategory B2 describes how children's interests guide both the activities and the objectives. This seems to be an interpretation of the curriculum's formulation about participation and influence, which, under the heading Children's influence, states: "The needs and interests which children themselves express in different ways should provide the foundation for shaping the environment and planning activities" (National Agency for Education, 2016, p. 12). Considering children's interests when making a pedagogical plan is clearly a good example of participation. However, the idea held by some staff that children's changing interests should be allowed to change or stop a pedagogical plan means that there is a risk of only addressing content at a shallow level.

Contrary to some of the staff's ideas, Pramling Samuelsson and Sheridan (2003) describe participation in a way that does not necessarily mean stopping or changing an activity or a learning objective to accord with children's interests. They relate participation to learning rather than interest, in that participation is taking children's perspectives into account by interpreting their actions and expressions. This leads to an understanding of children's intentions and competences, from which the preschool teacher can work to develop children's knowledge. Whichever view of participation one holds, allowing children to actively participate and at the same time maintain the learning objective requires knowledge about the learning object (Pramling Samuelsson & Sheridan 2003; Doverborg et al. 2013; Larsson 2013), which is what this study and others have shown to be lacking.

Implications

As mentioned earlier, the focus on academic skills in ECE is increasing internationally (OECD, 2006). As the changing orientation has generated several of the challenges of teaching technology, the results and implications presented here have international value.

First, the commission of the preschool, along with its inclusion of teaching content areas, must be clear to all preschool staff. This therefore needs to be addressed by in-service and pre-service training. The second issue to address is the preschool staff's need for adequate knowledge in technology and how it should be taught in the preschool context. This would enable them to teach the content area from different perspectives and entries and to take children's interests and competences into consideration. According to Rohaan et al. (2012), acquiring such knowledge would have a positive effect on the staff's self-efficacy, lead to more technology teaching and improve their attitude towards technology, thereby targeting the challenge described in subcategory A3. However, as is shown in subcategory C2, knowledge about technology and how it can be taught is not easily addressed by in-service training for a few staff members, because it is likely the newly acquired knowledge is not shared with colleagues. Subcategory C2 indicates that when only a few staff in a work team have the required knowledge to teach a specific content, it can sometimes result in the content not being taught at all. To prevent this, every staff member who does not have adequate training in technology education should be provided with in-service training.

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Design to Understand: Promoting Higher Order Thinking through T/E Design Based Learning

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Abstract

The theoretical premise of Design Based Learning (DBL) as implemented in Technology and Engineering Education is that learners acquire habits-of-hand (designerly abilities) as a means for developing the habits-of-mind (designerly ways of knowing) needed to recognize and understand relationships among content and practice. Specifically, the pedagogical intent behind Technological/Engineering Design Based Learning (T/E DBL) is promoting understanding of the connections among disciplinary content and practices (schematic domain) as a prerequisite for making informed decisions (strategic domain) derived from that understanding (NAGB, 2008; Achieve, 2013). In this context, *design to understand* is the primary instructional goal.

Cognitive demands increase along the continuum of higher order thinking from declarative, to procedural, to schematic, and finally to strategic (decision making). Integration of content and practices employing a T/E DBL approach is believed to inherently impose the type of cognitive demands tomorrow's problem-solvers must be prepared to address. As an extension of prior efficacy research (Wells, 2016a), this study was designed to further evidence the potential of T/E DBL for improving a student's capacity to respond to higher order cognitive demands inherently imposed by biotechnical design based challenges. Specifically, using a pre-experimental one-group pretest-posttest design, a mixed-discipline group of graduate students enrolled in a Design Based Biotechnology Literacy (DBBL) course were assessed on their abilities to respond to the continuum of cognitive demands imposed by two distinctly different design based biotechnical Problem Scenarios. Findings further evidenced the strong connections between T/E DBL strategies to intentionally teach specific content and practices, and improved capacity of students to respond to imposed cognitive demands inherent within T/E design challenges.

Keywords: technological/engineering design based learning; higher order thinking skills; imposed cognitive demands; design based biotechnology

Designing to understand

The goal of P-12 education writ large is development of literate individuals with the capacity to think critically and utilize acquired knowledge as a tool for solving complex 21st century problems. Such capacity is requisite to, and reflective of, individuals who have moved beyond content knowledge and achieved true understanding. Understanding is what enables the learner to recognize when and where knowledge can be leveraged for determining a viable solution to any given problem scenario. As an instructional strategy, engaging learners in T/E DBL instills a genuine “need-to-know” critical for positioning them to acquire deep understanding of relationships among STEM content and practices. The learner’s need to know initiates question posing, which is a unique characteristic of T/E DBL and central in directing the learner through all phases of engineering design (Wells, 2016b). As an ongoing cognitive process, convergent and divergent question posing prompts the learner to transition between what they currently know (resident knowledge domain) and what they still need to know (concept domain) as they work toward making informed design decisions. These cognitive transitions are unique “designerly ways of knowing” (Cross, 1982) leading the individual toward true understanding. The pedagogical intent of T/E DBL is for learners to acquire habits-of-hand (designerly abilities) as a means for developing the habits-of-mind (designerly ways of knowing) requisite to gaining understanding. More precisely, to promote student understanding of the connections (schematic knowledge) among disciplinary content and practices requisite for making informed decisions (strategic knowledge) derived from that understanding (NAGB, 2008; Achieve, 2013). In this context, the primary instructional goal of T/E DBL is having learners *design to understand*.

Learning potential ascribed to STEM integration

Competition for the flat world economies of the 21st century demands a workforce prepared in the STEM (science, technology, engineering, and mathematics) fields to solve our complex global problems (Committee on Prospering in the Global Economy of the 21st Century, 2007, 2010). As has historically been the case, education is viewed as the means by which we prepare such a workforce and is once again being pressed to prepare individuals with the capacity to integrate content and practices of the STEM disciplines. Initial response has been large scale curricular reform to develop new integrative STEM education frameworks needed for departing from the traditional mono-disciplinary approach that is failing to prepare students to solve real-world problems (National Governors Association [NGA], 2011; Bybee, 2010, 2013; National Research Council [NRC], 2010, 2011, 2012, 2014). Implementation of such integrative curricula increasingly features T/E DBL as the primary instructional vehicle for transdisciplinary integration of STEM content and practices. Furthermore, there is a growing body of research in science education providing evidence that T/E DBL can improve students’ critical thinking skills (Fortus, et al., 2004; Cantrell, et al., 2006; Mehalik, Doppelt, & Schunn, 2008; Schnittka & Bell, 2011; Wendell & Rogers, 2013). As a result, technological and engineering design are increasingly embraced as a core instructional method believed to make explicit the connections among STEM content and practices (Kolodner, 2002; NAGB, 2008; NGSS Lead States, 2013). Acquisition of such higher order cognitive abilities can be observed through the knowledge types demonstrated by the learner. As an instructional strategy, T/E DBL is ideal for engaging the learner in experiences that elicit demonstrations of all four knowledge types: procedural *(knowing how)*, declarative *(knowing that)*, schematic *(knowing why)*, strategic *(knowing when and where)* (Rye, 1949; Anderson, 1983; Alexander, Schallert, and Hare, 1991; Li & Shavelson, 2001; Wells, 2010). The demonstration of knowledge types provides a mechanism for assessing higher order thinking skills employed by the learner in response to inherent cognitive demands imposed during any given phase of T/E design. Learner responses to this full spectrum of cognitive demands allows for assessment of their knowledge gains along the continuum from declarative (low) to strategic (high) throughout the design process.

Documenting the extent to which T/E DBL can and does impose higher order cognitive demands on the learner addresses the need for demonstrating the efficacy of that pedagogical approach for promoting higher order thinking abilities. Efficacy research is generally accepted as a precondition for effectiveness trials (Sloane, 2008), but few have been conducted to establish T/E DBL as an efficacious instructional intervention. To that end, the research presented here is the second in a series of efficacy studies (Wells, 2016a) designed to establish T/E DBL as a viable pedagogical approach that when intentionally capitalizing on imposed cognitive demands can promote higher order thinking.

Technological context: Biological systems

Three mutually inclusive contexts of technological activity provide the framework for studying the human designed world: Physical, Biological, and Informational Systems (ITEA, 1996, p. 17; 2006, p. 14). Within the context of Biological Systems, biotechnology is a content area addressed in K-12 technology education standards in the U.S., and internationally in countries such as Korea, Great Britain, and New Zealand to name but a few (France, 1999; Wells & Kwon, 2009). Internationally since 1994, in the field of technology education, biotechnology has been operationally defined as “any technique that uses living organisms, or parts of organisms, to make or modify products, improve plants or animals, or to develop microorganisms for specific purposes” (Wells, 1994, p. 60; Ministry of Education, 1995, p. 12; ITEA, 2002, p. 33; 2006, p. 16; ITEA, 2000 & 2007, p. 149). Explicit within this definition are a set of four criteria specifying the characteristics for what is and what is not biotechnology (Wells, 1995, p. 12: (a) *any technique* – the entire spectrum of biotechnical practices, from micro to macro processes, (b) *uses living organisms* – inclusion of live organisms (such as plants, microbes, fungi, and even macro scale organisms such as human beings), (c) *or parts of organisms* – specifies any component and/or cellular element within the organism can be isolated and used independently (organelles, enzymes, proteins, DNA, etc.), and (d) *to make or modify products, improve plants or animals, or to develop microorganisms for specific purposes* – specifies that the full range of potential biotechnical applications. This definition underpins the Design Based Biotechnology Literacy™ (DBBL) curriculum used to present students with open-ended biotechnical systems challenges structured to intentionally teach the content and practices inherent within the design of a viable prototype. The T/E design approach for teaching through biotechnical systems design naturally and uniquely imposes upon a learner the full spectrum of cognitive demands from procedural to strategic.

Purpose

As an extension of prior research (Wells, 2016a), the purpose of this efficacy study is to further evidence the validity of T/E DBL as a viable pedagogical approach for improving the capacity of students to respond to higher order cognitive demands inherently imposed by the design of functional biotechnical prototypes. The prototype design challenges, Problem Scenarios, used in this research were selected from the Bioprocessing chapter of the 2017 *Design Based Biotechnology Teaching Guide* (Wells, 2017). This efficacy study was guided by the following set of research questions.

To what extent does graduate student (learner) engagement in biotechnical Problem Scenario prototyping design challenges demonstrate:

a) learner gains in targeted science, technology, engineering, and mathematics content and practice knowledge (declarative and procedural);

b) improved learner capacity for responding to inherent higher order cognitive demands (schematic and strategic); and

c) further evidence supporting the T/E Design Based Learning pedagogical approach as a valid instructional method for promoting deep understanding?

Method

Research design

The research design guiding this study followed the same pre-experimental, one-group pretest/posttest design (Creswell, 2014) as previously reported (Wells, 2016a). In the conduct of this research a battery of data collection instruments was administered (Biotechnology Stages of Concern, Awareness, General Content Knowledge, ProbScen Content and Practice Knowledge, Terminology, and Literacy), each intended to independently assess multiple student variables. However, the focus of this paper is on presenting evidence of the cognitive demands inherently imposed by and intrinsic to any technological/engineering design challenge. Therefore, reported in this paper are pre/post changes in biotechnical content and practice knowledge (CPK) corresponding to the continuum of cognitive demands (i.e., cognitive gains exhibited across four knowledge types) imposed by the selected design based Problem Scenarios.

Participants

The participant group was comprised of educators enrolled in a 16-week DBBL™ graduate course at a major U.S. Mid-Atlantic research university. The course was designed to immerse participants in successive biotechnology design based learning experiences, with adherence to Deweyan philosophy (Dewey, 1938) for intentionally linking understandings gained in one experience to those necessary for the next. Furthermore, immersion was tailored to be grade appropriate for students whom participants in this study were currently teaching. Of those enrolled in the course, 70% (14) were female and 30% (6) male, and together representing each of the STEM disciplines, as well as elementary level generalists (Table 1). All students were practitioners teaching grade levels from elementary to university, and with years of teaching ranging from 1 to 20. It is important to note that only the 5 participants (25%) representing technology or engineering disciplines had any prior T/E design experience. Furthermore, though adequately prepared educators in their mono-disciplines, they lacked an equivalent level of expertise for teaching subjects other than their own. Given their formal disciplinary preparation, it is fair to conclude these participants are reflective of representative disciplinary sub-samples. Though this may be the case, it must be recognized that any attempt to replicate this study using a similar sub-sample might well produce different results. Therefore, as a follow on efficacy study there is no intent to generalize results of this research beyond the convenience sample population.

Table 1: *Student Disciplinary Demographics*

Gender	Number of Students Representing Discipline Areas				
	Science	Technology	Engineering	Mathematics	Elem/Multi

Procedure

Intervention

Using a web-based, synchronous, audio/video platform the DBBL course was delivered simultaneously to 6 on-campus and 14 distance learning students. This real-time audio/video platform ensured that all students were provided the same instruction, teaching materials, and course supplies, thus minimized any appreciable pedagogical differences throughout the 16 weeks of regularly scheduled 3-hour class sessions. T/E DBL was the instructional vehicle used to engage graduate students in a successive continuum of designerly experiences structured by two biotechnical systems design challenges. All DBBL design challenges are authentic, ill-structured Problem Scenarios providing students with the sociocultural context and need, and a biotechnical systems design challenge inclusive of parameters and constraints within which they must work to produce a working prototype. The first Problem Scenario presented to students was the Alternative Fuels Bioreactor (Bioreactor Scenario), followed by a more complex design challenge, the Microbial Fuel Cell (M-Fuel Cell Scenario). Students were organized into five "consultant teams" with four members, each representing science, technology/engineering, mathematics, and elementary education. Every student was to design and construct his/her own individual biotechnical solution, but were required to consult with members of their team throughout all phases of the design process. Consultant teams were reorganized with different students for each of the two Problem Scenarios but maintained the same interdisciplinary composition. Guided by the Problem Scenario and supported by their team of consultants, every student was to design, develop, test, and evaluate a working biotechnical system prototype.

The Bioreactor Scenario challenges students to design a functioning bioreactor prototype that will harness a common yeast, *S. cerevisiae*, immobilized in alginic beads to metabolize a dextrose substrate for the purpose of producing ethanol as an alternative fuel. The M-Fuel Cell Scenario is the more complex challenge, requiring students to design a functioning microbial fuel cell that exploits the electron production abilities of select benthic microorganisms to generate an electrical current sufficient enough to power a small load (a few millivolts).

For each Problem Scenario students were provided approximately six weeks to engage in the T/E design process and arrive at a viable solution. Two key teaching tools were used to structure and facilitate their biotechnical systems design: (1) the PIRPOSAL model of integrative STEM education and (2) the Interactive Engineering Journal (Wells, 2016b). Given to course participants for use as an instructional framework, the PIRPOSAL model (Fig. 1) conceptually conveys the eight phases of design engineers engage in when responding to an engineering challenge. Pedagogically the model serves to illustrate the "designerly ways of knowing" (Cross, 1982) required of the learner in order to achieve a viable engineering prototype. All phases of the engineering design process are initiated by question posing (what do I know, what do I need to know). In every phase of engineering design learners are confronted with the need to know, requiring them to first draw on their resident (factual) knowledge to determine what they currently know (convergent thinking), which then leads to "what if" questions (divergent thinking) that reveal what they must come to know in order to move forward in the design process. Rapid transitions between convergent and divergent thinking continuously require learners to synthesize new content and concepts in order to advance their understanding and then use it for design decision-making. This process of convergent and divergent thinking ultimately results in deep understanding and development of engineering habits of mind.

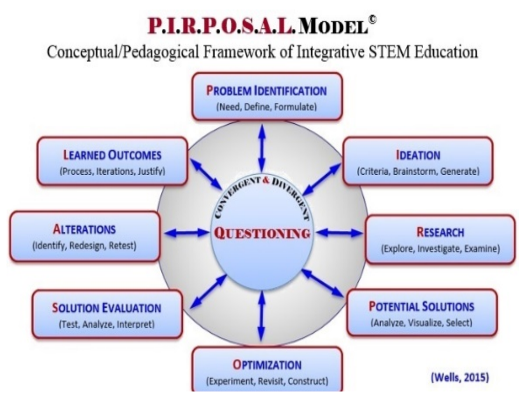

Figure 4: PIRPOSAL Model of I-STEM ED

Working to the goal of designing to understand, the Interactive Engineering Journal (IEJ) provides the leaner with continuous documentation of their design journey, and the teacher with a tool for assessing learning gains as they had instructionally intended through successive design experiences. Used as a required design tool, students make daily entries (notes, ideas, sketches, plans, observations, data, etc.) documenting the details of their engagement with the design process. By incorporating the elements of the PIRPODAL model, the IEJ structures student engagement in a sequence of successive experiences intended to draw attention to key relationships between technological and biological variables critical to their making informed biotechnical design decisions. As a design tool, the IEJ guides students in their exploration and exposure to prerequisite biological and technological content and practices specific to each Problem Scenario and necessary for progressing through successive phases of design.

