

Science and Mathematics Education Centre

**Science Teacher Knowledge of Physics Concepts in School-Based
Assessment of Practical Work: A Solomon Islands Case Study**

Lionel Cliff Kakai

**This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University**

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number SMEC-35-14.

Signature:  _____

Date : 1st June 2018

ABSTRACT

Informed by a theoretical model of phases of the school curriculum, this study sought to explore and document Solomon Islands teacher trainees' and practising science teachers' views and experiences about teaching, learning and assessment of physics concepts in practical work that was assessed in the high schools. In particular, this study used a conceptual framework integrating key research areas to explore and understand the participants' level of pedagogical content knowledge to teach and assess physics concepts. The interest and motivation for this study arose from a review of the science education literature as well as the researcher's personal experiences and reflections pertaining to the quest to improve the nexus between what is intended for and what was attained by learners. Subsequently, this study focused on teacher trainees' and practising science teachers' perceptions and classroom practices as a pivotal facet in minimising the gap between the intended and attained curriculum.

Guided by a case study design, this study employed a triangulation mixed methods approach. As such, bounded by the phenomenon investigated and the geographical context of this study, both qualitative and quantitative data were concurrently collected and generated from participants' views and experiences. The data were comprised of 124 survey responses, seven practising science teacher interviews and seven trainee science teachers in a focus group interview. Findings from both data sources were complementary and their inferences were triangulated and discussed as a coherent account in relation to the literature review, the conceptual framework and the researcher's sociocultural perspectives. Subsequently, the findings for this study provide a context and guidelines to improve science teachers' pedagogical content knowledge for teaching, learning and assessment of scientific concepts in the school-based assessment of practical work in science education.

This study found that the majority of participants perceived science education as an important avenue for developing learners' understanding of scientific concepts, skills and attitude for use in their everyday livelihood. Besides, the findings suggested that developing learners' understanding of scientific concepts and skills would also benefit

them in their future careers as well as for nation building and economic development. The findings also indicated that the majority of participants perceived they had knowledge about teaching, learning and assessment of scientific concepts. However, there were inconsistencies regarding the participants' perceived physics content knowledge as well as their knowledge of learners' preconceptions and misconceptions in physics concepts. Consequently, there were indications of a mismatch between participants' perceptions and practice, and between the prescribed aims and participants' perceived aims for the school-based assessment curriculum. This mismatch presents an obstacle to closing the gap between what is intended and what is attained in the science curriculum. Furthermore, the findings for this study indicated considerable challenges that seemed to impede the implementation of a school-based assessment of practical work. The main obstacles, which are also common to other similar sociocultural and geopolitical contexts are the lack of resources and basic logistics as well as crowded classrooms.

Apart from addressing these obstacles, this study has placed emphasis on the importance of enhancing science teachers' perceptions and practice in order to minimise the gap between intended and attained school-based assessment of practical work. As such, this study recommended that teacher training and ongoing professional learning programs for science teachers should provide the teaching, learning and assessment knowledge as well as practice that integrates the key research areas such as: the understanding of scientific concepts, nature of practical work, school-based assessment and pedagogical content knowledge. That said, while this study had limitations on the sample size, time and geographical location, the framework developed from this study can be used to inform and develop future research in science education in and beyond Solomon Islands. Specifically, the results and information from this study can be used to frame an intervention study that aims to improve the effectiveness of science teaching, learning and assessment in the school-based assessment of practical work. This would in turn enhance learners' achievement as well as the quality of science education.

DEDICATION

This thesis is dedicated to the memory of my beloved father

The late Peter Kakai (Senior)

who encouraged me to pursue a Doctor of Philosophy. Although, he passed on eight years before I started this academic journey, I will forever be grateful for his vision.

And to my mother

Mary Palmer Kakai

for her unconditional love with unwavering prayers and moral support

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CONFERENCE PRESENTATIONS

Part of this thesis have been shared as papers and oral presentations in the following conferences:

- *School-Based Assessment of Physics Concepts in Science Education: A Case Study in Solomon Islands*. A stand-alone paper presented at the Vaka Pasifiki Education Conference – ‘Education for What? Revisited’. 5 – 6 June, 2016, Kukum Campus, Solomon Islands National University, Honiara, Solomon Islands.
- *A Solomon Islands Study of School-Based Assessment and Teacher Pedagogical Content Knowledge*. A stand-alone paper presented at the 2017 NARST Annual International Conference – ‘Glocalization and Sustainability of Science Education Research and Practice’. 22 – 25 April, 2017, Grand Hyatt, San Antonio, Texas, United States of America.
- *A Solomon Islands Study of Teacher Pedagogical Content Knowledge and School-Based Assessments of Physics Concepts*. A stand-alone paper presented at the 9th International Conference on Science, Mathematics and Technology Education – ‘Sustaining Science, Mathematics, and Technology Education for Future Generations’. 7 – 10 November, 2017. Universiti Malaysia Sabah, Kota Kinabalu, Malaysia Sabah.

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LIST OF ABBREVIATIONS

AL	Advanced Level	54
CEO	Chief Education Officer	99
CHS	Community High School	17
CIA	Central Intelligence Agency	15
CK	Content Knowledge	105
DFAT	Department of Foreign Affairs and Trade	16
EA	Education Authority.....	99
ECE	Early Childhood Education.....	17
ESIRP	Education Sector Improvement and Reform Programme.....	16
FCI	Force Concept Inventory	71
HSD	Head of Science Department	98
IMTPG	Interconnected Model of Teachers Professional Growth	74
JSE	Jounior Secondary School.....	17
MEHRD	Ministry of Education and Human Resources Development.....	2
NCB	National Curriculum Board	25
NEAD	National Education Assessment Division.....	18
NEAP	National Education Action Plan.....	3
NoS	Nature of Science	32
NSS	National Secondary Education	17
NSTA	National Science Teacher Association	33
OBE	Outcome Based Education.....	2
PCK	Pedagogical Content Knowledge.....	3
PEDF	Pacific Education Development Framework	20
PIFS	Pacific Islands Forum Secretariat.....	3
PISA	Program for International Assessment.....	54
PK	Pedagogical Knowledge	105
PS	Primary School	17
PSS	Provincial Secondary School	17
PT	Practising Teacher.....	158