For the Bioreactor Scenario design challenge an immersive strategy was selected whereby students acquired the necessary biology and technology content and practice knowledge on a need-to-know basis as they progressed back and forth through various phases of design. Detailed in a course handout, the PIRPOSAL model was used as both a tool for teaching about, and for guiding students through, all phases of T/E design. As an immersive strategy, no didactic instruction of content or practice was provided for the Bioreactor Scenario. The M-Fuel Cell Scenario involved a more complex set of concepts regarding the microbial generation of free electrons and how those electrons might be harnessed for use in an electric circuit. In light of this a quasi-immersive strategy was used wherein a small degree of didactic instruction was necessary to facilitate the M-Fuel Cell Scenario. Discussions during weekly class meetings were also instrumental in students confirming their understandings of various technological and biological concepts, processes, and practices critical to the successful prototype performance.

Instrumentation

Prior to any discussion of design based biotechnology or Problem Scenarios, the first class meeting began with the administration of two web-based “pretest” Content and Practice Knowledge (CPK) questionnaires. The first CPK questionnaire was developed for the Bioreactor Problem Scenario and the second for the Microbial Fuel Cell. Items on both CPK questionnaires were drawn from the NAEP 12^{th} grade Science and 8^{th} grade Technology and Engineering sample content and practices questions (NCES, 2017) or developed in close alignment with specific NAEP sample test items specific to biology and technology content and design-based practices intentionally targeted within the instructional design of both Problem Scenarios. All CPK items were independently analyzed by an expert from both engineering and biological science education, who then met with the researcher to discuss, arbitrate, and reach consensus on alignment of each with one of the four imposed cognitive demands (declarative, procedural, schematic, and strategic). As example, Table 1 provides two items drawn from the NAEP sample questions, with comparison to those used on the CPK.

Table 1: NAEP Sample questions: Example comparisons

NAEP Sample Question	CPK Corresponding Question
Explain how particle size affects permeability.	Sodium alginate droplets placed in a solution of calcium chloride solidify on contact into gelatinous spheres. When algae are mixed in with the sodium alginate before being dropped into the calcium chloride solution, the single-cell algae are trapped within the gelatinous spheres when they solidify. When the spheres of trapped algae are placed in a nutrient solution, why are the algae still able to utilize the nutrients outside the gelatinous spheres in the surrounding solution?
When sulfuric acid, H_2SO_4, is broken down into separate elements, how many different elements result? a) 2 b) 3 c) 6 d) 7	When dextrose, $C_6H_{12}O_6$, is broken down into separate elements, how many different elements result? a) 2 b) 3 c) 6 d) 7

Upon completion their prototypes and final reports for both the Bioreactor and Microbial Fuel Cell Problem Scenarios, the “posttest” CPK questionnaires were administered, occurring 8 and 14 weeks respectively beyond the week one administration of the CPK pretest. Both posttest questionnaires contained the same pretest items, though the order in which items were presented was different.

Findings

Data analyses of responses to both pre and post CPK questionnaires were conducted to assess student gains in content and practice knowledge when responding to items aligned with the continuum of imposed cognitive demands. Of the 77 points possible from the 18-item Bioreactor CPK questionnaire, 4% targeted procedural knowledge, 36% declarative, 47% schematic, and 13% strategic. Similarly, for the 88 points possible from the 30-item Microbial Fuel Cell CPK questionnaire, 4% targeted procedural knowledge, 34% declarative knowledge, 34% schematic, and 28% strategic. Table 2 presents pretest/posttest data analyses for the Bioreactor Scenario, and Table 3 presents data analyses for the Microbial Fuel Cell Scenario.

Table 2: 4A bioreactor scenario: Pre-test/post-test biotechnology domain knowledge

Domain		*M*	*SD*	*SEM*	*df*	*t*	*p*	†ES
All Domains Combined								
	Pre-	45.50	10.62	2.37	19	13.25	0.0001*	2.22
	Post-	67.25	8.66	1.98				
Declarative								
	Pre-	15.35	3.38	0.75	19	3.05	0.0066*	0.88
	Post-	18.80	4.37	0.98				
Procedural								
	Pre-	2.10	0.79	0.18	19	1.83	0.08	0.41
	Post-	2.40	0.68	0.15				
Schematic								
	Pre-	12.30	5.99	1.34	19	11.59	0.0001*	2.07
	Post-	23.55	4.80	1.07				
Strategic								
	Pre-	15.75	5.20	1.16	19	6.90	0.0001*	1.59
	Post-	22.50	3.03	0.68				

Notes. n = 20; *p < .05, two-tailed, paired; †Effect Size

Table 3: 4C microbial fuel cell scenario: Pre-test/post-test biotechnology domain knowledge

Domain		*M*	*SD*	*SEM*	*df*	*t*	*p*	†ES
All Domains Combined								
	Pre-	24.20	7.26	1.62	19	21.38	0.0001*	5.59
	Post-	66.85	7.97	1.78				
Declarative								
	Pre-	7.00	3.64	0.81	19	19.19	0.0001*	5.06
	Post-	23.80	2.97	0.66				
Procedural								
	Pre-	0.55	0.60	0.14	19	15.77	0.0001*	5.31
	Post-	2.95	0.22	0.05				
Schematic								
	Pre-	11.40	4.55	1.02	19	13.32	0.0001*	3.97
	Post-	30.90	5.25	1.17				
Strategic								
	Pre-	5.25	4.44	0.99	19	3.79	0.0012*	1.19
	Post-	9.20	1.58	0.35				

Notes: n = 20; *p < .05, two-tailed, paired; †Effect Size

Results from the Bioreactor CPK (Table 2) indicated significance ($p < .05$) for pretest/posttest differences for the Combined (aggregate) Domains and individually for the Declarative, Schematic, and Strategic Domains. Given the small population size for this efficacy study, Cohen's *d* was calculated to determine the practical strength attributable to these mean differences. In all instances of significance, the mean differences were substantiated by large effect sizes (.88 to 2.22). Results from conducting the same set of analyses on data collected from the M-Fuel Cell CPK (Table 3) indicate significance ($p < .05$) for the Combined Domain, and as well individually across all four cognitive demands. Cohen's *d* was again calculated to determine the practical strength of the mean differences, which shows all instances of significance were substantiated by large effect sizes ranging from 1.19 to 5.59 (Table 3).

Of the 20 students in the course, 16 represented three disciplinary subgroups comprised of members prepared to teach one of the core STEM disciplines, and a fourth subgroup with four members prepared to teach at the elementary level. Given that preparation of elementary teachers in the U.S. focuses most heavily on the content of language arts and mathematics, generally they are not heavily prepared in science, technology, or engineering content or practice (VLIS, 2017). As such, data analyses of this subgroup compared to data analyses for the science, technology/engineering, and mathematics subgroups may provide insights performance differences among participants across disciplines. In presenting such comparisons it is important to recognize the limitations to interpretation of data analyses given the very small numbers within each subgroup. However, these comparisons have the potential for suggesting whether, as a result of engagement in DBBL challenges, significant differences are found between subgroup pre/post CPK performance based on their mono-disciplinary preparation.

Table 4: Bioreactor scenario subgroup comparisons: Pre-test/post-test all domains combined

Subgroup Discipline	*n*	*M*	*SD*	*SEM*	*df*	*t*	*p*	†ES
Science	7							
Pre-		50.57	10.42	3.94	6	6.78	0.0005*	2.40
Post-		69.71	4.31	1.63				
Tech/Eng	5							
Pre-		43.20	10.47	4.68	4	7.75	0.0015*	2.48
Post-		64.80	6.53	2.92				
Math	4							
Pre-		41.75	15.92	7.96	3	6.47	0.0075*	1.72
Post-		66.00	11.92	5.96				
Elementary	4							
Pre-		43.25	1.50	0.75	3	3.21	0.0487*	2.41
Post-		65.00	12.68	6.34				

Notes: n = 20; *p < .05, two-tailed, paired; †Effect Size

Table 5 Microbial fuel cell scenario subgroup comparisons: Pre-test/post-test all domains combined

Subgroup Discipline	*n*	*M*	*SD*	*SEM*	*df*	*t*	*p*	†ES
Science	7							
Pre-		22.14	7.20	2.72	6	10.31	0.0001*	5.09
Post-		64.86	9.42	3.56				
Tech/Eng	5							
Pre-		28.80	6.87	3.07	4	15.73	0.0001*	6.57
Post-		67.20	4.60	2.06				
Math	4							
Pre-		23.75	9.74	4.87	3	10.19	0.0020*	5.42
Post-		71.75	7.89	3.95				
Elementary-	4							
Pre-		22.50	4.80	2.40	3	7.67	0.0046*	2.40
Post-		62.50	9.98	4.99				

Notes: n = 20; *p < .05, two-tailed, paired; †Effect Size

Tables 4 and 5 present findings from data analysis comparing subgroup performances on the Bioreactor and M-Fuel Cell Scenario CPKs respectively. Findings for both Problem Scenarios indicate that there were significant within-subgroup CPK pre/post performance differences ($p < .05$), and that all were substantiated with very high effect sizes. Furthermore, across all subgroups differences in pre and post mean scores were minimal. Prior research on design based learning have reported similar results (Calabrese-Barton, 1998; Doppelt, et al., 2008; Wells, 2016a) supporting the efficacy of this instructional approach.

Discussion

The research presented was an investigation into the cognitive demands that are imposed on students while engaged in the design of functional biotechnical prototypes. The research sought to determine whether student engagement in the DBBL intervention facilitated gains in their biotechnology content knowledge (procedural and declarative), improved their capacity for responding to inherent higher order cognitive demands (schematic and strategic), and whether achieving learning outcomes as targeted within the design of instruction provided further evidence that T/E DBL is an efficacious pedagogical strategy.

Overall class performance on the CPK questionnaires for both the Bioreactor and M-Fuel Cell design challenges demonstrate that as a group, participants made significant gains in their understanding of targeted STEM content and practice outcomes (Tables 2 and 3). As well, the significant improvement in their performance along all four knowledge categories, in particular schematic and strategic, suggests that the DBBL approach exhibits strong potential for promoting higher order thinking. Given student abilities to respond to the continuum of lower to higher order cognitive demands inherent in DBBL, these results clearly suggest that the intervention was effective for the entire participant group, and more interestingly, equally effective across disciplinary subgroups (Tables 4 and 5). That elementary level educators who were not prepared in a core STEM discipline respond equally well to the inherent cognitive demands as those who were, is significant regarding the broader educational potential of technological/engineering design based learning.

Findings also show overall CPK pretest scores on the Bioreactor scenario were significantly higher than those on the M-Fuel Cell scenario, which for several reasons might be expected. As is typical of those who enroll in the DBBL course, the majority of students in this study have never engaged in technological/engineering design, and none have experience in designing biotechnical systems. Anticipating this demographic, the course is designed to engage students first in a more straight-forward biotechnical design challenge, and a gradual introduction to the PIROPOSAL phases of design. Accordingly, the Bioreactor questionnaire addresses content and practices that are more familiar to participants. The M-Fuel Cell scenario however is a far more complex biotechnical system to design, both technologically and biologically, requiring a much greater content and practice knowledge base. In light of this, and given both pretests questionnaires were administered at the start of the first class meeting, it is expected that the average class pretest scores would be higher for the Bioreactor CPK.

The course is designed to intentionally engage students in a series of successive design experiences, each contributing knowledge and practice applicable in the next (Dewey, 1939); i.e., content and practices required to complete the Bioreactor scenario are applicable in the design of the M-Fuel Cell scenario. As a result, even though a more complex design challenge, it would be expected that after 16 weeks of successive design experiences from both DBBL challenges, CPK posttest scores for the second design challenge would be higher. This was the case for posttest CPK scores on the M-Fuel Cell challenge, suggesting content and practices acquired from the first design challenge were applied in solving the second.

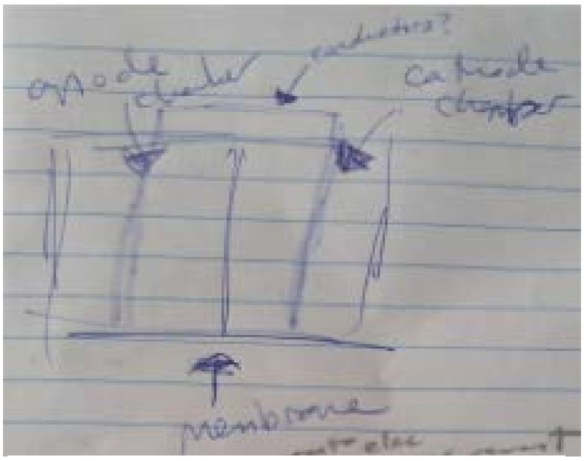

Figure 2: Brainstorming Phase - MFC Concept

In addition to the collection of quantitative data, the IEJ and Problem Scenario final reports on both design challenges provided rich qualitative data documenting gains in participant understanding. Though analyses of these data are not presented in this paper, these sources corroborated the quantitative findings by also demonstrating significant gains in both content and practice. As example, Figures 2-4 are photos of one student's IEJ pages showing progressive conceptual changes in systems design from early to late PIRPOSAL phases of design as a result of continual content investigations, predictive analysis, testing, and iterative design alterations. Resultant changes in understanding by this elementary educator are also clearly captured in the following pedagogical reflections quoted from their M-Fuel Cell final report:

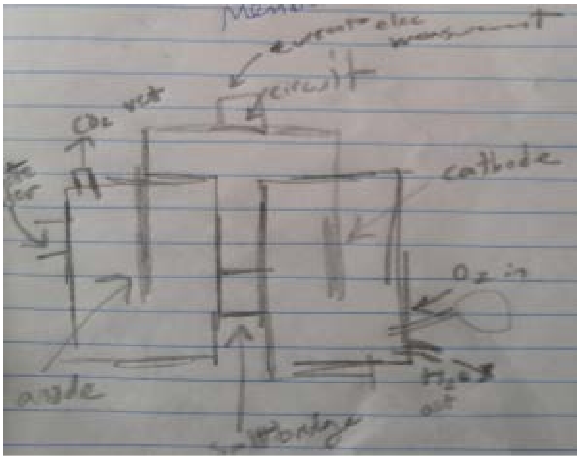

Figure 3: Post Research Phase - MFC Concept

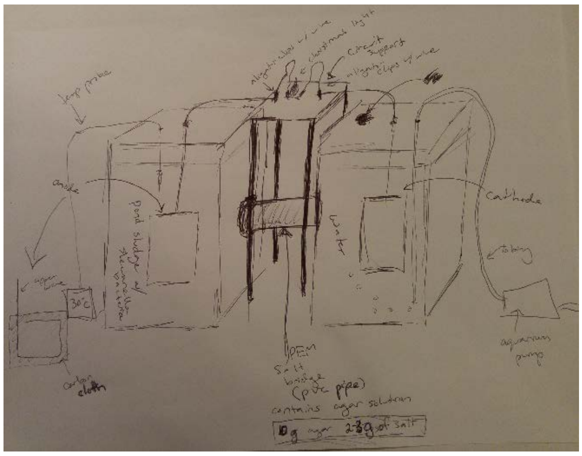

Figure 4: Post Alterations Phase - MFC Concept

> Within a more defined challenge like the MFC…. I found that personally I spent the majority of the time within the Research phase. The research varied in topic, starting with generalized MFC knowledge, then answering specific chemical and biological questions, moving into electrical questions, and finally even needing to research the tools we would use. I also found that it was very clear to me when I had reached a benchmark in the Learned Outcomes phase.
>
> I think as an elementary educator I see tremendous possibility within the second design approach. The more structured design challenge would be a good way to begin with the concept of design challenges, allowing students more structure throughout the process. The breakdown of disciplinary knowledge was very identifiable, the design and tool needs were clear, and the process of question-driven research was done with a very specific goal in mind.

Qualitatively, the IEJ images and final report excerpts together present compelling evidence for the promotion of higher order thinking resulting from inherent cognitive demands imposed by T/E design based learning. It is anticipated that a report on results of qualitative data analysis from this study will be forth coming in a future publication.

Conclusions

This research sought to provide further evidence that T/E design based learning is an efficacious pedagogical strategy for promoting higher order thinking. Findings demonstrated clear connections between student engagement in the design of biotechnical systems prototypes and their improved capacity for responding to all four levels of cognitive demand inherent to the design challenge. These results are similar to those from previous effectiveness studies (Wells, 2016a) and corroborates the efficacy of T/E DBL as a viable pedagogical approach for promoting higher order thinking and deep understanding of connections between content and practice. Though compelling, the implied significance of these findings must be tempered by limitations of this research. Much more research is needed to address these limitations, with particular attention to establishing a more rigorous alignment of assessment items with the intentional teaching of targeted content and practice inherent within T/E DBL.

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A Study on the Relationship between the Local High School Student's Information Utilization and the Learning Behavior about Manufacturing

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Abstract

Nowadays there is little difference between town and country in the way people live.

We think the student's respective regional communication is related to a way of information utilization every area.

We did a survey by questionnaire about information utilization to the high school student, and his friend who live in an area and an urban area.

As a result, the high school student who lives in a local area was doing characteristic information utilization. The information was being utilized as behavior of manufacturing. We found the relation of the learning behavior about information utilization and manufacturing in various factor.

Keywords: High school students, information utilization, learning behavior

Introduction

Toyama showed area information collection was performed aggressively at the bed in which he has the great interest to a residential area, and that a student tends to be utilizing various media[1)].

A population decrease in an area is developed in Japan. Activation of communication in the area is needed to activate an area. Learning in an area can think the communication activation concerned with social information on an area is indispensable, and is formed through sharing of regional information. Resident's area participation is also necessary. It's necessary to be to investigate the area communication reality of the high school as preliminary consideration of an area communication investigation in an area and consider how a problem in area information circulation is related to behavior for manufacturing.

Print media such as community information publications and local newspapers and a broadcast such as local televisions and radios.

It is included from utilization of CATV and constructed network of information to the service which made low Cal. on the recent net the subject. Development and the spread of the various communication media out of which an area media theory study has been formed continually made a communication map in an area grove meeting change completely. Grasp of the communication situation in the local community becomes difficult by the society which made the conventional single area media the center. Complicated communication will be numerous and be, and is bilayer more-like by the current state by appearance and the spread of an information terminal of multiple functions for smart phone, and is developed. It's the feature to sort student's area from this study and analyze a way of information utilization.

Japanese technology education

The contents by which "the independent attitude" and "the settled power" are regarded as the high-level scholastic aptitude can judge a school education in Japan from today's educational flow which also esteems a thought judgement as well as knowledge and a skill, etc.. Such as causing of own affirmative sense is considered as the ability of the carrier development again, I can think the field which concerns a present-day educational problem big.

Yamada device which raises a motivation of manufacturing through teaching materials. But I thought there was something which also has an influence on the will of the manufacturing besides the education method[2)3)].

Ohashi is different from the school kind as the elementary school and the junior high school in manufacturing in a development stage at an elementary school and a junior high school[4)], it becomes possible to plan for a skill rise for further manufacturing by its empirical or a child and a student understand a way of manufacturing logically according to the development stage, and acquiring a skill. It's being told. The information a learner gets is big and related it's empirical and to understand logically, and it can be said that a readiness to learner's manufacturing is changing.

Purpose

It becomes uniform for information utilization and how to learn by the spread of the internet. But the characteristic peculiarity of the information utilization and the relation with the learning behavior of manufacturing of the local high school student are considered. The purpose of this study is to make the relation between the local high school student's information utilization and the learning behavior about manufacturing clear.

Method

A survey by questionnaire was performed to 80 students of a Japanese B high schools in Ashiya-city, Hyogo with 91 students of a Japanese A high school in Kitauwa-county, Ehime in October, 2016 and November. An A high school in Ehime Prefecture is away from the city in a mountainous region. That's local school. B high school in Hyogo Prefecture is near an inner city and is a traffic convenience. That's school in the city. We had the way to investigate learning behavior every media from data of a questionnaire.

We asked 4 laws（The will he would like to make with information）by the free description about the contact degree and the will of the manufacturing of the book, web, SNS（Social Networking Service), the whole country television, the local television, the radio, the newspaper, the father and the mother.

High school student's information utilization and the learning behavior about manufacturing

The degree of the will of the respective sources and the manufacturing by information of a local student is indicated in Table1. The degree of the will of the student's respective sources in the city and the manufacturing by information is indicated in Table.2. Both students have high dependence for information collection through a network. The big difference is not seen between the local student and the urban student.

Table 1: The respective sources and the manufacturing by information of local student

Local	Book	Web	SNS	Network Broadcast		Radio	News paper	Library	Father	Mother
				Wide	Local					
Daily	8	36	70	57	18	3	4	6	49	64
Several times weekly	16	23	14	12	25	6	10	11	14	7
Once a week	10	14	2	5	15	2	9	4	6	6
Several times monthly	16	6	3	9	11	8	12	11	1	3
Fewer times	28	5	0	4	13	17	13	18	10	4
None	13	5	2	3	8	54	42	40	9	7
Total	91	89	91	90	90	90	90	90	89	91

Table 2: The respective sources and the manufacturing by information of urban student

Urban	Book	We b	SNS	Network Broadcast		Radi o	News paper	Library	Fathe r	Mothe r
				Wide	Local					
Daily	6	39	72	61	21	3	3	4	48	69
Several times weekly	16	26	4	10	15	4	3	1	10	5
Once a week	8	7	1	4	8	6	5	5	3	2
Several times monthly	14	4	1	2	3	8	8	8	6	1
Fewer times	20	3	0	1	17	12	15	18	5	1
None	16	1	1	1	16	47	46	43	8	2
Total	80	80	79	79	80	80	80	79	80	80

Figures 1, 2, 3, and 4 are the figures which indicated the will of the high school student's manufacturing with the high degree of contact of the respective information.

Influence of a book changes neither as shown in Figure 1. A local high school student shows the will of the manufacturing by a web and SNS as shown in Figure 2 and Figure 3. Almost no newspaper influences are shown in Figure 4.

Figure 1: Book and motivation for manufacturing

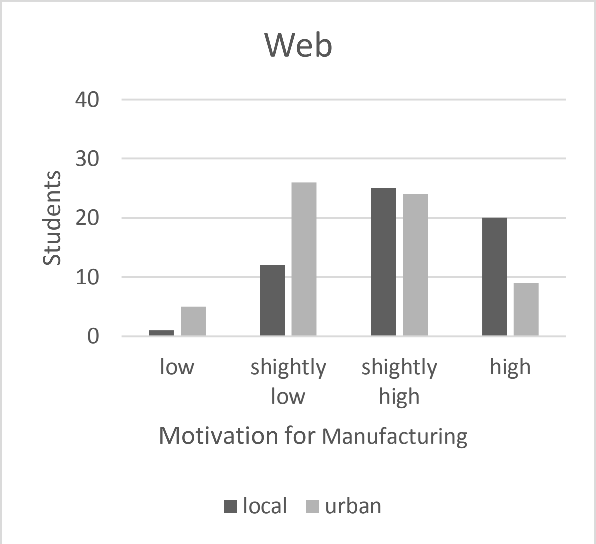
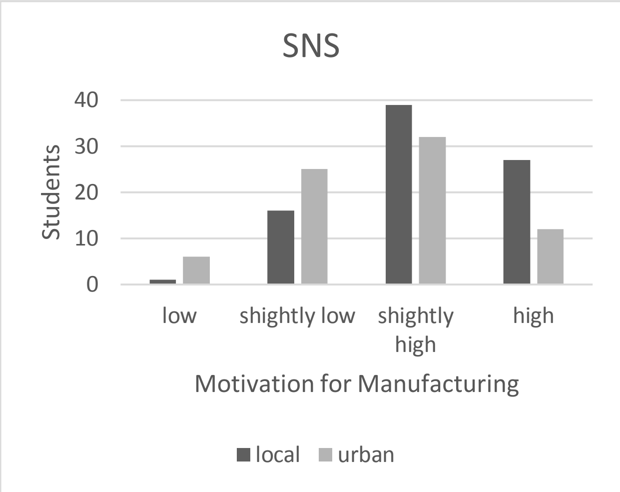


Figure 2. Web and Motivation for Manufacturing

Figure 3: SNS and motivation for manufacturing



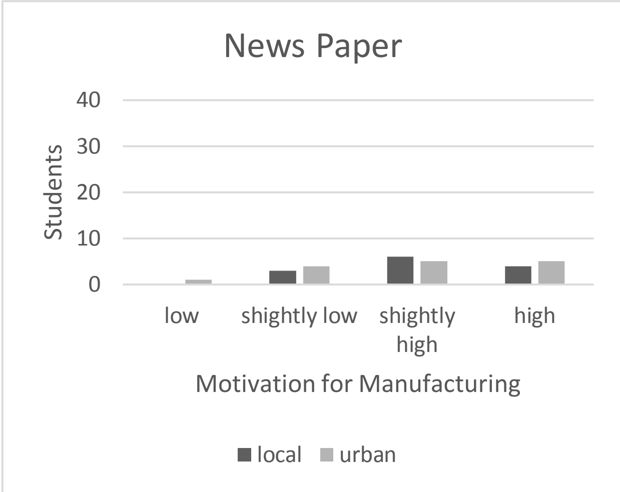


Figure 4: News Paper and Motivation for Manufacturing

Figure 5 is the main Comments of impressions of a local student. A local student wrote more comments.

A point of information is known conversantly, but information in the big area isn't obtained.

I don't also know at localness, but I find out well that I watch television.

It's smaller in the quantity of information collection than the whole country.

Figure 5: Local Student's Comments

Influence by the kind of information

The degree of information contact of the local high school student and the high school student in the city hardly changes. There is a feature in learning behavior by the case that a local high school student gets information on a web and SNS. There are a lot of students who come to have high will of the manufacturing by a web and SNS for a local student. The difference by the newspaper and other sources isn't admitted. A local student can consider that learning behavior of manufacturing becomes active by being conscious that one is left from information.

Conclusion

We did a survey by questionnaire about information utilization to the high school student who lives in a local area and an urban area.

The high school student who lives in a local area was doing characteristic information utilization. The information was being utilized as behavior of manufacturing. There is a feature in learning behavior by the case that a local high school student gets information on a web and SNS. We found the relation of the learning behavior about information utilization and manufacturing. A teacher can raise learning by guiding in a way of student's information acquisition

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Development of Teaching Process for the Measurement and Control System Learning

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Abstract

It is one of the goals of technology education in Japan to notice the measurement and control system used in daily life and to solve the problem of life. Problems related to measurement control have been pointed out that it is difficult to attract students' interests so far. Therefore, we decided to challenge the practice of teaching and its effect on the present study using teaching materials on measurement and control developed so far.

Accordingly practicing lessons using this teaching material (allmay), the following was shown. Through this practice, students are increasingly interested in programs, measurement control, and automatic control incorporated in their lives, and it seems that there has been some effect on them. From the student's impression many opinions were obtained saying "By controlling the model, I could understand the mechanism" and "By programming, it is convenient because I can move things according to my own way".

Keywords: technology education, measurement and control system, daily life, teaching process

Introduction

In Japan's school education, there is a national standard that clearly states the learning objective and learning content called the Instructional Guidelines, and it is revised approximately every ten years. It is scheduled to be confirmed in 2018, and now it is debated for the revision of the next it progresses.

In the current Instructional Guidelines of technology education, many tasks have been pointed out from various viewpoints. For example, lack of learning opportunities to acquire ability to evaluate technology and consider concrete application method from multiple aspects such as society, environment and economy, or lack of learning opportunities to design according to purpose and condition and to devise efficient information processing procedure. Therefore, the government indicated policy on importance of information technology, focusing on programming and information security, emphasis on nurturing ethics concerning attitude and technology to create, protect and utilize intellectual property (MEXT, 2017a, p.179). Therefore, the next Instructional Guidelines indicated that the following opportunities for learning were provided in the "information technology" of junior high school. They are two: "Understanding the mechanism of the measurement and control system, making safe and appropriate programs, checking the operation and debugging and so on.", "Finding and setting problems, in addition to conceive a measurement and control system based on the flow of input and output data, to concretize the procedure of information processing, to think about the process of production and evaluation, improvement and correction." (MEXT, 2017b, p.119). In view of the above, this study focused on programming learning on measurement and control in information technology education at junior high schools, a field of technical education in Japan.

Looking at the preceding research, Idosaka et al. (2011, pp.9-16) reported that autonomous control robot was a teaching material of students' high interest, as a result of practicing lessons using multiple robots for teaching materials. It also shows that autonomous control robot could be effective to students' knowledge, understanding and mastery of skills in devising lessons. However, this lesson is not a simultaneous class, but students themselves are doing independent learning in the time of “Comprehensive learning”. Comprehensive learning is one of Japanese school subject has a Cross-cutting learning. Murata et al. (2016, pp.256-270) have reported that through the activities to create a program to solve 5 puzzles, improvement of interest and improvement of understanding on algorithms have been shown. Meanwhile, a few tasks were left; lesson time was lacking depending on the level of programming ability, such as 25% of students who could not solve applied tasks and time loss due to detailed coding mistakes.

From these studies, the effectiveness of programming learning for junior high school students using robots and puzzles has been demonstrated. However, there are no practical reports focusing on the issues pointed out in the current Instructional Guidelines (MEXT, 2017a). It has been pointed out that it is difficult to relate to life in Japanese “Measurement Control Learning” by programs using robots (Yamamoto.et.al, 2013, pp. 9-14). In this research, in order to effectively advance learning of measurement control by programming, the purpose of the research was to propose a teaching process that directly studied the technique of automatic control incorporated in life. It is considered that learning experiences of techniques related to automatic control in daily life can enhance students' interest.

Instruction and Teaching Materials

Instruction plan of the programming learning

The learning objective of this instruction plan is "to think about the mechanism of automatically controlled products used in life and think about programs that make them even more convenient". This class practice was carried out in 7 hours of the field of "information technology" in Junior high school (table.1). As shown in the table, students learn how to program, by learning how products are controlled by programming, in order to learn the mechanics of automatically controlled products. After that, students also worked on the development of a system that can solve the problems of daily life by using simple teaching materials that students can program. Furthermore, in order to learn to improve the developed system, the students exchanged views within the class. By using extended terminals, it is possible to extend the functions of input and output.

Subject: junior high school third grader, 35 (16 boys and 19 females).

Implementation time: From July 2016 to October.

Materials cost: school-owned.

Table.1 Instruction Plan

Timetable	Class objective	Learning activities	Guidance on teaching
		learning.	y of

Teaching materials

Hardware

The hardware used in this research is a small board equipped with PIC microcomputer (18F14K50), with one speaker and one LED built in the base (Figure 1). In this hardware, various sensors can be added to input / output terminals, and programs can be written by connecting to the PC. In addition, input from the sensor can be made from the connectors of input 1 and input 2, and it corresponds to input by many sensors such as a sound sensor, a tilt sensor, a light sensor, a human sensor and a magnetic sensor. A signal input from the sensor can be output from a music box and LED on the board, and can output from the output 1 connector and the output 2 (motor drive) which is the base terminal.

Software

Control of the hardware is performed with exclusive software packaged in the hardware. This software basically arranges the icons and completes the flowchart, but BASIC and the Japanese version programming language can also be used. Also, it has a function to display Japanese explanation next to the flowchart. With this software, students can easily learn the fundamentals of the program, "order, iteration, branching". Also, it is possible to create complex programs in conjunction with hardware. For example, "Program to play C/F/E (musical scale) when it gets dark". An example of the program is shown in Figure 2.

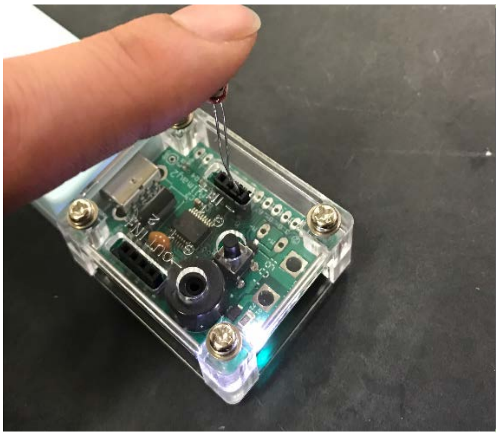


Figure 1: The hardware (allmay) Figure 2: The software (in Japanese)

Results of Class Practice

Example of handling teaching materials in class practice

In 4th, 5th-Learning time "Let's make model using measurement control system", students set technical problems from their lives and society, and made models for solving and created programs. In addition, students clarified the purpose and conditions of measurement and control based on the created program, and made improvements from social, environmental, economic and safety aspects. From this 4th learning time, all the students took a group of three to four students in one group and learned. The technical problems chosen by each group were "railroad crossing", "crime prevention door", "flood gate", "automatic key", " automatic watering machine " and so on.