QSA	Queensland Studies Authority	25
RAMSI	Regional Assistance Mission to Solomon Islands	16
SBA	School-Based Assessment	1
SCORE	Science Community Representing Education	37
SINF6SC	Solomon Islands National Form 6 School Certificate	79
SINU	Solomon Islands National University.....	8
SISC	Solomon Islands School Certificate	6
SOE	School of Education	97
SPA	Science Practical Assessment.....	53
SPBEA	South Pacific Board for Educational Assessment.....	3
SPSS	Statistical Package for the Social Science.....	119
SSE	Senior Secondary Education	17
TAS	Teacher Assessment Schemes	53
TCK	Technology Content Knowledge	105
TK	Technology Knowledge	105
TPACK	Technological Pedagogical Content Knowledge	68
TPK	Technological Pedagogical Knowledge.....	105
TT	Trainee Teacher	158
TVET	Technical and Vocational Education and Training.....	17
UK	United Kingdom.....	26
USA	United States of America	26
USP	University of the South Pacific.....	5

CHAPTER ONE

Introduction

1.1 Organisation of this Thesis

This thesis reports on a study which explored and documented both trainee and practising science teacher participants' views and experiences about teaching, learning and assessment of physics concepts in the school-based assessment (SBA) of practical work in Solomon Islands. This thesis consists of seven chapters and eight appendices.

Chapter One presents the introduction which describes the motivation, background, purpose, context, theoretical framework, significance and a synopsis of the research design employed for this study.

Chapter Two reviews the key research areas in the science education literature that form the conceptual framework of this study as well as identifies the gap and novelty of the knowledge that this study contributes to the existing body of knowledge in science and physics education.

Chapter Three reiterates the purpose and research questions, details the research design employed as well as describes the sample size and measures used for this study. In particular, Chapter Three describes the case study design and triangulation of the mixed methods employed and highlights the ethical considerations for this study.

Chapter Four reports the quantitative findings for this study according to the five scales or knowledge components as outlined in the survey instrument used.

Chapter Five reports the qualitative findings for this study under pre-guided and emerging themes generated from interviews and focus group discussion.

Chapter Six presents the discussion which synthesises the findings of this study in relation to the literature review discussed in Chapter Two, the research questions for this study as well as the researcher's sociocultural and contextual reflections.

Finally, Chapter Seven presents the key summary, details the implications and limitations, suggests future directions for related research and provides the researcher's concluding remarks for this study.

This thesis introduces the study in Chapter One using a first person approach, which is considered more reflexive and humanistic (Oliver, 2014). This approach is favoured in order to provide a personal and constructivist perspective underpinning the motivation, background and fitness for purpose of this study. Thereafter, Chapter Two to Chapter Seven are written using a third person approach, which is widely used in many other theses (Oliver, 2014). Finally, Section 7.6 in Chapter Seven is also written in the first person to present the researcher's own reflections and concluding remarks pertaining to the process and outcome of this study.

1.2 Overview of Chapter One

Firstly, the explanation for the motivation for this study is presented in Section 1.3 followed by the background to the study in Section 1.4. The underlying theoretical framework for the study is outlined in Section 1.5 followed by the statement of the purpose and research questions for this study in Section 1.6. Next, the sociocultural and geopolitical context for this study is described in Section 1.7. Then the significance of this study is highlighted in Section 1.8 followed by a synopsis of the research design in Section 1.9. Finally, a summary of this chapter is presented in Section 1.10.

1.3 Motivation for this Study

Education reform in Solomon Islands since 2004 has included a major shift from Objective-Based Education to Outcome-Based Education (OBE) (Ministry of Education and Human Resources Development [MEHRD], 2011). This recent shift to OBE has placed "emphasis on school-based continuous and formative assessment needs to be supported by changes in teaching methodology. Teaching methodology must ensure that methods used are appropriate. Teaching methods are central to the realisation of the learner-based OBE" (MEHRD, 2015, p. 46). This is similar to another educational undertaking driven by the notion of utilising SBA curriculum for multiple assessment purposes as promoted by the South Pacific Board for Educational

Assessment (SPBEA) (Pacific Islands Forum Secretariat [PIFS], 2009). These kinds of undertakings have provoked and motivated me to undertake this study. Whenever I have the privilege to participate or be involved in any educational undertaking as mentioned, I have always had this concern about the impact of the science teachers' teaching qualities. How can teachers utilise and implement these new changes in order to provide effective teaching, learning and assessment which in turn should improve learner achievements? I was concerned with the nexus between the intentions and the actual attainment of the changes in the education curriculum.

The Solomon Islands government is striving to provide a quality education system and curriculum. The objectives of the National Education Action Plan (NEAP) for 2016 – 2020 focuses on three main strategic goals to achieve a quality education. The three goals are “access, quality and management” (MEHRD, 2017, p.i). According to the MEHRD (2007a, 2017), one of the essential ingredients to achieve these goals is to ensure that there are enough well-trained, qualified and motivated teachers to deliver a quality education. In this regard, I was motivated to explore and document science teachers' views and experience in order to identify ways to enhance science teachers' pedagogical content knowledge (PCK) in science and physics. As generally accepted, enhanced PCK has a positive impact on science teachers' ability to deliver quality science teaching, and in turn contributes to a quality education with the goal to improve learners' achievements in science and physics subjects (Evens, Elen & Depaepe, 2015; Kind, 2009). Hence, this study sought to enhance the capacity of science teachers to effectively implement what is intended and envisioned in the science education curriculum in Solomon Islands. In essence, a key component of the goal to achieve quality education in Solomon Islands is to strive for excellence in science education.

Science education in Solomon Islands aims for scientific literacy, encompassing the notion that learners should be prepared for further tertiary studies as well as for life-long learning in everyday life after high school (MEHRD, 2007b, 2010). Such an aim is essential for learners' development in science education since many of them would either continue into higher tertiary education or start their civic lives in their own communities. Wieman and Perkins (2005) claimed that with such an aim the “physics community should take the lead in providing effective and relevant science education for all students” (p. 36). Wieman and Pekins (2005) claimed that general physics

concepts are more appropriate to science education because of their relevance to the physical world where learners would eventually live their civic lives. As such, I was motivated to focus this study on exploring the importance of science education, particularly physics as a subject in science education.