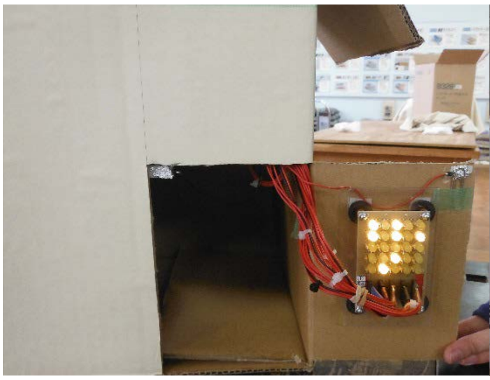
"Crime prevention door"

Contents of life assignment set: There are numerous stolen cases due to absence of home every year, and it is necessary to strengthen crime prevention.

Measures to solve problems: If the thief opens the door without taking the procedure of cancellation, the security system threaten the thief with the warning sound and electronic bulletin board.

Description of model and measurement and control system: The overview is shown in FIG. If the door is illegally opened and closed, a large sound is emitted by the touch sensor, and a message is displayed on the electronic bulletin board (Figure 3).

After the presentation, there were many functions that students want to add in the future, such as reporting to police, taking pictures, and so on. The photo shows the presentation board used for the presentation (Figure 4).



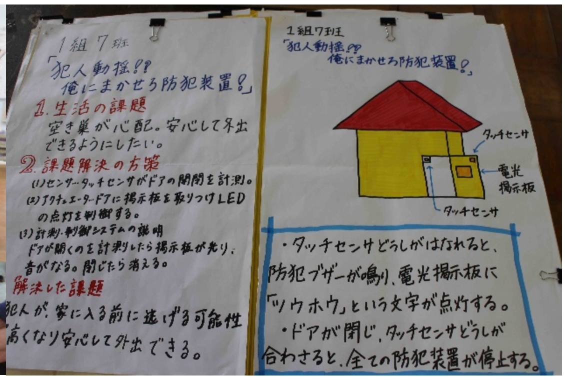


Figure 3: Crime prevention door Figure 4: Presentation board

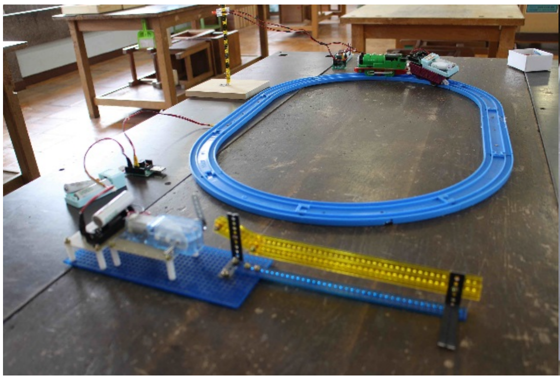
" Automatic watering machine "

Contents of life assignment set: It was found that railroad crossings are established with various controls with sound (warning sound), light (signal), breaker (motor / mechanism). With a railroad crossing close to the station, you can open and close a railroad crossing with efficiency by considering a train that stops at the station and a train that passes through the station.

Measures to solve problems: First of all, they produced a railroad crossing model. When the train approaches, an alarm sounds and the signal flashes. Furthermore, the circuit breaker closes and the traffic stops.

Description of model and measurement and control system: When the light sensor senses the passage of the train, it sounds a warning tone, flashes the signal (LED) and lowers the railroad crossing. Furthermore, if another light sensor senses the train, stop the warning sound, flicker of the signal and raise the breaker (Figure 5).

After the presentation, they recognized several things again. It is difficult to know when the train is approaching and when to remove the breaker. It is necessary to adjust so that it will be at an appropriate timing. The photo shows the presentation board used for the presentation (Figure 6).



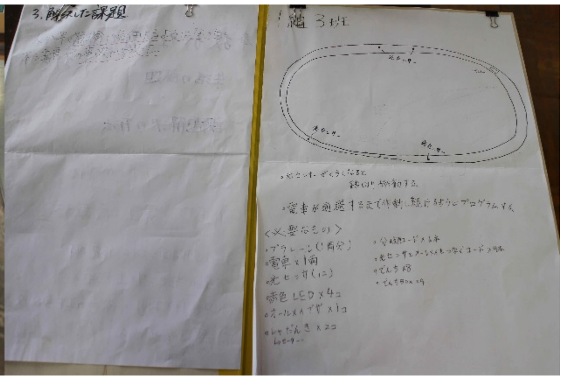


Figure 5 Automatic watering machine Figure 6: Presentation board

Students' Reaction to This Lesson

Students gathered the ideas on the model created in the learning portfolio. This learning portfolio was created before and after their model making. We classified improvement points that they pointed out at the time of model making and presentation from their descriptions (Table 2). In this table, “after presentation (number of students)” means additional number to “before presentation (number of students)”. From this table, many students find improvement points in the linkage between sensors and actuators. In this portfolio, we were unable to direct the students' awareness to the improvement points of the program, so we would like to reconsider them in the future.

In addition, we conducted a survey of 39 students to implement the evaluation of this class practice. The contents of the survey were conducted by four methods based on self-evaluation on improvement of interest in measurement control and knowledge acquisition. In all items, an average value of 3 points or more was obtained, and an interest in the measurement control intended in this research was recognized (Table 3).

Table 2: Improvement points

No	Improvement points	Number of students	
		Before presentation	After presentation
1	Improvement on sensors	12	6
2	Improvement of actuator	14	5
3	Adjusting the program	8	4
4	Linkages between sensor and actuator	20	9

Table 3: Student evaluation

No.	Items	Mean	S.D.
1	Was the class fun?	3.37	0.61
2	Has the interest in measurement control increased?	3.00	0.83
3	Did you understand the flow chart?	3.03	0.67
4	Has the interest in model making increased?	3.27	0.64
5	Were you able to solve the problem?	3.20	0.61
6	Did you understand the mechanism of measurement control?	3.13	0.73

Discussion and Conclusion

Problems related to measurement control have been pointed out that it is difficult to attract students' interests so far. Therefore, in this research, we examined teaching process which studied directly the technique of automatic control incorporated in life, and carried out class practice. As a result of the studies, the interest in self-controlled things around us has increased through this class practice. Also, from the student's impression many opinions were obtained saying "By controlling the model, I could understand the mechanism" and "By programming, it is convenient because I can move things according to my own way". To be interested is a very important element of nursing at an early stage of learning. In the future, we should also discuss how we can enhance learners' interests.

In addition, this research aims at teaching practice on measurement control based on Japanese guidelines for teaching. The development of science and engineering personnel seems to be a very important learning content in the future as seen in STEM education in Europe and the United States. Therefore, with this research as a starting point, we would like to also discuss about international science and engineering human resources development.

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Programming Learning in Elementary Education using Sphero and Tickle

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Abstract

"The programming education" for elementary schoolchildren is conducting various challenges for setting it a compulsory subject in Japan. As a result of having investigated precedent studies, problems to solve about the "selecting teaching materials", "the managing instruction time" and "evaluation of those learned effects to students' ability" were shown. The purpose of this study is aiming to propose a programming curriculum and to evaluate it from school teachers.

Therefore, this study examined an instruction process to learn programming using, "Sphero" and "Tickle" for elementary education. "Sphero" is a robot for teaching material and "Tickle" is a programming software.

In this study, the instruction process was set four hours and final goal was to learn the importance of thinking in order. The research method planned and practiced classes at elementary school, and assessed the effectiveness of the classes from the questionnaire of teachers who was observing.

As a result of testing classes, approximately 80% of the students achieved the goal that were three tasks. In addition, this classes were assessed as a appropriate at elementary school students from the questionnaire of teachers.

Keywords: Elementary education, Curriculum, Programming education, Information education, Class practice

Introduction

Programming education has been beginning to be promoted now in each country. They are thinking to educate of the ability for "logical thought" and "problem solving" of children and are aiming at superiority in the economic growth by promoting of the IT business (Japanese Ministry of Education, 2014, pp.5-17). In the U.K., a class of the computing has been already carried out from 5 years old in a board school (Hashimoto, 2016, website). In Australia, learning of programming from 8 years old to 13 years old was made a compulsory subject from 2016. In addition, in Finland, New Zealand, Korea, various countries including Hong Kong, the programming learning in the elementary course begins (Japanese Ministry of Education, 2014, p.7).

On the other hand, a modification of the education environment by the IT is promoted in Japan. In "the world's most advanced IT nation, creation, declaration" that is one of Japanese policies, it is written down about the promotion of the learning of the programming in the elementary school (The Prime Minister's office, 2016, pp.15-16). Furthermore, in 2020, learning of the programming is going to be made a compulsory subject in an elementary school. (Japanese Ministry of Education, 2016, website). Thus, in Japan as well, promotion of programming education is planned and it is necessary to explicitly show practical guidance methods for the educational site.

We investigated a precedent study on programming learning of the elementary school to examine the location of the problem of the programming learning in this study.

More than 80% of children used commands for discriminant procedure of key inputs and conditional branching as a result that Mori.et.al (2011, pp.387-394) practiced 26-hour programming education using "Scratch" for a fourth grader. From these results, they report that programming is possible at an elementary school stage.

Kikuchi et al. (2013, pp.249-256) taught ten of the elementary school 4th and 5th graders programming guessing 11 hours using the robot (LEGO NXT). As a result, it is reported that knowledge on programming has been confirmed. However, it has not been practiced in general schools, such as children who are interested in the target at university events, or like a one - to - one guidance system.

Yamamoto et al. (2014, pp.21-29) examined for 4th graders, 4-hours class practices learning of the systematic programming using WeDo and Scratch and reported that children learned constant knowledge and skill. However, it is shown in continuation of the learning will and the understanding of the term that improvement of the instruction is necessary. In addition, as data about interest of the programming, it is reported by the impressionistic essay after the class that expression, "it is interesting" "it is fun" decreases so as to become the upper grades (Koyama, 2014, pp.166-169). In these precedent studies, problems such as motivation and the interest of the learner, the degree of the understanding are shown in programming learning.

Kobayashi et al. (2015, pp.228-229) performed class practice of the smartphone application production for fifth graders. However, a problem was shown about the evaluation of those learned effects to pupils' ability. This type of problem is that teachers should deal with preparation. In addition, as a result of having investigated precedent studies, problems to solve about the "selecting teaching materials" and "the managing instruction time" were shown. In other words, to make a better class, the teacher has to examine an "evaluation method" and "instruction time" and "teaching materials" before the programming class.

Therefore, we performed a class practice of the programming learning that examined the teaching materials and instruction plan that we considered to maintain the motivation of the elementary schoolchild. Also, at the teaching materials about this class practice, instruction time, the evaluation method was analyzed by the opinion of the incumbent teacher whom I taught it and visited. In this way, in this study, we suggested class content about the programming learning and analyzed it about an evaluation method, the teaching materials and the instruction time at the point of view of the instruction plan.

Construction and Teaching Materials

Instruction plan of the programming learning

This class practice was carried out in 4 hours of "the integrated study" of the 4th grader(table.1). "The integrated study" is kinds of subject that integrated subject such as Ecology, Sociality, and other subjects in Japanese school. Their learning objectives were set as "they can feel programming needs", and "they can program Sphero in order by group activities, and can make programs."

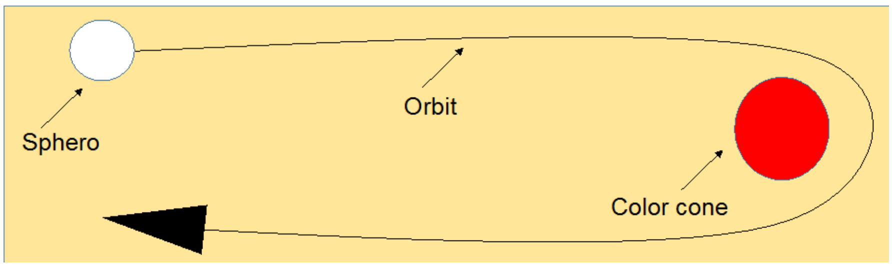
Students learn the basics of programming through various tasks (obstacle avoidance in this classes) by using Sphero which is hardware in classes and Tickle which is application dedicated to tablet terminals. Learning in the game form preserves the interest of the student and it is thought that ingenuity in the process of programming creation also occurs.   Learning in the game format will keep children's interests and it is thought that children's ingenuity in the course of programming creation will also occur. Also let the children experience the radio control operation and the program operation, and make the program aware of convenience and necessity.

Table 1: Instruction plan

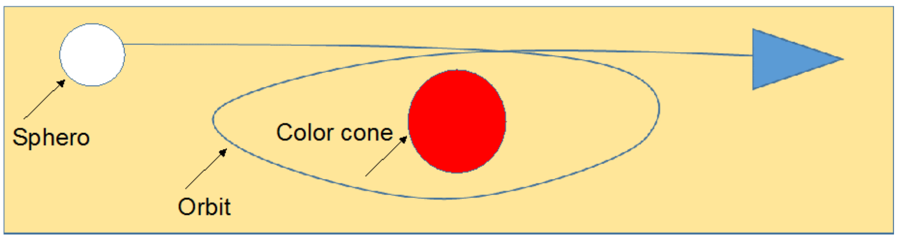
timetable	Class objective	Learning activities	Guidance on teaching
1st-Learning time	"Let's learn about programs around you"	Students notice common points between programs around them (such as athletic meetings programs) and machines moving programs. Students learn that the program progresses things in order.	The teacher shows Sphero and asks questions based on familiar things and products (such as athletic meetings program) so that children's interests can be enhanced from the beginning.When showing Sphero, the teacher introduces as if it is moving with magic, it leads to motivation for learning. The teacher organizes the commonalities the children noticed and makes the program aware of things to progress things in order.
2nd-Learning time	"Let's learn about the convenience of a programing"	Students actually experience the actions of Sphero through radio control operation of Sphero. Students observe how they can repeat exactly the same behavior when controlled by a program.	When students operate Sphero in each group in radio control, the teacher sets the time and takes care that all the students can touch. The teacher uses the fact that Sphero is spherical, let students experience the difficulty of manual operation. After repeating the radio control operation that meanders around the color con the teacher asks the question whether it can repeat the exact same action and notices the difficulty. By programmatic control, the teacher makes the students observe how to repea the same task accurately, and makes the students learn the difference from the radio control operation and its merits.
3rd-Learning time	"Let's program (Sequential task)"	Students learn about commands of basic programs (forward, backward, curves, power etc.). Students tackle sequential tasks 1 and 2 in groups. Before actually creating the program, students discuss in the group and make it easy to summarize the program's policy in the flowchart.	The teacher pairs Tickle and Sphero and lets the students learn Tickle's basic command by using the electronic blackboard. The teacher prepares tasks using color cones. Prior to starting the programmin students will use the flow chart to conduct discussion activities and summarize the policy as to what kind of program to create. Task 1 and task 2 can be cleare with a combination of basic commands without using complex control such as loop.
		The group finished tasks 1 and 2 creates the program of task 3 using iterative control.	In task 3 as well, the teacher instructs to begin with creating a flow chart through discussion. Using iterative control, the teacher instructs you to

There are three tasks of programming used in the lesson. An overview of each task is shown in Figure 1. Task 1 is a program returning around the outside of the color cone and programming sequential processing that can be solved with the most basic commands. Task 2 is a program that goes straight after completing a round around the color cone. This Task 2 is a programming that adds commands to children who solve Task 1 to control more accurate Sphero. Task 3 is an application task with a high degree of difficulty, such as returning to a predetermined position, which takes repetitive instructions during the program. This Task 3 is an application programming utilizing repetitive instructions in order to make Task 2 programming more structured.