It was promoted that one of the facets in improving the quality of education in Solomon Islands and other Pacific Island nations is to refocus on assessment strategies in schools (Fasi, 2005; Lingam & Lingam, 2016). In particular, it is imperative to focus “in the area of school-based assessment, which is a relative newcomer on the regional stage” (Lingam & Lingam, 2016, p. 92). The SBA curriculum is one of the assessment strategies promoted by the SPBEA since it can be utilised for multiple assessment purposes (Fasi, 2005); specifically, assessment purposes such as the assessment of learning (summative purpose) and assessment for learning (formative purpose) (Bell, 2007; Fasi, 2005). For summative purposes, assessment is conducted after learning has taken place, whereas for formative purposes, assessment is for learning during the learning process (Bell, 2007). This notion of utilising SBA for multiple purposes and the change from Objective-Based Education to learning outcomes in OBE are significant concepts that motivated me to carry out this study.

I was specifically motivated to explore and document science teachers’ views and experiences on teaching, learning and assessment of scientific and physics concepts in the SBA of practical work curriculum. I wanted to involve the main facilitators within the implementation phase, those who are responsible to translate what is intended to what is attained in the science SBA curriculum. The responsible people at this pivotal phase are the science teachers. As such, I wanted to involve both the trainee and practicing science teachers. I believe their perceptions based on their knowledge, understanding, beliefs and experiences in physics and science education are vital for my quest. What they provide would form the basis to develop informed sociocultural and contextual improvements within the context of utilising SBA to enhance teaching, learning and assessment in physics and science education as a whole. In this regard, my primary motivation was to explore and document alternative ways to bridge the gap between what is intended and what should take place in the classroom to achieve the expected outcomes.

1.4 Background to this Study

Science education influenced by developing and progressive learning philosophies and theories has gone through many major reforms over the years (Christou, 2016; De Jong, 2007). Predictably, the underlying philosophies, theories and strategies in science education will continue to evolve over time (Bell, 2007). The major science reforms over the past decades in most western countries like the United States of America, United Kingdom, Australia and New Zealand were also felt or trickled down to small Island nations in the South Pacific (Gray, 1999; Scaglione, 2015). Although later than other developed countries, Solomon Islands is one of the small island nations and a developing economy in the South Pacific that had also felt the trends and waves of reforms in science education as well as education as a whole.

The waves of reforms in science education also influenced the SPBEA to revisit educational strategies in all levels of education in the South Pacific region. The Solomon Islands government with assistance from consultants in education from Australia, New Zealand and the SPBEA have also opted to reform the country's education system. The ongoing educational reform, which started in 2004 in Solomon Islands, is based on the learning ideologies that underpin the concept of OBE. According to Spady (1988), OBE puts the emphasis on learning outcomes and not teaching objectives. Instructions and the process of teaching, learning and assessment are based on the outcomes that are intended to be achieved. Emphasis is also placed on the use of formative assessment or assessment for learning more than summative assessment which is the assessment of learning. In this regard, teaching, learning and assessment is an ongoing process during learning and is measured by the learners' ability to demonstrate the intended learning outcomes.

Previous changes in Solomon Islands education and particularly in science education were based on foregoing learning theories such as, the discovery and personal constructivist theories (De Jong, 2007). Added to that, these changes were also influenced by a study conducted by Fradd and Crawford (1986). The two authors were from England but as science teachers in Solomon Islands in the early 1980s, they investigated why local learners had difficulty coping with science courses at tertiary education level, particularly, at the University of the South Pacific (USP) in Fiji. Fradd

and Crawford (1986) found that Solomon Islands learners were lacking in self-directed study skills and were practically incompetent in many science practical subjects, especially physics. Their findings along with support from learning theories influenced change in the Solomon Islands science education that eventually led to the introduction of the SBA in Year 10 and Year 11 in the 1990s. More appropriately, that change was in line with and also influenced by the assessment strategies promoted by the education providers in the South Pacific region, namely, SPBEA and USP, who respectively provided Year 12 and Year 13 courses.

The SBA is seen as a more progressive and formative approach than one-shot examinations at the end of a school term (MEHRD, 2007b, 2010). This was similar to previous SBA implementations in Queensland and New South Wales, Australia (Broadfoot, 1994; Maxwell, 2004), New Zealand (Crooks, 2002), Zambia (Kapambwe, 2010), Fiji (Thimmappa & Sharma, 2003) and Hong Kong (Yip & Cheung, 2005). In Solomon Islands, the SBA is compulsory in science for all Year 10 and Year 11 learners, who would sit for their SISC at the end of Year 11. Further to that, the MEHRD in Solomon Islands has plans to have a combination of SBA and external examinations for all subjects at Form three level (Year nine) (MEHRD, 2007b, 2016). In this regard, SBA will also be an important component for all subjects at Year nine in Solomon Islands education. Therefore, this study is timely in providing researched information with regards to the use of SBA for teaching, learning and assessment in science education.

Previous studies in Solomon Islands within the field of education and educational assessment, such as Walani (2008), Sade (2009), Daudau (2010), Kakai (2010) and F. Rodie (2014), indicated that many teachers have minimal understanding, skills and knowledge of educational assessment. Additionally, a study by Lingam and Lingam (2016) in Solomon Islands suggested that even school leaders need professional upskilling in “matters pertaining to improving the practices of assessment, which would ultimately provide the benefit of a higher quality of education” (p. 103). Likewise, from their respective intervention studies, Sade (2009) and F. Rodie (2014) asserted that Solomon Islands teachers need to enhance their understanding, skills and knowledge about the different types of assessment. F. Rodie (2014) created a professional development (PD) module to enhance Year nine science teachers’ skills

and confidence in summative assessment practices. Prior to that, Sade (2009) also developed a PD module to assist technology education teachers in Solomon Islands to implement the new technology education curriculum. Both Sade (2009) and F. Rodie (2014) claimed that their interventions with teacher professional development modules produced positive outcomes. This was reflected in their participants' post intervention responses and teaching practices.

This study focused more on identifying ways to enhance science teachers' PCK. Studies indicated that science teachers' PCK is a pivotal factor in carrying out effective teaching, learning and assessment (Moreland, Jones & Cowie, 2006; Shulman, 1986). Besides, learners must trust their teachers as the experts in scaffolding and providing effective feedback as well as feed-forward when implementing formative assessments (Bell, 2007; Cowie, 2000). In fact, a study conducted by P. Rodie (2011) in Solomon Islands indicated that, many beginning high school teachers were not adequately prepared for some aspect of their teaching roles. She found that while they were not well prepared to teach, they were also placed in difficult classroom environments. And, that there was a "general lack of teaching resources, crowded classrooms, and lack of specialised classroom facilities and equipment for subjects such as Science" (p. iv). Even experienced practicing science teachers have similar difficulties (Kakai, 2010). Given such a difficult environment, science teachers' PCK is pivotal in finding improvising ways to make teaching, learning and assessment effective in the classroom (Shulman, 1987). However, one challenging factor is that not all science teachers have similar teacher training or ongoing professional learning.