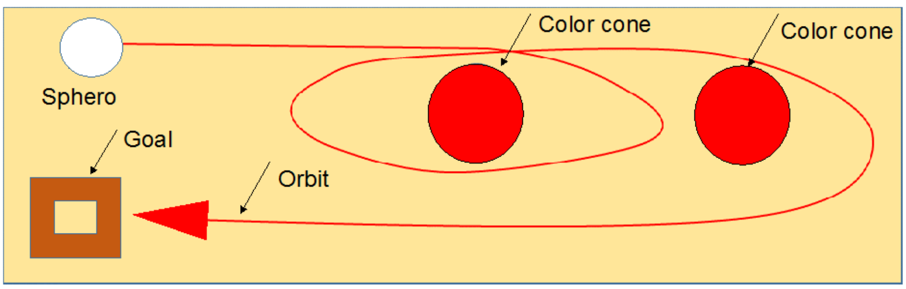
Task1 ： Sequential initial task



Task2 ： Sequential application task



Task3 ： Iterative task



About Sphero

Sphero has built-in accelerometers, wheels, LEDs and computers that control them, in high-density polycarbonate balls of tennis ball size (Figure 2). Because it is made of high density polycarbonate, it will not break even if it is dropped, and it is very rugged design because it also has water resistance (Otsuka, 2014, website).

Figure 2: Overview of Sphero

Since Sphero can control by dedicated application with pairing of Bluetooth, it does not cause crosstalk even when using multiple Sphero at the same time. In pairing, the connection between the tablet terminal and Sphero can be distinguished by Sphero's light emission pattern and tablet display. The operation of Sphero can be finely adjusted, it can operate at about 2 meters per second, and the operation time can run for 1 hour with charging for 3 hours. From these features, it can be said that it is easy to handle even for elementary school students. It is actually used in classes in the U.S (Sphero SPRK, 2015, website).

Other than these, in addition to radio control operation, a number of mechanisms showing children's interest are implemented, such as output adjustment, jumping, rotation and other special mobility. Moreover, special application such as "draw & drive" which can move Sphero according to the locus drawn on the screen with finger, and "Sphero Macrolab" which can be more advanced programming are enriched.

About Tickle

Tickle is a dedicated application that applies Scratch as a programming language for teaching the foundation of programming to children (Nomura, 2015, website). Tickle (tickling) is also named from Scratch(scratching). In this application, children can build code blocks and run basic programs, so children can visually learn how programming works. The operation time, speed, and direction can be controlled by entering numbers, and programs can be derived according to specific events such as loops, conditional branches, and the like. Furthermore, since the work screen is written in Japanese, it is also a great merit that it is easy for Japanese elementary school students to handle.

After upgrading, it became possible to operate on various tablet terminals equipped with iOS 8.0 or higher, such as iPad, iPhone, iPodtouch.

Child's Reaction to This Lesson

For the students, the operation using the tablet terminal was relatively smooth, and the students were able to learn the basics of programming in a short time. Also, as a result of incorporating gaming elements, students' interests were constantly high throughout the practice from the observation of student activities. In this practice it is a useful result that the observers and the class teacher reported that all the students worked with learning with the will to the end.

As for the assignment, all groups were able to clear up to sequential Task 2 and approximately 80% of the groups cleared Task 3. In addition, students experienced the necessity of programming by feeling the difference between radio control operation and program operation. In Task 3, a complicated force acts on Sphero and fine adjustment such as stopping at a certain point becomes essential, so a program that calculates power setting and slip is required. Therefore, it was difficult for all groups to solve the task.

Assessment of these Practices

In this study, the research method planned and practiced classes at elementary school, and assessed the effectiveness of the classes from the questionnaire of teachers who was observing.

Survey Items and Methods of Analysis

This practice was carried out for 56 children, and after that, survey was carried out by 14 external observation faculty members.

The contents of the survey were 9 items shown in the Table 2 on the appropriateness of programming learning. The survey result was scored as "Yes" → 4 points, "if anything yes" 3 points, "if anything no" → 2 points, "No" → 1 point, and the mean and the standard deviation were obtained .

In addition, we studied teacher's class evaluation by answer of free description format for getting information in detail.

Result of Survey Items

The results of the survey are shown in Table 2. The number of the assessment shows the number of teachers who evaluated. As many teachers in all the items indicated that they were appropriate "4", the average value was relatively high, exceeding 3.5. Therefore, the programming learning classes and teaching materials practiced in this study were evaluated as being appropriate according to the student's developmental stage.

The expected effect of the class practice proposed this time is to improve the interest and understand the necessity of programming. These are the contents to be learned first before programming skills and expertise in elementary school programming learning and are thought to be important.On the other hand, one of the issues indicated is related to instructional time. In compulsory programming learning, anxiety about the guidance time is a matter which has always been pointed out. It is thought that it is necessary to devise teaching process so that teaching time will not be lacking even in future faculty members.

Table 2: The contents of the survey for assessment

No.	items	Mean	S.D.	assessment 4	3	2	1
1	Were the learning contents appropriate for programming learning?	3.86	0.36	12	2	0	0
2	Were the learning contents appropriate as a 4th grade, considering the developmental stage of the students?	3.71	0.47	10	4	0	0
3	Was the hardware suitable as a teaching material?	3.50	0.65	8	5	1	0
4	Was the software suitable as a teaching material?	3.57	0.51	8	6	0	0
5	Do you think students could understand the necessity of programming?	3.71	0.47	10	4	0	0
6	Do you think students could master basic programming knowledge?	3.57	0.65	9	4	1	0
7	Do you think students were able to increase interest in programming?	3.79	0.43	11	3	0	0
8	Was the time allocation of this lesson appropriate?	3.50	0.76	9	3	2	0
9	Do you think that the teaching process is easy to connect to the next stage?	3.50	0.65	8	5	1	0

Result of Free Description

Tables 3 and 4 summarize the teacher's point of view for teaching practice by free description by positively and negatively. On the positive side, the learning effect to the students, collaboration with other subjects, and the significance of the teaching materials were pointed out. On the negative side, anxiety about budget and personnel, lack of guidance time, anxiety about construction of systematicity were pointed out.

For selection of teaching materials which was a problem from previous research, good responses are also accepted from Result of Survey Items and Result of Free Description. On the other hand, budget and the necessity of teacher training were acknowledged, and it was also necessary to conduct practical research like this research. It is extremely important to set up the tasks according to the developmental stage, and it is necessary to consider the learning objectives and the task assignments of the teaching materials as a list. For that purpose, it is suggested that a systematic curriculum is required, which clarifies the features and learning goals of programming teaching materials, which are on the market, and which scenes in the developmental stage should be incorporated.

Table.3 The positive comments of the free description

Classification	Comments
On learning effect	Students can learn the problem solving skills, collaborative attitudes and the connection between society and programming.
	Students can realize active learning that students can help each other, regardless of their skills through discussion activities.
	This lesson is effective for students' logical thinking ability, attitudes to improve by trial and error, and development of problem solving abilities.
	I felt it important to create the first image, such as the athletic program. It was an effective teaching process to make us aware of familiar programs.
Collaboration with other subjects	In this lesson, you can collaborate with other subjects such as using English articles with subjects overseas programming education.
	It can cooperate with mathematics lessons such as speed and time, angle and figure.
	Thinking in order in other subjects can be widely applied.
	By collaborating with various subjects, we can realize the goodness of ICT equipment and make it more familiar.
Benefits of teaching materials	It was good that the students knew where they made a mistake at once.
	Students can realize the gap when a real product is moved by a program.
	First I felt it was effective to learn the basics of the program on iPad etc.
	An easy-to-understand programming material such as Sphero is reliable.

Table 4: The negative comments of the free description

Classification	Comments
Anxiety concerning budget / personnel reservation / training	In elementary school there is concern about talent shortage from the teacher's skill side.
	I felt it necessary to enrich the workshop on programming learning.
	Inadequate understanding of teachers / lack of facilities
	Budget, human resources, training issues
	Although there are various problems such as budget and human resources, programming learning does not start as long as it does not forcefully give direction.
Problems related to teaching time	There is concern about delay in class due to malfunction of equipment.
	There was a time problem such as the time of the last summary being shortened.
Collaboration with other subjects / Systematicity of elementary and junior high schools	It is necessary to make an annual instruction plan considering cooperation with other subjects and junior high school.
	Necessity of systematic study
	Because mathematical thinking was also a necessary class, some students who were not good at arithmetic faced difficult times.

Conclusion

The purpose of this study is aiming to propose a programming curriculum and to evaluate it from school teachers. Therefore, this study examined an instruction process to learn programming using, "Sphero" and "Tickle" for elementary education. In this study, the instruction process was set four hours and final goal was to learn the importance of thinking in order. The research method planned and practiced classes at elementary school, and assessed the effectiveness of the classes from the questionnaire of teachers who was observing. As a result of testing classes, approximately 80% of the students achieved the goal that were three tasks.

Again, it is extremely important to set up the tasks according to the developmental stage, and it is necessary to consider the learning objectives and the task assignments of the teaching materials. For that purpose, we could corporate with each county to make a systematic curriculum.

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Development and Implementation of Teaching Material based on STEM Education for Japanese High School Students to create a "Magnetic Top": Discussions for Enhanced Understanding

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Abstract

This study examines the outcome of an activity based on Science, Technology, Engineering, and Mathematics (STEM) education to create a magnetic top in a Japanese high school science class. The experiment involved winding an enameled wire around a bolt to create an electromagnet. Two groups were formed among students with one group using iron bolts and the other stainless steel bolts to promote discussion on the properties of an electromagnet. The group using iron bolts was successful in creating an electromagnet while the group using stainless steel bolts failed to do so. In this way, a situation was created for intentional discussion. Besides this, a strategy to foster discussion, "Think-Pair-Share," was used to promote understanding about the nature of the coil. This experiment was conducted in a one-hour class in December 2016 for 54 high school students of 12th grade in Japan. Three important findings were noted after the experiment: 1) The group using stainless steel bolts contributed more to the discussion since their outcome was negative. 2) The "Think-Pair-Share" was effective in encouraging discussion that was wide-ranging and from various perspectives. It was clear that discussion between two people was important. 3) The teaching strategy of inducing cognitive conflicts could deepen discussion and eventually lead to self-learning, consistent with STEM education's goals.

Keywords: STEM education, Magnetic top, Cognitive conflicts, Think-Pair-Share

Introduction

The method of implementing natural science education in Japan varies greatly between primary education and higher education. The former is based on the course of study, but the latter uses standards set by the educational institution. This difference can be seen when teachers develop educational materials. In the former, teaching materials are developed in accordance with the course of study. In the latter, teaching materials are developed in accordance with the educational policy of the institution.

Such a gap between the education systems of primary and higher education leads to serious differences in educational values among educators. In some cases, the learner acquires knowledge in primary education that does not apply to higher education, creating a knowledge gap. Therefore, learners may not keep up with courses in higher education. There are few studies aimed at resolving the gaps in elementary, secondary, and higher education. To overcome these gaps, we should create new standards.

The "Science and Engineering, Human Resource Development Strategy," published by the Ministry of Education, Culture, Sports, Science and Technology (2015), similarly intends to create new standards. This publication promotes the continuous and systematic development of gifted and talented students through project study. In the face of a decreasing workforce population, this strategy promotes efforts to develop science and engineering personnel with high added value. According to the study done by Senda(2013), this strategy is based on STEM education in Europe and the United States but also takes into consideration Japan's unique efforts in terms of content.

Teaching materials based on Science, Technology, Engineering, and Mathematics (hereinafter referred to as "STEM education") education were used in class practice. STEM education is a learning process leading to inquiry, problem solving, creativity development, collaborative research, and so on beyond the subjects, school types, and grade frameworks, and included elements for lifelong learning. Specifically, it refers to a kind of education that creates new concepts while spinning fragmentary concepts, and as questions begin to get resolved, new questions are raised. Furthermore, the concept of STEM education can be used for continued learning at higher levels as well, including self-learning. It results in in-depth discussions on exploratory activities and practice, such that it ultimately results in self-learning.

Purpose of research

To understand the processes of developing an electromagnet and its properties, in this study, new teaching material were used to create a "magnetic top" using electromagnets and reed switches. A magnetic top comprises permanent magnets and electromagnets and is one of the well-known science toys in Japan. This research is aimed at implementing STEM education in high school science.

Research Method

Investigation timing and object

This study was conducted in a one-hour class in December 2016 for 54 high school students 2th grades in Japan. We adopted the STEM education perspective and carried out class practice focusing on the dialogue activities in the setting of a natural phenomenon starting from cognitive conflict.

STEM education system to promote self-learning

According to the "National Research Council of the National Academies" (2012), the method of practicing STEM education is described in the "K-12 Framework for Science Education." We decided to adopt the following flow with reference to this method.

Setting assignment ⇒ Planning and execution of investigation ⇒ Data analysis and interpretation ⇒ Mathematical interpretation ⇒ Construction of explanation ⇒ Discussion based on evidence ⇒ Information gathering and evaluation.

In particular, the "K–12 Framework for Science Education" outlines methods of STEM education that include disciplinary core ideas, crosscutting concepts, and practices. Disciplinary core ideas explain phenomena related to natural science and are precisely constructed through daily activities and social life. Mathematics plays an important role in the crosscutting concepts, which help students understand the meaning of core concepts beyond the subject area and grade. In practice, teachers can expect sustainable learning by using structured crosscutting concepts that encourage new questions. According to the K–12 framework, teachers can provide a context of learning by coupling practice and disciplinary core ideas. Furthermore, the framework urges teachers to instruct students in practices and crosscutting concepts in context, not in the vacuum state. In other words, the practices become the crosscutting concepts that bridge the disciplinary core ideas.

This study chose the theme of implementation after considering core concepts from multiple areas, sustainability, and things related to entrance examinations. The magnetic top is used to help students learn about the electric field in physics, but it also requires a knowledge of technology, engineering, and mathematics for students to make it themselves and understand its principles. Teachers begin using the magnet beginning in the fifth grade of elementary school. After that, the magnet can form a sustainable learning cycle on the same theme that can be used up to the university. Questions on electricity and magnets frequently appear on high school and college entrance examinations.

Developing teaching material to induce cognitive conflict

The method of creating a "magnetic top" is shown in Yamaoka et al. (2017). We created a "magnetic top" using the tools shown in Figure 1.

Figure 1: Preparations for making “Magnetic top”

Normally, a top rotation will stop if time goes by. However, in Figure 2, as can be seen, the "Magnetic top" begins to rotate. In the case of this teaching material, the top keeps turning until the battery runs out. In this sense, this phenomenon could be used as a teaching material to start a dialogue among students from the evident cognitive conflicts.

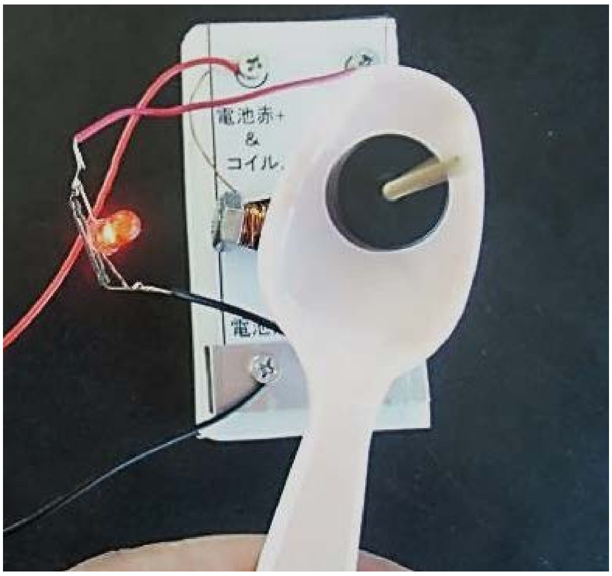

Figure 2: The top keeps turning

This experiment involved winding an enameled wire around a bolt to make an electromagnet. Therefore, as shown in Figure 3, straw was placed on the bolt and an enameled wire was wound from above. As a result, it was possible to replace the bolt after winding the enameled wire.

Figure 3: The bolt inserted into straw

As shown in Figure 4, two types of bolts were prepared. One was a stainless steel bolt and the other an iron bolt. The bolts were somewhat different in color, but made using the same standards. Two groups were formed with one group using iron bolts (hereinafter referred to as "iron group") and the other stainless steel bolts (hereinafter referred to as "stainless steel group"). Each group consisted of 27 people. The students were randomly divided into two groups within classes in which the target students were those who had scored almost the same on the regular examination conducted in the first year of high school. Therefore, homogeneity is preserved with regard to the results of the target students.

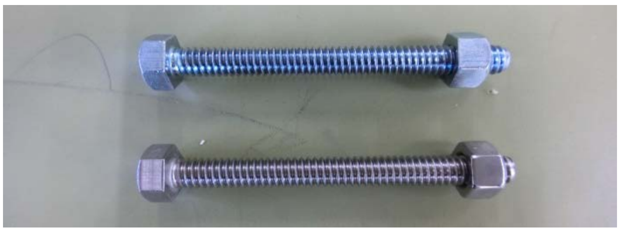

Figure 4: Two types of bolts actually used

An electromagnet energizes a coil wound around a magnetic core. Therefore, the iron group succeeded in creating the electromagnet while the stainless steel group did not. Although, as shown in Figure 5, there were some color differences between the two types of bolts, iron bolts possess the property of being attracted to magnets. In this experiment, the top was the magnet itself, and all the students had the magnets. Considering that the stainless steel group could distinguish the iron bolts, opportunities became evident to confirm the properties and definition of electromagnets.

Through such an intentional condition setting, we designed classes that induce cognitive conflict and invigorate debate to explore the cause.

Implementation of worksheet and questionnaire survey

To analyze students' enhanced understanding, a "Think-Pair-Share" worksheet was created to be used in the class, which focused on the descriptive content. In the worksheet, the following two questions were asked:

Question 1 : How do you make a top that keeps turning forever?

Question 2 : How do you explain this phenomenon?

Analysis protocol using Text Mining

The description in the worksheet was analyzed using the text mining technique. This study was performed using the text analysis system KH Coder Ver. 2.Beta.32 (hereafter, "KH Coder"), developed by Higuchi (2014). KH Coder analyzes a variety of qualitative data, such as text, audio, and video. This method incorporates aggressively specific methods of content analysis, and can perform quantitative analysis of the data as well. By using KH Coder, the entire text can be divided into the smallest possible units; as a result, it is possible to extract more term patterns. In this study, term patterns appearing in the description in the worksheet were extracted using KH Coder, and were developed from these results.

Network of collocation in KH coder

KH Coder can divide data into units called morphemes, the smallest possible units of text, and can thereby extract more apparent term patterns. The extracted terms are drawn in a circle; circles appearing pattern similar can draw a network of collocation connected by a line. The greater number of occurrences of an extracted term, the larger the circle becomes, and the appearance pattern resembles closely, the line becomes thick that connects the circle each other. In this study, the KH Coder network of collocation was drawn in order to investigate the implementing STEM education in high school science.

Results and Discussion

The study was conducted at a high school in Ishikawa Prefecture. The actual practice time is two hours. This study was put into practice following the steps below.

1st step: Asking questions and defining problems. Why does the permanent magnet keep rotating?

2nd step: Developing and using models.

3rd step: Planning and carrying out investigations. When creating an electromagnet, students were divided into two groups: one using an iron core and one using a stainless-steel core. The iron group succeeds in the experiment, but the stainless-steel group fails the experiment. Here, the class discusses why the iron group succeeded while the stainless-steel group failed. In order to answer this question, students require knowledge of pole switching and the ferrite magnet used as a frame.

4th step: Analyzing and interpreting data.

5th step: Using mathematics and computational thinking. Students might think that the graphic reed switch turns on when the angle with the magnet is about 45 degrees. The strength of the electromagnet is proportional to the product of the number of turns of the coil and the strength of the current flowing through the coil. Based on the properties of these coils, we rebuilt the experimental plan and tried again. The stainless-steel group tried increasing the number of turns, but they still did not succeed. One group noticed that the color of the iron cores was somewhat different. Therefore, students might hypothesize that the materials are different. Groups who noticed the difference in core materials repeatedly examined how to prove it. The frame material is a ferrite magnet. I brought the magnet close to the coil and students decided whether it was iron or not, depending on whether it could be attracted. By checking the definition of the electromagnet, students could confirm what effect the iron core had. In fact, we observed the permanent sesame that moved and repeatedly discussed why the coma turns.

Analysis of the free description of the worksheet

In the description in the worksheet created during the lesson, the emerging patterns of words used were extracted. Tables 1 and 2 summarized the number of occurrences of extracted words in the description results. Table 1 summarizes the description results of the iron group, and Table 2 that of the stainless steel group.

Table 1: Number of occurrences of extracted words from the iron group (A part)

Question	Extracted word	Think (n=27)	Pair (n=27)	Share (n=27)
Question 1	Coil	4	3	38
	Motor	0	0	25
	Magnet	7	9	25
	Centripetal force	0	0	17
	Magnetic force	11	7	14

Question 2	Coil	12	7	17
	repulsive forces	6	2	17
	N poles and S poles	4	1	16
	Rotation	8	1	8
	Magnet	5	1	7

Table 2: Number of occurrences of extracted words from the stainless steel group (A part)

Question	Extracted word	Think (n=27)	Pair (n=27)	Share (n=27)
Question 1	Motor	2	4	25
	Coil	0	1	21
	Magnet	4	3	20
	Magnetic force	9	9	17
	Current	7	5	8
Question 2	Motor	2	2	16
	Current	3	3	13
	The plus electrode and the minus electrode	2	4	12
	Magnetic force	6	10	9
	Force	5	5	8

As shown in Table 1, the words "motor" and "centripetal force," which had never been used in discussions between two students was found to be often used in the discussions shared by the whole class. It was presumed that this was a scene shared by the whole class, describing what the specific presenter mentioned directly. On the contrary, as shown in Table 2, the terms shared by the whole class could be used to some extent in a discussion between two people. It can be inferred that this would be a good conversation between two students.

Network of collocation for the "Think-Pair-Share"

Networks of collocation were drawn based on the description in the worksheet of both the iron group and the stainless steel group. The minimum number of occurrences was extracted five times more terms. The resulting networks of collocation concerning the "Think-Pair-Share" activity are shown in Figures 5 and 6.

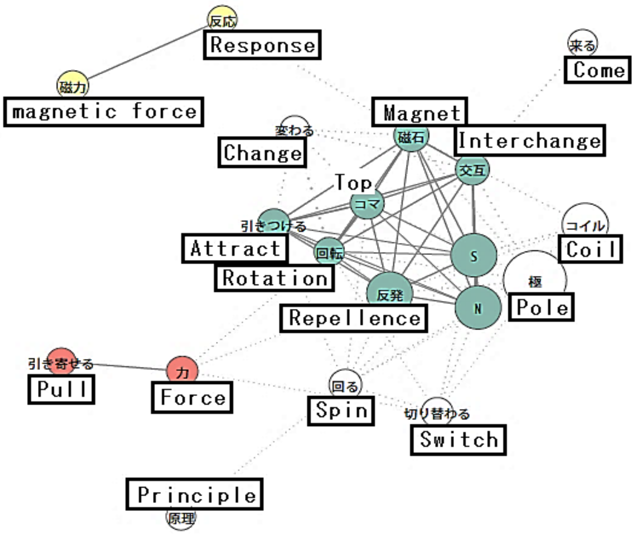

Figure 5: Networks of collocation for the "Think-Pair-Share" activity (the iron group)

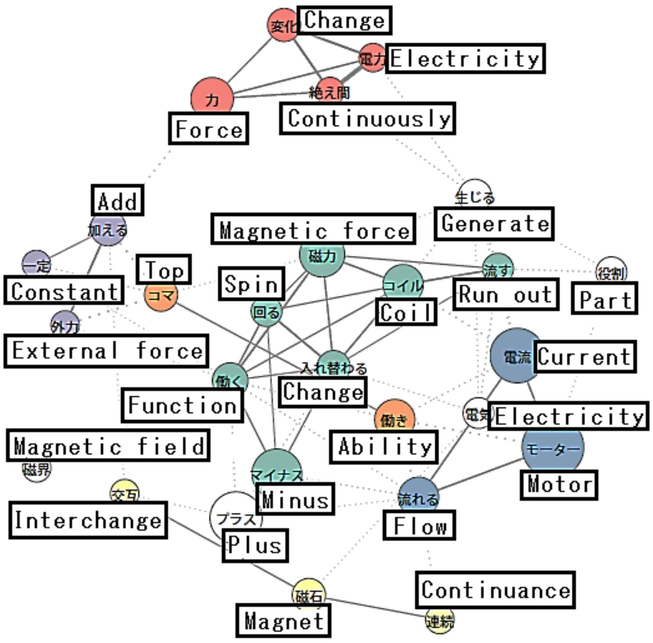

Figure 6: Networks of collocation for the "Think-Pair-Share" activity (the stainless steel group)

As Figures 5 and 6 indicate, a lot of related words and phrases were extracted by the stainless steel group more than the iron group. Additionally, the stainless steel group not only had a large number of extracting words, but also many extracted words and phrases could explain the principle. For example, it was related phrases such as "Coil" and " Magnetic force", "Motor" and "Current". These were one of the evidences that a discussion such as explaining the principle of the motor and the principle of permanent sesame was done. Understanding the phenomenon while explaining the principle led to an essential understanding. In this way, it seemed that the stainless steel group was undergoing constructive debate. And, it will trigger self-learning attitudes suggested by STEM education. Therefore, it was inferred that it was the stainless steel group that the discussion was active.

In this research, we focused on the number of words used in the discussion. However, we could not investigate the contents in this study. Therefore, next study focused on the contents of the discussion and looked forward to the consistency with STEM education.

Conclusion

This study examines the outcome of an activity based on Science, Technology, Engineering, and Mathematics (STEM) education to create a magnetic top in a Japanese high school science class. As a result of implementation, three important findings were noted after the experiment: 1) The group using stainless steel bolts contributed more to the discussion since their outcome was negative. 2) The "Think-Pair-Share" was effective in encouraging discussion that was wide-ranging and from various perspectives. It was clear that discussion between two people was important. 3) The teaching strategy of inducing cognitive conflicts could deepen discussion and eventually lead to self-learning, consistent with STEM education's goals.

Acknowledgement

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New Technology Education Curriculum in National Curriculum in Korea and its Implications to Global Technology Educational Circles

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Abstract

'Technology' is one of the newest subject in common educational institutions worldwide. The study of technology and resulting curriculum content being taught in schools is currently a global effort that continues to gain momentum.

Technology education profession has become less enamored with tools, machines, processes, and products and is becoming more interested in broader topics of significance, such as technological systems, problem-solving activities, impacts of technology, and even the integrating with other disciplines such as science and mathematics for decades. This new and growing interest has caused the technology education profession to address many topics including goals, curriculum organizer, integration and so forth.

In Korea, technology education is approximately one-half of a compulsory subject, 'Practical Arts' at the elementary and 'Technology-Home Economics' at the secondary level nationwide.

A national curriculum of two subjects, Practical Arts and Technology-Home Economics for all students in Korea was newly revised in 2015. Technology education curriculum in new Korean national curriculum is made up of two main areas: (1) Technological system including production technology, transportation technology, and communication technology and (2) Utilization of technology including standard, invention, and sustainability.

This study covers goals, curriculum organizers and/or contents, achievement standard of technology education in the two subjects, 'Practical Arts' and 'Technology-Home Economics' in Korean national curriculum. Some challenges and opportunities like an appropriate universal curriculum contents of technology education as an integral part of general education in global village including Korea are also discussed.

Keywords: Korean Technology Education, Curriculum Organizer, New Curriculum Organizer, National Curriculum, universal curriculum contents

Introduction

The increasing importance and influence of technology on individuals and society is forcing general educators to include technology education in order to help students to understand technology, use technology wisely, and know how to control technology in order to meet societal change. Vocational oriented technology education was acceptable then and general technology education is needed now around the world for the last few decades. Justification of technology education differs from one country to another.

Technology education as an independent subject and integral part of general education began to be offered to secondary students since 1970 under the name of 'G*isul*' (it literally means technology) in Korea. Contributions of technology education to the cause of Korean education and industry have been great by providing technological knowledge and capability. On the other hand, there have been issues and problems about technology education curriculum, instruction, and teacher education since 1970 in Korea

Recently Korean Government revised mandated national curricula for kindergarten, elementary, middle and high schools in 2015.

The purpose of this study was twofold: to analyze major characteristics and a framework of new national technology education curriculum and to suggest its implications to global educational circles including Korea.

Following research questions were addressed in order to analyze major characteristics of new national technology education curriculum and to suggest its implications to global educational circles including Korea, following research questions were addressed:

(1) What are characteristics of technology education in Korean national curriculum?

(2) What is a framework for technology education in Korean national curriculum?

(3) What are implications to global technology educational circles?

A variety of literature including Korean curricula was reviewed for the purpose of the study. A brief Korean educational system and school curricula are described in order to promote an understanding of Korean technology education.

Korean Educational System and Curriculum

The current Korean school system is the singular track, ladder-type schooling of a 6-3-3-4 pattern. Figure 1 shows the structure of the formal Korean educational system. Education in Korea is compulsory for all children from 6 to 14 years old and between these ages there is virtually 100 percent attendance at school. In general, 99% of middle school graduates entered high school. Middle school graduates are provided with an option for three tracks: general high school, Special purpose high school, and vocational high school. The academic year consists of two semesters. The first semester begins on 1 March and ends on 31 August. The second semester extends from the beginning of September to the end of February.

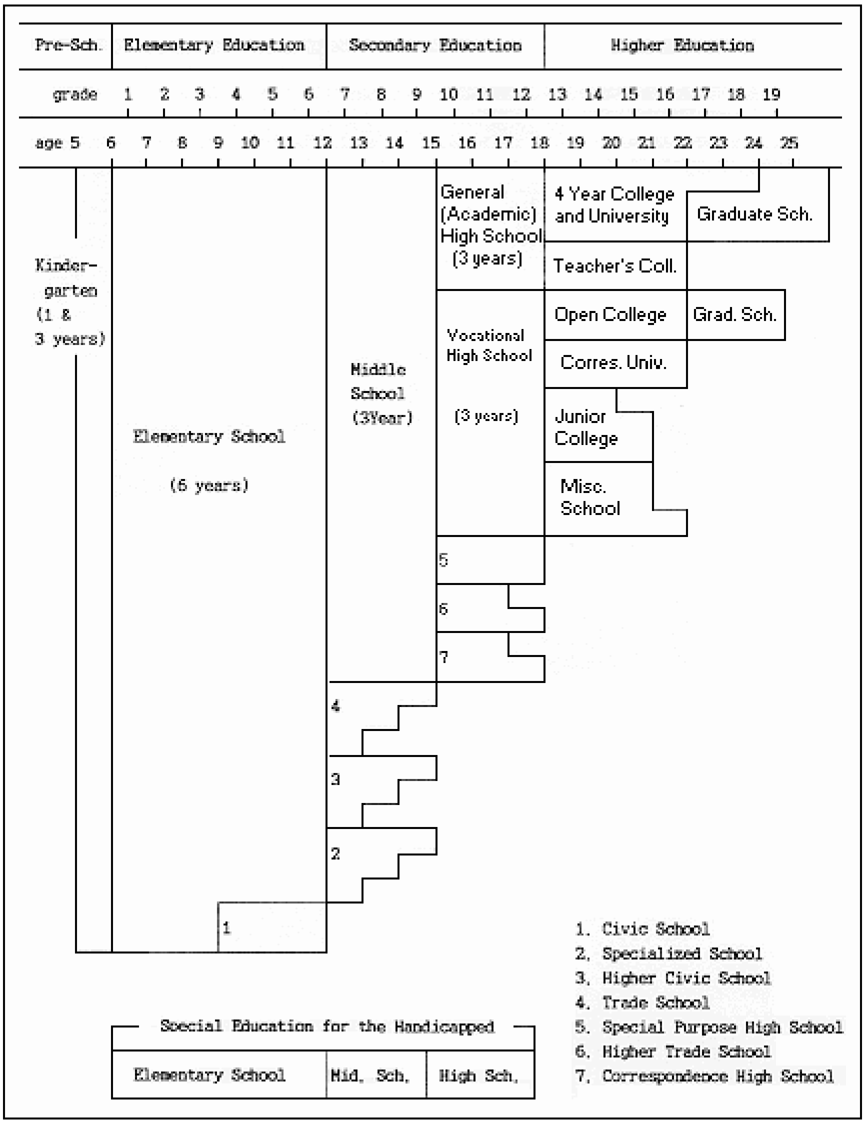

Figure 1: Structure of the Korean educational system

School Curriculum in Korea

Korea has had a strong national system of education since 1948. There is a mandatory statutory common curriculum for each school level across the country. National curricula for each school provide the framework, within which contents are organized by school or teacher, and criteria or the development of textbooks and instructional materials. As a matter of fact, most of the specific details of national curricula for each school level are determined by Ministry of Education. Therefore, school curriculum content and time allocation are uniform with a few variations at the regional and local levels. These curricula are revised as occasion demands every 5, 6 or 7 years to cope with new educational needs and social changes. Suggestions for curricula revision are made by a variety of committees that include curriculum specialists, university professors, classroom teachers, administrators of the Ministry of Education, members of local boards of education, and researchers of educational research institutes.