On the one hand, although some science teachers have appropriate subject content knowledge, they may lack pedagogical knowledge with insights to teach and assess scientific concepts, skills and other affective aspects of learning. For example, after teaching for 14 years, Hoban (2002) admitted that, although he knew the subject content, it was an awakening for him to realise the complexity of learning underpinned by different teaching, learning and assessment theories. This was similar to my own teaching experience before I learnt about different teaching, learning and assessment theories. Although I developed confidence with my content knowledge I was not aware of the appropriate pedagogical knowledge. Being aware of the pedagogical knowledge is significant for effective teaching, learning and assessment (Loughran, 2011). This

aspect was one of the background factors that influenced this study, and for me to explore and document science teachers' views and experiences regarding their PCK for use in the SBA of practical work.

On the other hand, some science teachers who graduate from institutions that focus more on pedagogy may have less subject content knowledge to teach science at high school level. Such was indicated in studies by Isak and Mohamed (2008), and Halim, Meerah and Buang (2010) with Malaysian physics teachers. Similar to these studies, Kasanda (2008) also found that science teachers in Namibia lack the content knowledge because of their teacher training background. Besides, Saleh (2011) found that even third year Bachelor of Science Education trainee teachers in Malaysia who were about to teach science, had the same level of conceptual understanding of Newtonian force concepts as their Year 10 science learners. In saying that, in Solomon Islands, the Bachelor of Teaching program at the Solomon Islands National University (SINU) focuses more on classroom pedagogy (Solomon Islands National University Handbook [SINU], 2017). This aspect was another background factor that influenced this study, and for me to explore and document the views and experiences of the trainee science teachers at the SINU.

Furthermore, like many other developing economies Solomon Islands has a large number of untrained teachers who may lack both the content and pedagogical knowledge as well as other knowledge components for teaching, learning and assessment (MEHRD, 2007a, 2017). This is a challenge not only for Solomon Islands but for other Pacific island nations as well (PIFS, 2009). This challenge is associated with the notion that science teachers should be seen as trusted experts with developed and appropriate PCK to teach and assess scientific concepts and skills (Cowie 2000). In this regard, this study is novel since it sought to address the challenge by employing a conceptual framework which integrates the understanding of scientific concepts, practical work, SBA and PCK into a more coherent platform to effect the process of teaching, learning and assessment in science education.

For the purpose of this thesis, the conceptual framework for this study embodies a coherent relationship of key research areas that are premised to address a gap identified in the existing theoretical framework presented in Section 1.5. In this regard, the theoretical framework is an existing theory that has been validated while the

conceptual framework is the logical and coherent integration of key research areas that guides this thesis (Grant & Osanloo, 2014). As such, the conceptual framework for this study is presented in Section 2.2 in Chapter Two while the theoretical framework is outlined next.

1.5 Theoretical Framework for this Study

This study is underpinned by a theoretical framework that postulates a gap between the intended curriculum and attained curriculum (Goodlad, 1979; Rosier & Keeves, 1991; Van den Akker, 1998). This theoretical framework was initially developed by Goodlad (1979) and modified by Rosier and Keeves (1991). Subsequently, based on his longitudinal review on different curriculum reforms in many different countries, Van den Akker (1998) summarised and highlighted the distinctions between the curriculum representations from ideals to outcomes. He distinguished and termed the curriculum representations in an order of a process from: ideal curriculum to formal curriculum, perceived curriculum, operational curriculum, experiential curriculum and finally attained curriculum. The first two curriculum representations, ideal and formal comprised the guiding philosophy, rational and mission along with the documents that underlie and further elaborated the curriculum vision. The main players here are the curriculum designers while teachers can also participate. The last two curriculum representations, experiential and attained, represented what the learners actually experience during their learning and the “resulting learning outcomes” (p. 422). While teachers play an important role, the main subjects in these two curricula are the learners’ achievements.

The theoretical focus for this study lies within the perceived and operational curriculum, which represents teachers’ perceptions and interpretations of the curriculum, as well as their “actual instructional process in the classroom” (p. 422). The main players here are the teachers themselves. Perceived and operational curricula are imperative to the theoretical basis of this study since they are pivotal in the process of bridging the gap between the ideal curriculum and the attained curriculum as depicted in figure 1.1. According to Van den Akker (1998), the perceived and operational curricula are the essential facets in the process of minimising the gap between the ideal and formal curriculum to the experiential and attained curriculum.

This theoretical framework posits that teachers play an imperative role in translating what is intended to what is attained in any curriculum reform.

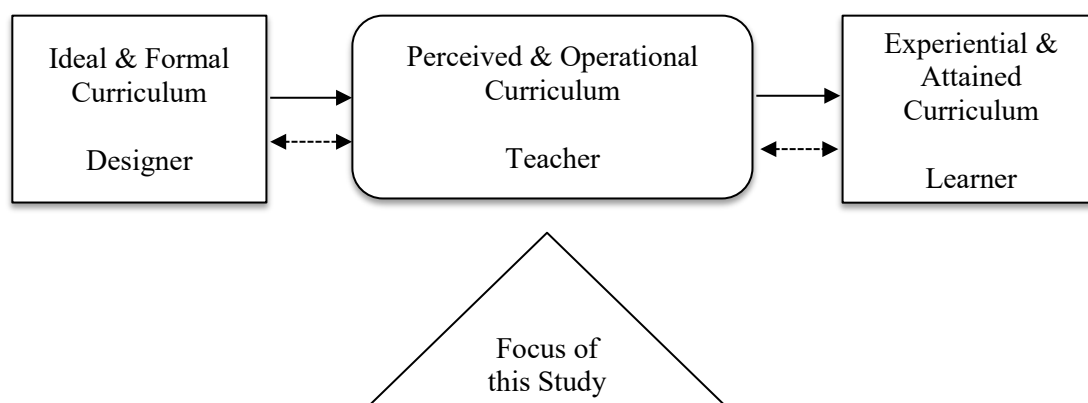


Figure 1.1. The process from the ideal and formal curriculum to experiential and attained curriculum. The focus of this study is on the perceived and operational curriculum.

According to Van den Akker (1998), the effectiveness of constructing the bridge depends very much on teachers' perceptions; knowledge and understanding of their subject content; knowledge of ideal and formal curriculum; knowledge of pedagogy and the underlying learning theories; knowledge of learners and their environment. These knowledge components and understandings can be transformed and translated into teachers' teaching practice which in turn should enhance the attained curriculum (Van den Akker, 1998). In this regard, the challenge of enhancing teachers' appropriate knowledge and skills is crucial within this theoretical gap. To address this challenge in science, many recent studies have put a lot of emphasis on the significance of improving science teachers' PCK in science education in general (Cheung, 2016; Hodson, 2014; Osborne, 2014). Subsequently, based on this theoretical basis, this study premised that science teachers should enhance their PCK in the SBA of practical work curriculum.

In essence, PCK is a key knowledge that distinguishes an effective teacher from someone who is a specialist with either content or pedagogical knowledge and it is crucial to learners' achievements (Shulman 1987). Out of his seven categories of teaching knowledges, Shulman (1986) conceptualised two main components that are vital for PCK. One is a teacher's knowledge for representing subject content and

specific topics in plausible ways. The other is a teacher's knowledge about learners' learning difficulties, conceptual interpretations and misconceptions. Shulman (1999) proposed that "those who use these ideas now and in the future will give more attention... to the connection between teachers' knowledge and the ultimate consequences for students' learning and development" (p. xi). Indeed, apart from other factors that influence learners' learning and development, recent studies had found that teacher quality has become the most important factor (Knight & Duschl, 2015). As such, science teachers' PCK was explored in this study.

This study was also based on the notion that science teachers should be able to make connections between teaching, learning and assessment of scientific concepts using the SBA of practical work. It is important to note that practical work is not theory free (Hodson, 1998; Wellington, 1998). Learners need to have a conceptual understanding in order to make informed decisions while conducting practical work in science, let alone using practical work for formative and summative assessment purposes. Besides, Hodson (1998) claimed that learning scientific concepts from practical work can be confusing and demotivating for learners. As such, science teachers should know and understand how to teach and assess scientific concepts using practical work. This involves the notion that SBA curriculum can be used for formative and continuous summative assessment purposes.

Formative assessment is woven into the process of teaching and learning of content, context and skills while summative assessment is the assessment of what had been learnt and developed (Bell, 2007; Green & Johnson, 2010). Hence, on the one hand, formative assessment involves effective scaffolding and feedback as well as feedforward to assist learners to link and construct the intended understanding of scientific concepts from their preconception during the learning process (Green & Johnson, 2010). On the other hand, summative assessment is embedded in the notion of "fitness for purpose" (Stobart, 2006, p.34). That is, summative assessment activities are constructed in a way that learners should be able to demonstrate what they are assessed on (Harlen, 2005). As such, summative assessment activities and instructions should be familiar to both learners and their science teachers and similar activities should have been used during the teaching and learning process (Green & Johnson, 2010). Given these different aspects of assessment processes, science teachers'

understanding of scientific concepts, formative assessment and summative assessment are essential for the implementation of the SBA of practical work as well as for the theoretical basis for this study.

In sum, given this theoretical framework, this study premised that science teachers' PCK is an essential ingredient in bridging the gap between ideals and attained curriculum. In saying that, I have been using the terms 'ideal' and 'intended' curriculum interchangeably. However, for the purpose of this thesis the term 'intended' curriculum is used dominantly to represent the curriculum ideals, visions, materials and assessments (Cornbleth, 1990; Grundy, 1987).

1.6 Purpose for this Study

This study was purposely designed to explore and document the trainee and practising science teachers' perceptions, experiences, beliefs and understanding of scientific and physics concepts in the SBA of practical work. These two cohorts were imperative to this study since the trainee science teachers were on training and yet to practice while practising science teachers already had real classroom experiences. Thus, it was significant to identify and understand the similarities and differences of the participants' PCK in relation to teaching, learning and assessment of physics concepts in the SBA of practical work. The data from these two cohorts were integrated, analysed and synthesised with the underlying conceptual framework for this study, specifically, to develop a set of guidelines that can provide information for teacher training and ongoing professional learning programs. This set of guidelines can also be used to inform the development of PCK for other subjects in science as well as other subjects in high school education.

The purpose of this study was underpinned by the notion that, both trainee and practicing science teachers have the onus to implement a new curriculum or the existing curriculum in science classrooms. This is represented within the perceived and operational curriculum in the theoretical framework for this study. Hence, science teachers have the responsibility to bridge what is intended to what is attained in the SBA of practical work curriculum. Subsequently, this study has provided an opportunity for me to further explore and understand the science teacher participants' views and experiences pertaining to the premise of improving their PCK on the SBA

of physics concepts. Although their views and experiences are socially and culturally contextual to Solomon Islands science education, the information from this study can provide a framework for improving similar aspects of science education in other sociocultural and geopolitical contexts.

On the whole, this study premised that science teachers should enhance their PCK in order to bridge the gap between what is intended and what is attained in the teaching, learning and assessment of physics concepts in the SBA of practical work in Solomon Islands science education. It is hoped that the interest of this study is fully realised, especially when it comes to addressing the gap between intended and attained curriculum. It was on this basis that this study was sought to improve what is actually taking place in the science classrooms.

1.6.1 Research Questions

The purpose for this study was addressed by exploring the following research questions:

1. What do trainee and practising science teachers know and understand about scientific and physics concepts in science SBA?

The first question sought to explore both trainee and practicing science teachers' perceptions, experience, beliefs and understanding about the importance of teaching, learning and assessment of physics concepts as well as scientific concepts in general within the context of science education and the SBA of practical work.

2. How do trainee science teachers' view and experience their learning and assessments of physics concepts?

The second question sought to explore specifically the perceptions, beliefs, experiences and understanding of training science teachers about their learning and assessment of physics concepts within the context of the SBA of practical work.

3. How do practising science teachers view and experience their teaching and assessing of physics concepts?

The third question specially sought to explore the perceptions, beliefs, experience and understanding of practicing science teachers with respect to their own teaching and assessment of physics concepts within the context of the SBA of practical work.

4. What do trainee science teachers suggest as ways to improve their learning, understanding and assessment of physics concepts?

The fourth question is asked to explore suggestions from trainee science teachers about what, why and how they perceive as improvements to their learning and assessment of physics concepts in the SBA of practical work.

5. What do practising science teachers suggest as ways to improve their understanding, teaching and assessment of physics concepts?

Finally, the fifth question is specifically tailored to elicit suggestions from practicing science teachers about what, why and how they perceive as improvements to their teaching and assessment of physics concepts in the SBA of practical work.