The newest Korean system of school curriculum was proclaimed in 2015 will be effective respectively as follows:

1) From March, 2017 for 1~2 graders of Elementary School,

2) From March, 2018 for 3-4 graders of Elementary School, and 1 graders of Middle & High School,

3) From March, 2019 for 5-6 graders of Elementary School, and 2 graders of Middle & High School, and

4) From March, 2020 for 3 graders of Middle & High School.

Table 1 shows the new curriculum of elementary school in Korea. The hours of lesson shown on the table represent the minimum school hours allotted for 34 weeks per year. One hour of lesson represents 40 minutes and length of lesson is adjustable to circumstance such as developmental level of students, characteristics of subject contents, school circumstance and so on. Hours of 'Science/ Practical Arts' lesson include hours of 'Practical Arts' lesson only for 5~6graders. Technology education is implemented as a part of 'Practical Arts' for 5th grader through 6th graders at the Elementary level.

Table 1. Elementary school curriculum

Classification \ Grade		1~2 Year	3~4 Year	5~6 Year
Subjects	Korean Language	Korean 448	408	408
	Social Studies/Moral Education		272	272
	Mathematics	Mathematics 256	272	272
	Science/ Practical Arts	Disciplined Life 128	204	340
	Physical Education		204	204
	Art (Music/Fine arts)	Intelligent Life 192	272	272
	English	Pleasant Life 384	136	204
	Sub total	1,408	1,768	1,972
Creative Experiential Activities		336 Safe Life (64)	204	204
Total hours of instruction		1,744	1,972	2,176

Source: MOE (2015). *Junghakyo kyoyukkwajeong (*Notification No. 2015-80 of the Ministry of Education, Appendix 3), p.8. Portions translated by author.

Table 2 outlines the new curriculum of the middle school in Korea. The hours of lesson shown on the table represent the minimum school hours allotted for 34 weeks per year and one hour of lesson represents 45 minutes. Technology education is a half of 'Technology-Home Economics' in secondary schools in Korea since the year of 1997. Middle school student should take subject 'technology-home economics' in the 1st grade through 3rd grade.

Table 2. Middle School Curriculum.

Classification \ Grade		1~3 Year
Subjects	Korean Language	442
	Social Studies(including History)/Moral Education	510
	Mathematics	374
	Science/Technology-Home Economics/ Information	680 (Information 34)
	Physical Education	272
	Art(Music/Fine arts)	272
	English	340
	Electives	170
	Sub-total	3,060
Creative Experiential Activities(including sports club activity)		306
Total hours of instruction for 3 years		3,366

Source: MOE (2015). *Junghakyo kyoyukkwajeong (*Notification No. 2015-80 of the Ministry of Education, Appendix 3) p. 10. Portions translated by author.

Table 3 shows the new curriculum of general high school which is college bound. The units shown on the table are a periods of 50 minutes per week during17 weeks of one semester. One semester consists of 17 weeks and one week consists of 5 days. General high school students select one of two tracks- a humanity and social track or a natural science track when they are in the 2nd (eleventh) grade.

While commonly required subjects in the high school are decided by Ministry of Education, required subjects by tracks are organized by the municipal and provincial office of education and elective subjects by tracks are selected by each high school. Therefore, required subjects by tracks can be varied by the municipal and provincial offices of education. The electives shown in tables 3 are selected not by each student but the school. Once selected by the school, students attending that school have to study that optional subject: these subjects are more appropriately called 'compulsory electives' in this sense.

Table 3. General high school curriculum

Source: MOE (2015). *Junghakyo kyoyukkwajeong (*Notification No. 2015-80 of the Ministry of Education, Appendix 3), p. 14, 16. Portions translated by author.

	Subject areas	Subject Cluster	Common Subject (Units)	Required Completion Units	Elective Subjects	
					General Electives	Career Electives
Subject Cluster	Foundation	Korean Language	Korean Language(8)	10		
		Mathematics	Mathematics(8)	10		
		English	English(8)	10		
		Korean History	Korean History(6)	6		
	Inquiry	Social studies (Including History/Moral Education)	Integrative Society(8)	10		
		Science	Integrative Science (8) Scientific Inquiry Experiment (2)	12		
	Physical Education - Art	Physical Education		10		
		Art		10		
	Life-Culture	Technology-Home economics		16	Technology-Home Economics, Information	Agricultural Bio-science, General Engineering, Creative Management, Ocean Culture and Technology, Home Science, General Intellectual Property
		Second Foreign Language				
		Chinese Classics				
		Culture				
	Sub-total			94	86	
Creative Experiential Activities						
Total Completion Unit						

Curriculum of Technology Education in the New National Curriculum

Technology education goals reflect an increased emphasis on technological literacy and/or competency. Not only goals and curriculum but also the subject name and target students of technology education as an integral part of general education have been changed according to the educational and social changes since 1970.

In late 90's technology education in Korea has undergone a dramatic change. Technology education and Home economics were consolidated into one subject, Technology-Home economics, when Korean Government revised national curricula for kindergarten, elementary, middle and high schools in 1997. There was some conflicts in the process of and after merging the two subjects into one such as organization of curriculum, hours of instructions, teacher education and so on.

A national curriculum of two subjects, Practical Arts and Technology-Home Economics for all students in Korea was newly revised in 2015. The following was emphasized in the new technology education through national curriculum of the two subjects for elementary and secondary students:

First, sequence of curriculum contents needs to considered between Practical Arts at the elementary and Technology-Home Economics at the secondary levels.

Second, the purposes and contents of technology education were organized according to technological system which consist of production technology, transportation technology and communication technology system. In addition to achievement criteria were set up according to suggested contents elements out of three technological systems.

Third, learning experience of technological problem solving was reinforced along with creation, integration and so on.

Fourth, competencies of applying technology to industry & society such as software invention, standardization, and sustainable technology.

Fifth, knowledge, attitude, and activity about safety were reinforced in relation to transportation, vocation and so forth in the new curriculum.

Helping pupils to cultivate technological competence was suggested as a major goal of technology education in 2015 revision curriculum in Korea.

The following purposes were suggested to realize the goal of cultivating technological competence: helping students to cultivate competence of technological problem solving, utilizing technology, and technological system designing on the basis of understanding of technology. Figure 3 shows purposes of technology education in 2015 revision curriculum in Korea.

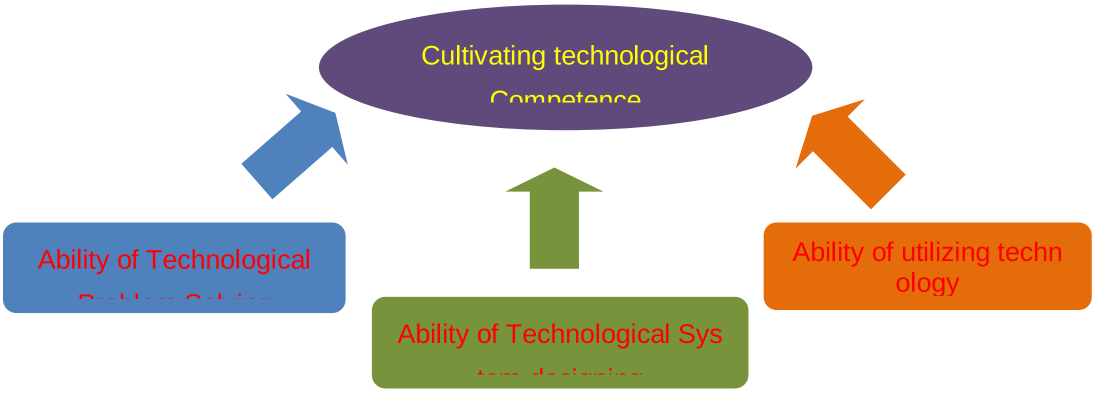

Figure 2. Purposes of technology education in 2015 revision curriculum in Korea.

Technology education curriculum in the new Korean national curriculum is made up of two main areas: (1) Technological system including production technology, transportation technology, and communication technology and (2) Utilization of technology including adaptation, standard, invention, and sustainability. The standard in the 'utilization of technology' emerged as totally new and unique curriculum organizer in technology education. Figure 3 shows framework of technology education in 2015 revision curriculum in Korea.

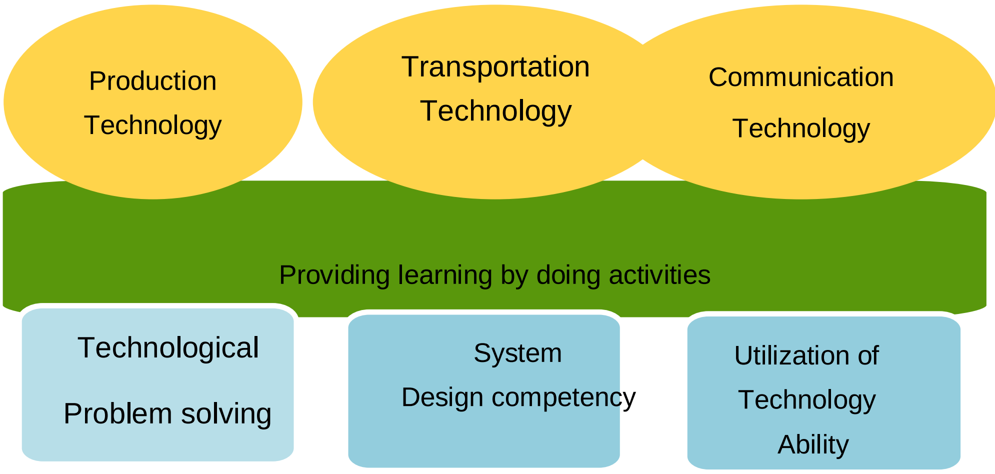

Figure 3. Framework of Technology Education in '15 Revision Curriculum in Korea

Competency of technological problem solving refers to competence to solve technological problems through four major stages: (1) identification of problems, (2) exploring ideas, (3) realization of ideas, and (4) evaluation of solution.

System design competence is an ability and positive attitude to develop technological systems through four of steps of selection of Input, determining process, evaluation of out output, and determining feedback for the purpose of efficient function of the system.

Utilization of technology competence means ability to develop & innovate, integrate, and adopt production technology, transportation technology, and communication technology in a real world in relation to standardization, invention, sustainability.

Table 4 shows framework of technology education curriculum including contents elements for ladder school system including elementary, middle and high school in South Korea.

Table 4. The framework of technology education curriculum for Korean school system

	Area	Core Concept	Contents (Generalized Knowledge)	Content Elements		
				Elementary School	Middle School	High School
Home Life						
World of Technology	Technological system	Creation	· Production technology use a variety of resources to produce useful goods for human life.	· bio-technological system · Cultivation of plant. · breeding of animals	·Manufacturing technological system ·Manufacturing technological problem solving ·Construction technological system ·Construction technological problem solving · Future Technology and bio- technology	·Cutting edge manufacturing technology ·Cutting edge construction technology ·Cutting edge bio technology
		Efficiency	· Transportation technology improves the efficiency of space transfers in humans or objects.	·transportation technology and life. · safety management of transportation means	·Transportation technological system ·Transportation technological problem solving ·New/renewable energy	·Cutting edge transportation technology ·Cutting edge communication technology
		Communication	· Communication technological system produced and processed information and shared by various way and devices to transmit.	· understanding of software · stages of problem-solving. · element and structure of programing	·Communication technological system ·Communication technological problem solving ·Media & mobile Communication	
		Adaptation	· Through rational decision-making processes, humans design their future and respond to advances in	· world of work and vocation · self-understanding and exploring vocation	· Development of technology · Technology & social changes	· technology and vocation · industrial accident

	Utilization of Technology		technology and social change.			· safety of automobile
		Innovation	· The inventions in the problem-solving and standard in the development technology contribute to the innovation and development of the nation and society.	· Invention and problem-solving. · protection of personal information and intellectual property · function and structure of robot	·Technological Problem solving ·Realization of idea for invention ·Technology Utilization & Standardization	· creative engineering design · invention and business starter-up · technical development and standard
		Sustainability	· Humans predict changes in life according to technology development and keep society sustainable.	· Future Eco-agriculture · agriculture experience in life	· appropriate technology · Sustainable technology	· Sustainable development

One of predominant features of new curriculum is an introduction of achievement criterion without suggesting purposes. The achievement criterion is defined a criterion of class activity that is combined contents which students have to learn from a subject with abilities to expect to be able to do after class (MOE , 2015b, p. i) in the 2015 revision national curriculum.

We have some challenges of technology education as follows:

(1) Technology education is a half part of subject 'Technology-Home Economics' currently. We need to secure self sufficient time allotment for both theory and practice lessons in technology Education. For example, we have only 1 or 1/2hour per week for technology lesson in Korean middle schools. Shortage of hours of technology lessons makes unqualified technology education in Korea.

(2) Standardization and sustainable technology have emerged as new and unique curriculum organizer and issued in technology education in Korea.

(3) Do we need a universal curriculum of technology education worldwide?

Dugger appointed "the need for research in what should be the most appropriate universal curriculum content for teaching technology in schools" from a global perspective a couple of decade ago (1995, p. 494).

Science education has common curriculum contents and/or organizers worldwide like physics, biology, chemistry, and earth science. Social studies also have common organizers worldwide such as politics, economy, history, and geography. However we done have a common curriculum organizers for the global technology education.

The following curriculum organizers were suggested in the new Korean national curriculum: (1) Technological system including production, transportation, & communication technology and (2) Utilization of technology including, standard, invention, and sustainability.

Manufacturing, Construction, transportation, communication, bio-technology and so on have been major curriculum organizers since 1980 in USA (ITEA, 1996; Savage, E & Sterry, L., 1990).

Subject contents of Design and Technology were defined as the following five areas (1) design, (2) make, (3) evaluate, (4) technical knowledge and (5) cooking & nutrition by the national curriculum in England (Department for Education, 2013).

Each country has an unique curriculum organizers. It is clear that we are in need of research in what should be the most appropriate universal curriculum organizer and/or content for teaching technology in schools around the globe.

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The Development of New Technology Teacher Education Curriculum in Taiwan

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Abstract

The Ministry of Education of Taiwan has proclaimed a new K-12 technology education curriculum in 2017. In this new curriculum, engineering design is recognized as the core concept in high school technology education curriculum, which guides students to integrate STEM subjects. In alignment with this new curriculum, two studies, which focused on in-serve teacher professional development and pre-serve teacher education program, have been conducted to get the technology teachers ready for implementing the new curriculum guideline.

In the two studies, the authors sought to analyze the content knowledge (CK) and pedagogical content knowledge (PCK) in alignment with new technology education curriculum, thus to identify, develop, and validate the core competencies that should be acquired by the future technology teachers. Consequently, several technology teacher professional development courses have been designed, and the current technology teacher preparation curricula were also reviewed and revised for adaption of the new technology education curriculum.

Keywords: technology education, technology teacher preparation curriculum, content knowledge, pedagogical content knowledge.

Introduction

Technology education in Taiwan formerly emphasized training for a technical profession and the development of life skills; in the past decade, however, the emphasis has gradually shifted to developing an understanding of the nature of technology, choosing appropriate technology, and the ability to solve problems (Figure 1). Even so, in view of the technological and socioeconomic advances in the twenty-first century, people must develop the ability to handle more in-depth learning and knowledge transfer to remain competitive (National Academy of Engineering & National Research Council, 2014). Accordingly, in school education, technology education should play a central role that results in students integrating the conceptual knowledge of science, technology, engineering, and mathematics (STEM) in their efforts to resolve real-world challenges.