The outcome of these research questions were sought to provide indications regarding both trainee and practising science teacher participants' level of PCK that are relevant to the effective implementation of the SBA of practical work curriculum in Solomon Islands.

1.7 Context of this Study

The context of this study frames the setting and environment that surrounds as well as influences the perceptions and experiences of the study participants and the phenomenon explored (Creswell, 2008; Vygotsky, 1986). Hence, the following section briefly presents the geopolitical, demographic, sociocultural environment as well as the educational system and science SBA curriculum for high schools in Solomon Islands (see Appendix G for maps and other details of the study context).

1.7.1 Solomon Islands Geopolitical Context

This study involved trainee and practising science teacher participants from Solomon Islands, a sovereign island nation in the Western Pacific region. Solomon Islands has

a total land area of 27,986 square kilometres with a coastline that stretches 5,313 kilometres (Central Intelligence Agency [CIA], 2016). The land area comprises six large islands and 992 smaller chains of islands, out of which only 347 islands are inhabited (Jones, 2001). Although small boats and ships are the main form of transportation, travelling between the islands is challenging due to poor infrastructure and geographical remoteness. For instance, when collecting data for this study, I had to travel a distance of just 114 km for six hours by boat from Honiara, Guadalcanal to Auki, Malaita. Then I had to travel another 108 km by truck for almost five hours to the school that is situated on the north-eastern side of Malaita. This experience is typical to what education officers, teachers and learners in schools around most of the remote and rural regions in Solomon Islands experience on a regular basis. Given this context, this study only involved participants from high schools and the SINU which are located in and around the capital city, Honiara on Guadalcanal as well as two schools on the island of Malaita. These two locations are geographically convenient given the limited time and finance to do this study under my Doctor of Philosophy program at Curtin University.

Solomon Islands is still a developing country. In 1893, Solomon Islands was declared a British Protectorate by the United Kingdom until 1978, when it gained its independence and remains part of the Commonwealth with a Governor General who represents the British Monarch (Moore, 2010). Solomon Islands has a democratic government with a constitution that was mostly influenced by the Westminster form of one legislative national parliament and nine provincial governments. The national parliament is comprised of 50 elected members who by a simple majority elect the Prime Minister to lead the Executive government for every four years (Moore, 2010). As such, educational policies may also change according to the Executive government of the day. This political context is significant since the outcome of this study can be used to inform and influence future improvements in education policies in Solomon Islands, as presented later in subsection 7.3.3.

1.7.2 Demography and Human Resources Development

This study explored an educational phenomenon that impacts the 20 percent of the population in Solomon Islands who attend high school. It was estimated that the population of Solomon Islands was about 600,052 in 2016, and is increasing by 36

persons daily (Countrymeter, 2016). The population comprises a mixture of about 95.3 percent Melanesians, 3.1 percent Polynesians, 1.2 percent Micronesians, and 0.3 percent of other races (CIA, 2016). With such a mixture of races there are about 86 different native languages and 120 dialects. However, English is the official language which is recommended as the language for instruction in schools and in the formal sector (Honan & Harcombe, 1997). The widely spoken and most common language for communication in everyday life is Pidgin, also known as broken English (CIA, 2016). While most people in Solomon Islands can speak more than one language there is a challenge for language transitions in classroom learning, teaching and assessment in formal schooling (Lotherington, 1998). Consequently, this context is imperative to the development of science teachers who would also teach and assess learners with diverse sociocultural backgrounds in Solomon Islands.

Solomon Islands has a growing and mostly dependent population who are gradually drifting to the urban areas (CIA, 2016). This poses a challenge for education in the urban centres along with the issue of nearly 50 percent of learners dropping out of their formal education at the end of the external examination classes (Department of Foreign Affairs and Trade [DFAT], 2014). One main challenge is to provide the learners with adequate knowledge and skills for life-long learning that they would use in their everyday civic lives after leaving formal education. Furthermore, education in Solomon Islands was further scrutinised after an ethnic tension between militia factions' from Guadalcanal and Malaita broke out into a civil crisis in 1999 (UNICEF, 2014). However, in 2003, an intervention by the Regional Assistance Mission to Solomon Islands (RAMSI) finally restored law and order (DFAT, 2014). Subsequently, the "Education Sector Improvement and Reform Programme (ESIRP)" (MEHRD, 2011, p. 1) was developed with more emphasis placed on "education for life" (p. 1) resulting in a shift of the education curriculum to OBE beginning in 2004. The changes in education in Solomon Islands were still in progress when this study was carried out and written up.

1.7.3 Educational Structure in Solomon Islands

The education restructure and reform in Solomon Islands are imperative to the context of this study. Prior to the introduction of formal education in the western context, Solomon Islands indigenous production of knowledge and its "transmission in

traditional forms of Solomon learning and teaching was not strictly egalitarian” (Watson-Gegeo & Gegeo, 1992, p. 11). Generally, the transmission of knowledge and understanding in Solomon Islands was socially and culturally constructed. Knowledge and skills were passed on through practical social interaction between the novices and the expert in situ or real life contexts. Learners or novices were practically prepared for real life and life-long learning through their livelihoods. Although different in nature, the concepts of real life and life-long learning resonate with the sociocultural and constructivist ideas that underpin the introduced OBE approach in Solomon Islands (MEHRD, 2011). That is, the OBE focuses more on the abilities of learners to construct and demonstrate the intended learning outcomes and life-long learning skills.

Currently, there are six levels of formal education in Solomon Islands. The six levels include Early Childhood Education (ECE), Primary School (PS), Junior Secondary Education (JSE), Senior Secondary Education (SSE), Vocational or Technical Education (TVET) and Tertiary Education (TE) (MEHRD, 2011). This study focused on the three types of schools within the JSE and SSE levels. In 2014, the three types of schools comprised of 223 Community High Schools (CHS), 15 Provincial Secondary Schools (PSS) and 12 National Secondary Schools (NSS). In addition, there are 43 TVET institutions and one National University (MEHRD, 2015). Although different in nature, the three types of high schools within the JSE and SSE levels have the same science SBA curriculum (MEHRD, 2011, 2016). However, the number of learners enrolled at JSE level was nearly twice that of the enrolment at SSE level. For instance, in 2016, there were 33, 474 learners enrolled at the JSE while only 18,557 were enrolled at the SSE. Additionally, only 18 percent of learners at SSE levels continue on to complete Year 13 (MEHRD, 2017). This reduction in enrolment within the three types of schools at JSE and SSE poses a challenge to enhance the science SBA curriculum, especially in the context of OBE and pragmatic learning of life skills as well as for life-long learning.

1.7.4 Science School-Based Assessment in Solomon Islands

As outlined in Section 1.4, the science SBA is often promoted as a way to improve the constructivist and pragmatic approach in assessment for learning (formative assessment) and assessment of learning (summative assessment). Currently, in Solomon Islands, the science SBA curriculum is predominantly used for continuous

summative assessments at Year 10 through to Year 13 (Kakai, 2010, MEHRD, 2010). The science SBA for Year 13 is designed and influenced by regional education providers like the SPBEA and the USP. Hence, this present study involved trainee and practising science teacher participants who were more familiar with the science SBA curriculum in Year 10, 11 and 12. In this regard, the science SBA curriculum for Year 10 and 11 was used in the context of this study. This is part of the SISC curriculum that learners undertake at the beginning of Year 10 and complete at the end of Year 11 the following year.

The SISC program is comprised of four core subjects which are compulsory for all learners and five elective subjects, with an option for learners to choose any two. The core subjects include English, Mathematics, Science and Social Studies while the elective subjects include Agriculture, Business studies, Home Economics, Technology Education and Christian Education (MEHRD, 2015). The subjects that have SBA as a component towards the SISC are Science, English, Home Economics, Agriculture and Technology. However, the weightings of assessment components for each subject vary. For example, Science has 70 percent from the final external written examination at the end of Year 11 and 30 percent from continuous summative assessment from SBA in Year 10 and 11 (MEHRD, 2010). Besides, in Year 12, the SBA of practical work makes up 40 percent of the 100 percent. This context is significant for this study since the science SBA component contributes almost half of the total assessment results towards the learners' final grades.

The science SBA curriculum for Year 10 and Year 11 consists mainly of practical works which are used as assessment activities. Learners are required to carry out the practical works and present their written reports for marking and assessment. However, the reports are marked and assessed by learners' respective science teachers in each school. Although marking rubrics are provided uniformly, the reliability of the science SBA result is not guaranteed since the actual marking depends primarily on the ability of each science teacher. This poses a concern since the science SBA component makes up 30 percent of the final marks that would determine the learner's grade in science for the SISC. A learner's aggregate for the SISC is crucial for selection by the National Education Assessment Division (NEAD) in Solomon Islands. Learners with the highest aggregates may go on to do Year 12 the following year. Those who

are not selected have to find alternative pathways into tertiary or vocational studies. Some may have to start their civic lives after attaining the SISC. This context of the science SBA is important for this study as well as for the Year 10 and Year 11 learners in Solomon Islands.

Although the science SBA for SISC has a booklet that contains practical work designs as well as guidelines for science teachers, the content is reviewed every two years (see Appendix A for 2010 - 2015 SBA booklet for details). Hence, it is hoped that the outcome of this study can be used to inform as well as enhance the review process in the future. Currently, the intended purpose of the science SBA is to assess learners' performed skills and abilities in science that are not possible to assess through written examinations. These include the ability to: follow instructions; use apparatus correctly; observe, record and analyse data; and draw scientific conclusions (MEHRD, 2010). However, while these performed skills and abilities are intended to be assessed, learners are assessed using their written reports that focus more on conceptual and procedural understandings (see Appendix B for a sample of physics practical work). Hence, this study is more concerned with the SBA of scientific concepts and procedures that learners are supposed to explain and describe in their written reports.

Given these contexts, this study sought to explore and document the trainee and practising science teachers' perceptions, experiences, beliefs and understanding of scientific and physics concepts in the SBA of practical work. Participants' views and experiences are imperative to the purpose of bridging the gap between what is intended and attained in the science SBA curriculum. In particular, the purpose of enhancing science teachers' PCK to teach and assess scientific and physics concepts in the SBA of practical work. This leads to the significance of this study which is presented next in Section 1.8.

1.8 Significance of this Study

This study is not only significant to the context of Solomon Islands and other South Pacific island nations but it would also be applicable to other sociocultural and geopolitical contexts globally. It is argued that one of the main ways of monitoring the multiple facets surrounding the concept and context of quality education in schools is by the level of learners' achievement (Fasi, 2005; Harlen, 2005). This is the outcome

of valid and reliable assessment information, which is generated by teachers and their learners from assessment activities within the teaching and learning process in schools (Bell, 2007; Lingam & Lingam, 2016). In regards to the science SBA, the science teacher's role is pivotal in the classroom. Hence, it is significant to explore and document their views and experiences. It is on this basis that this study is significant since it explored and provided information to improve the coherence between teaching, learning and assessments of scientific concepts in the SBA of practical work.

The outcome of this study is crucial to the development and implementation of the new national education curriculum in Solomon Islands which places great emphasis on learning outcomes and continuous SBA for learning in all subjects in both primary and secondary education (MEHRD, 2016). This is also a trend and an initiative promoted and encouraged by regional education providers such as the SPBEA, the USP and the Pacific Education Development Framework (PEDF) of the Pacific Islands Forum Secretariat. Besides, the information from this study can be used to improve educational assessment policies, school curriculum, classroom practices as well as teacher training and on-going professional learning programmes. Furthermore, this study provides a set of guidelines that can be used to enhance science teachers' teaching qualities in Solomon Islands as well as the South Pacific region as a whole. Accordingly, this study is significant not only for Solomon Islands but also for the Pacific region, especially, when a new curriculum is introduced, like in the case of Solomon Islands educational reform.

This study is the first of its kind in Solomon Islands and the Oceania region. Therefore, the outcome of this study would provide a novel contribution to the existing range of science education literature. Last but not least, the information provided in this study can also be used as a framework to design other future studies in science education.

1.9 Synopsis of the Research Design for this study

This study employed a "triangulation mixed methods" (Creswell, 2008, p. 557) approach within a case study design (see Chapter Three for more details). Hence, this study employed both quantitative and qualitative methods to generate two data sets from study participants, bounded by the phenomenon investigated as well as the geographical convenience of the schools visited (Cohen, Manion & Morrison, 2007;

Creswell, 2012). With triangulation mix methods the two data sets were collected in any order as in which ever came first. This design was favoured since although both data sets were independently collected they were complementary to each other's shortfalls and was regarded as triangulation (Creswell, 2012; Onwuegbuzie, 2002). That is using two different methods to generate and to validate data for the same phenomenon.