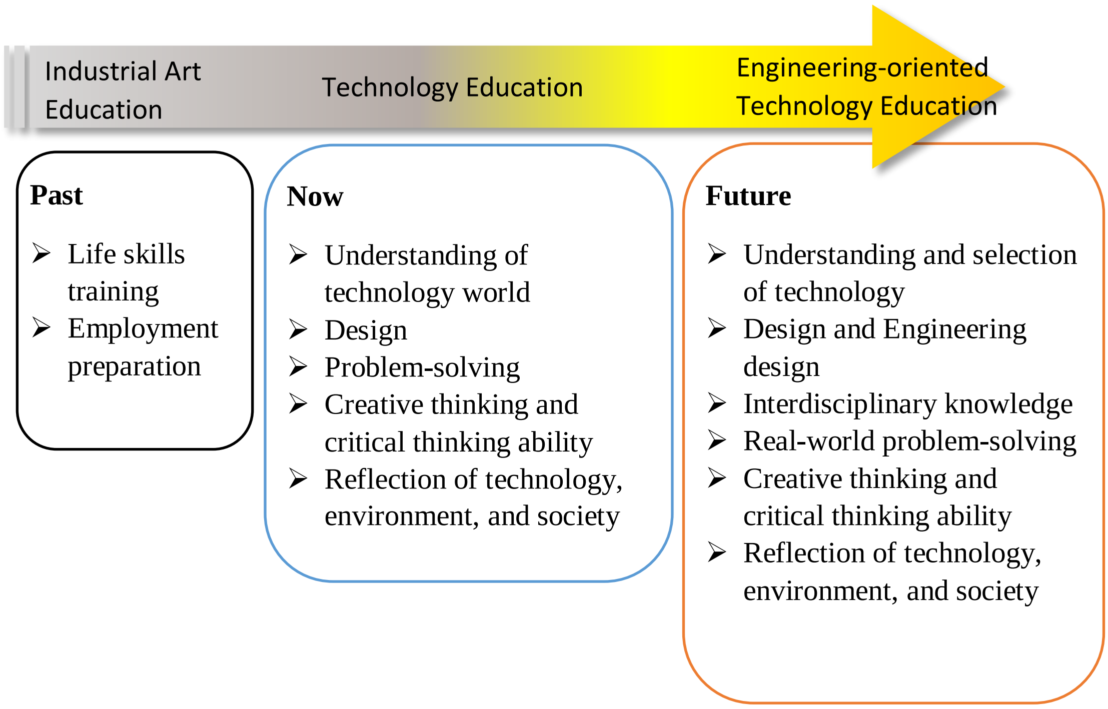

Figure 1. The evolution of technology education in Taiwan

Compared with conventional technology education, Taiwan's new curricula no longer emphasize an informative introduction to individual disciplines (e.g., communication, construction, and manufacturing); instead, they now focus on inter-disciplinary integration and application of conceptual knowledge. In elementary schools, developing the skills for applying technologies in daily life is emphasized; in junior high schools, students learn to implement their knowledge and skills in design creatively; and in senior high schools, engineering design and project-based learning is incorporated into the curriculum. Senior high-school students are guided to evolve from creative design and trial-and-error approaches adopted in junior high schools to a more systematic and logical approach to problem solving. Furthermore, students learn from practical experience in inter-disciplinary engineering design to flexibly implement conceptual knowledge and explore related engineering disciplines and become more motivated in learning STEM subjects.

Nevertheless, in the curriculum reform process, pedagogical content knowledge (PCK), CK, and the teaching methods applied by teachers are key factors that influence the efficacy of reform. To ensure that every future teacher of technology is thoroughly versed in their PCK and CK, the present authors have been commissioned by the Ministry of Education to develop professional development courses and teacher preparation curricula for technology teachers on the basis of the spirit and contents of the new technology curriculum guidelines. Hence, this article begins with an introduction to the new curriculum guidelines for technology education and then discuss the efforts that have been invested in improving the PCK and CK of in-service teachers and the plans for the training of future teachers subsequent to the new curriculum guidelines. This paper can hopefully be of reference in the field of technology education.

Purpose and core idea of new technology curriculum

The core concept of the new technology curriculum revolves around the concept of “design and making” to help students develop the abilities to “do” using their own hands (i.e., engage in practical implementation or design), to “use” the technologies, and to “think” creatively, analytically, and critically. More specifically, through technology education, students are expected to achieve competencies in four core aspects: Technological Knowledge, technological affection, operational skills, and integration abilities (Figure 2).

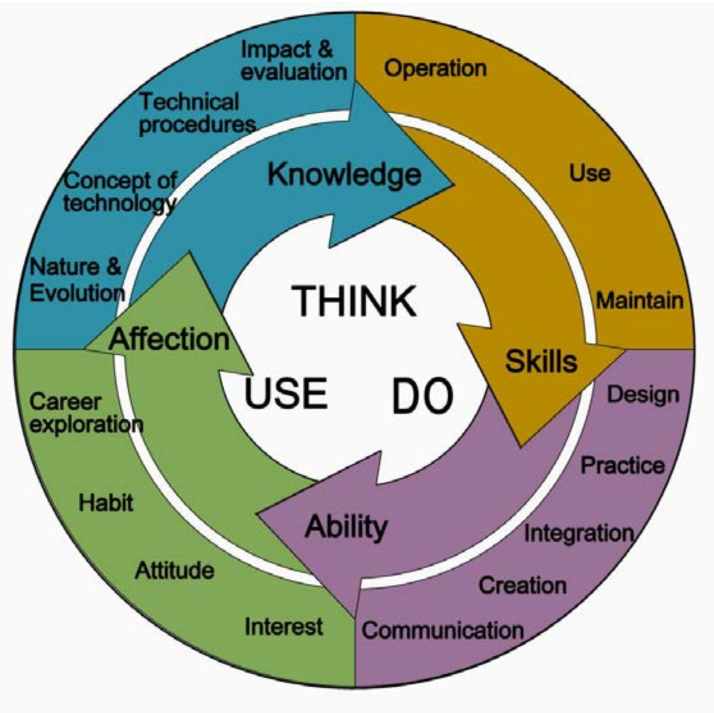

Figure 2. The core concept of technology curriculum

Of the four aspects, technological knowledge focuses on guiding students to accumulate knowledge concerning the nature and evolution of technologies, the concepts of various technologies, the procedures of technologies, as well as the knowledge to perform impact assessments of technologies (e.g., on the interactions between technology and society); technological affection focuses on guiding students to develop their interest in learning technologies, the correct attitudes for the use of technologies, and the habit of hands-on practice as well as to undertake career exploration; operational skills focuses on training students to operate machines and use materials and maintain technology products; and integration abilities focuses on guiding students, using inter-disciplinary project-based learning, to integrate and apply knowledge from multiple fields in design and to learn skills for effective communication and cooperation in the integration process to facilitate optimal use of creativity.

More specifically, the contents of the new technology education curriculum encompass four primary aspects, namely Nature of Technology, Design and Making, Application of Technology, and Technology and Society: (a) Nature of Technology emphasizes the introduction of vital and practical concepts of technology, such as the nature and evolution of technology, the operations of technology systems, various technology industries and trends in their development, and the relationship between technology, science, and engineering; (b) Design and Making emphasizes product design and the methods, techniques, and procedures of technology and engineering design to teach students how technology-related problems in daily life can be resolved and to develop students' interest and habits in hands-on experience; (c) Application of Technology uses project-based activities for hands-on experience that guides students in designing and making products that have interesting features and are practical and teaches them how inter-disciplinary knowledge can be integrated and implemented to solve problems. This aspect focuses primarily on the use and maintenance of technology products, mechanical and structural design, and the principles and applications of mechatronics; and (d) Technology and Society introduces the interactions and mutual impacts between technology, society, and the environment as well as aspects of career exploration, enabling students to reflect on the interrelationship between technology, society, the individual, the environment, and culture.

Because the new curriculum strongly emphasizes hands-on learning, teachers must integrate content covering Nature of Technology, Design and Making, Application of Technology, and Technology and Society into the core of project-based hands-on activities. In elementary schools, the curriculum for technology education centers around technologies' "application in life," emphasizing the recognition, understanding, and application of technology products in daily life. In junior high schools, the emphasis is on "creative design," particularly the creation procedures that involve the use of simple machines and tools for the processing of materials in order to expand students' creativity and designing abilities and to help them understand the development of technologies and their relationship with life. In senior high schools, the emphasis is on "engineering design," which stresses the importance of project-based activities, through which students are provided with the learning experience of the inter-disciplinary integration of conceptual knowledge and establish their ability in higher-order thinking (e.g., designing, innovation, and critique) in technology and engineering.

Supporting measures for in-serving technology teacher

The inclusion of engineering design in senior high schools is the largest change in the new curriculum for technology education. However, a high proportion of high-school teachers have never received training in this field during their teacher training. Consequently, these teachers are relatively unfamiliar with engineering design courses and teaching methods. Therefore, to enhance their CK and PCK, a supplementary program for teachers must be developed.

The content of this program is developed in a four-stage research process that involves various methods such as a literature review, expert interview, and an online questionnaire survey. The first stage focused on a comparison between the key points in the original and new curricula and the PCK that the in-service teachers already possess to help determine the topics and key points to be addressed in the program. In the second stage, experts were interviewed to examine the adequacy of the topics and key points identified in the previous stage, which were further refined through rolling correction. The third stage was a questionnaire survey, through which the opinions and suggestions of in-service teachers concerning the supplementary program were collected and assessed. During the fourth stage, experts in related fields were invited to compile the actual syllabuses on the basis of the topics and key points for the program.

Specifically, the professional development program consists of three courses. The instructional strategy adopted for these courses is to organize the courses around practical project-based activities to assist teachers in implementing what they have learned from the education courses. The following is a brief description of the three courses.

Formulating and Teaching Engineering Design Projects: Mechatronics and Electromechanical Control

The course aims to strengthen the teachers' CK and PCK concerning mechatronics and electromechanical control. Topics to be covered include an introduction to electronic circuit design, the integration of transmission mechanisms and control systems, programming and applications of microcontroller systems, an introduction to sensors and their control applications, and communication equipment and techniques in electromechanical control. Furthermore, theories of curriculum development, teaching material design, and instructional strategies are also included in the course to help teachers learn how related teaching skills can be applied.

Formulating and Teaching Engineering Design Projects: Mechanism and Structure

The course aims to strengthen teachers' CK and PCK concerning the principles and applications of mechanical design. Topics to be covered include mechanical and structural design, engineering materials and their applications, product development and manufacturing, and the applications of emerging technologies. Furthermore, theories of curriculum development, teaching material design, and instructional strategies are included to help teachers choose appropriate teaching methods.

Computer-aided Design and Manufacturing

The course aims to strengthen teachers' CK and PCK concerning computer-aided design and manufacturing (CAD/CAM), enabling them to respond to students' needs. Key topics to be covered in the course include the basic principles, theoretical basis, and applications of CAD/CAM (e.g. 3D graphics techniques, Computer Numerical Control, and 3D printing). Furthermore, knowledge related to the thought processes of technology design and engineering design as well as vital procedural knowledge of actual practices are also included to help teachers understand how knowledge of related techniques and equipment can be properly integrated into classroom.

New teacher education curriculum for pre-serving technology teacher

Other than the professional development programs for in-service teachers, the training of future teachers is also a concern that cannot be overlooked. In the framework of the new curriculum guidelines for technology education, the core CK for a technology teacher should cover the following fields: (a) Nature of Technology: the fundamentals of technology, and the relationship between technology, society, the environment, and various academic disciplines. Understanding the development and evolution of technology as well as the nature of technology are the key topics in this field; (b) Theoretical Knowledge of Technology: the physical, chemical, and mathematical laws and principles that support the operations of technological systems and products. Mechanics, structural theory, energy and kinetics, electronics, and related knowledge on emerging technologies (e.g., robotics) are all key topics in this field; (c) Knowledge of Technologies: professional knowledge for technicians or engineers such as understanding of materials, tools, and the characteristics, functions, and applications of technological systems and products; (d) Knowledge through Technologies: the technical knowledge necessary for the development, implementation, or feasibility of technologies, such as the methods and procedures for the processing of materials and the operation and application of common tools and machines; (e) Design and Problem-solving Procedures: the knowledge necessary to perform creative design or engineering design and knowledge concerning problem-solving procedures (e.g., modeling, optimization); (f) Communication and cooperation: the ability to effectively communicate, discuss, share design ideas, and solve problems with others; and (g) Critical thinking and decision-making: the knowledge and abilities to gather and analyze technology information from multiple perspectives to scientifically assess and evaluate the strengths and weaknesses of technology products and then formulate decisions or opinions accordingly.

The core PCK should cover (a) Knowledge of Learning Objectives: the understanding of the core aspects of technology education such as the philosophical background, context of development, academic value, teaching objectives, and expected results; (b) Curriculum Knowledge: the knowledge and ability to integrate related CK and teaching materials into a tailored curriculum for a particular learning stage. It also refers to knowledge that determines whether a certain curriculum or teaching material is adequate for a specific condition; (c) General Pedagogical Knowledge: the professional knowledge that teachers of all subjects should have; (d) Pedagogical Content Knowledge: knowing how to organize, present, and transform specific topics, questions, or content in response to the varying degrees of interest and learning capacity of learners; (e) Knowledge about Learners: the teacher’s knowledge about the learners’ characteristics, including the learners’ prior knowledge, learning capacity, aptitude, and misconceptions concerning various topics; (f) Knowledge of Educational Contexts: the teacher’s knowledge of classroom management, teaching environment planning, as well knowing how to obtain and use resources from community.

We further converted the core CK and PCK of the technology teachers into four core competencies: Technology Pedagogical Competency, Technological Competency in Hands-on Application, Design and Making Competency, Professional Attitude and Development Competency. Details of these four core competencies are as follows:

Technology Pedagogical Competency

Technology Pedagogical Competency refers to a teacher's capability to plan and facilitate an effective learning experience to help learners understand principal concepts and knowledge (Banks et al., 2004; Rohaan, Taconis, & Jochems, 2012; Rose, 2015). The major aspects include (a) Educational Ideals for the Subject: understanding the core values and theoretical basis of the subject and familiarity with the spirit and key points of the curriculum guidelines on technology education; (b) Curriculum and Teaching Material Design: the ability to analyze the framework and contents of the curriculum guideline to develop an adequate standards-based curriculum and corresponding teaching materials; (c) Teaching Methods and Strategies: the ability to use diversified teaching methods and strategies to guide learning on the basis of learners' characteristics; (d) Methods and Strategies for Assessment: the ability to design effective tools to conduct a meaningful assessment of learning experience; and (e) Planning and Management of Teaching Environment (technology classroom): the ability to plan for the teaching environment, manage it, and maintain its safety to render it an environment that supports learning from hands-on practices.

Technological Competency in Hands-on Application

Technological Competency in Hands-on Application refers to the teacher's familiarity with professional knowledge related to the curriculum, including the concepts, key aspects, and pedagogical applications of the subject (Banks et al., 2004; Ihde, 1997; Rohaan et al., 2012). Moreover, it is the ability to teach technology, to present the CK applications, to inspire learners' curiosity and creativity for the subject, to inspire learners to design, produce, and solve problems and help learners effectively connect the conceptual knowledge with their real-life experiences. Specifically, its main aspects include (a) Core Knowledge of the Technology Domain: theoretical knowledge in technology, such as the technology system, energy and kinetics, mechanism and structure, mechatronics, and programming; (b) Application of Knowledge in Technology: the ability to effectively apply the knowledge in design and making and understand the connection between technological knowledge and the real world; and (c) the ability to progressively guide learners in their process of knowledge comprehension and conversion, establishing higher-order thinking abilities, and solving problems by using technology.

Design and Making Competency

Design and Making Competency refers to the teacher's capability in planning and undergoing an effective creative design or engineering design process, which leads learners to develop the necessary design thinking, problem solutions, and practical skills in design and making (International Technology and Engineering Educators Association [ITEEA], 2003; Rose, 2015). Specifically, its key aspects include (a) implementing the process of design and engineering design: the capability to guide learners in using design and engineering design processes in a project, as well as the capability to plan an effective learning experience for a particular procedure (e.g., prediction analysis); and (b) accurately applying materials and tools: the capability to choose the proper materials and tools, to adequately assess risks in processing, and to teach correct and safe operating procedures to the learners.

Professional Development and Attitude Competency

Professional Development and Attitude Competency refers to the beliefs, ethics, and attitude necessary for the teacher (Owen-Jackson, 2008; Rose, 2015). Specifically, its key aspects include (a) Professional Development and Ethical Practices: the behavior that conforms to professionalism and professional ethics as well as the determination to actively continue professional development for lifelong learning; and (b) Communication and Cooperation: active participation in communications with the school's administrative staff and faculty and coordination of their teamwork.

In summary, the aforementioned core competencies have been developed as the basis for the future training of technology teachers. Required and elective courses designed for the development of Technology Pedagogical Competency, Technological Competency in Hands-on Application, Design and Making Competency, and Professional Development and Attitude Competency are to be developed to the teachers' training program.

Conclusion

In response to the rapid technological advancement and to strengthen the technological literacy of its people, new technology education curriculum guidelines are to be integrated into Taiwan's soon-to-be-implemented 12-year compulsory education. To help teachers both in service and in the future to acquire the necessary expertise and knowledge for the new curriculum, we conducted two projects, one to supplement the expertise of in-service teachers and the other to prepare future teachers for the CK, PCK, and core competencies that will be required for their positions. The findings can serve as a reference for promoting engineering design curricula in the field of technology education worldwide. The effectiveness, however, must be assessed in future studies, to ensure technology teachers realize the ideals and content of their curricula.

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