The quantitative data were collected using a survey. These data generated a general trend of the phenomenon by providing comparisons and relationships between variables in statistical and graphical representations (Creswell, 2012). The quantitative findings are reported in Chapter four. Complementary to this, qualitative data were generated using one-on-one and focus group audio recorded interviews. The qualitative data generated detailed and in-depth explanations and rich descriptions that were used to triangulate as well as complement the survey responses and inferences (Cohen, et al., 2007). The qualitative findings are reported in Chapter five.

1.10 Summary of Chapter One

This chapter began with an overview and organisation of the whole thesis. Then it provided the explanation for the motivation and background for this study. It has also outlined the purpose, research questions and the theoretical framework for this study. This was followed by a brief description of the study context which made this study different from studies in other geopolitical and sociocultural contexts. Subsequently, the significance of this study was highlighted followed by a synopsis of the research design.

This chapter was written using first person approach to express and emphasise the humanistic and personal constructivist aspects of putting this study together. The chapters that follow are written using third person approach which is widely used in many other theses. Next, Chapter Two discusses the literature review of the key research areas premised in the conceptual framework for this study.

CHAPTER TWO

Literature Review

2.1 Chapter Overview

While the previous chapter introduced this study, this chapter provides a review of literature regarding key research areas that underpinned the conceptual framework for this study. Hence, this chapter begins with a brief outline of the conceptual framework for this study in Section 2.2. Section 2.3 then discusses the understanding of scientific concepts followed by outlining the nature of practical work in Section 2.4 and nature of school-based assessment (SBA) in Section 2.5. Thereafter, aspects of pedagogical content knowledge (PCK) are discussed in Section 2.6 while Section 2.7 presents the summary for Chapter Two.

2.2 Conceptual Framework for this Study

The conceptual framework for this study is underpinned by an established theoretical framework which postulates a gap between intended and attained curriculum as outlined in Section 1.5 and illustrated in figure 1.1 (Goodlad, 1979; Rosier & Keeves, 1991; Van den Akker, 1998). With the premise that science teachers' PCK is a pivotal element in minimising the gap, this study integrates key research areas into a coherent conceptual framework that premised to enhance the nexus between teaching, learning and assessment of scientific concepts in the SBA of practical work and PCK. The integration of the key research areas in the conceptual framework for this study is illustrated in figure 2.1.

The conceptual framework premises that, if science teachers understood scientific concepts, then they can use practical work effectively to teach scientific concepts. This is indicated with Arrow 'a' in figure 2.1. Add to that, dotted Arrow 'b' indicates the premise that, knowledge of the nature and purposes of practical work can help science teachers to effectively teach scientific concepts. Besides, Arrow 'c' indicates the

premise that understanding the multiple nature of SBA is significant for teaching and assessing of scientific concepts while Arrow ‘d’ indicates the premise that science teachers’ understanding of scientific concepts is imperative for scaffolding and assessment for learning in the SBA of practical work. Arrow ‘e’ indicates the premise that practical work and SBA are equally related and both can be utilised to serve the purpose of teaching, learning and assessment of scientific concepts and skills. Therefore, this study premises that science teachers’ PCK is a central link that should comprise a coherent integration of the key research areas as depicted in figure 2.1.

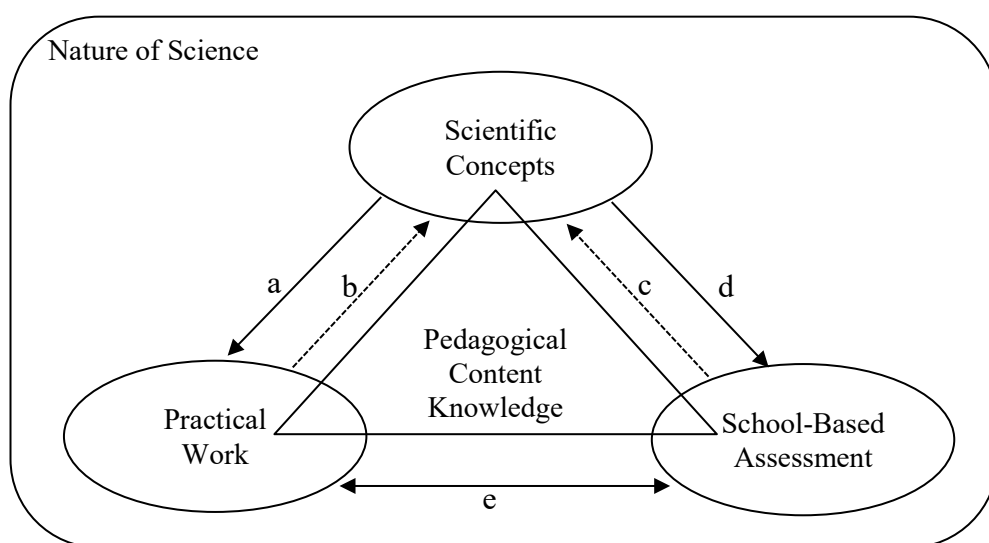


Figure 2. 1. Model of conceptual framework for this study

Currently, there is a lack of research that integrates the various components identified in this conceptual framework. Specifically, no research has been conducted to explore the views and experiences of science teachers regarding the nexus in teaching, learning and assessment of scientific concepts in the SBA of practical work. Hence, this study sought to explore and document both the trainee and practising science teachers’ views and experiences regarding the nexus between the key research areas. Specifically, this study sought to ascertain the importance of enhancing science teachers’ PCK in order to bridge the gap between what is intended and what is attained in the SBA of practical work curriculum.

Other studies had examined a particular key research area. For example, many studies examined various aspects of understanding scientific concepts (Fleer, 2009; Khishfe & BouJaoude, 2016; Slotte & Lonka, 1999). Similarly, many studies had investigated

the nature of practical work and its significance, effectiveness as well as challenges (Abrahams & Reiss, 2012; Bennett, 2003; Harrison, 2016; Millar, 2004). Besides, there are studies and reviews on the multiple use of SBA in both developed and developing economies (Bell & Cowie, 2001; Cheung, 2016; Chong, 2009; Malakolunthu & Hoon, 2010; Maxwell, 2004). Added to that, many recent studies had delve into defining the nature and importance of PCK (Berg, 2015; Jones & Moreland, 2003; Kind, 2009; Lehane & Bertram, 2016). Basically, these studies have provided discussions on different aspects of the key research areas identified within the conceptual framework for this present study.

Other studies had contributed research based literatures regarding a combination of two or three key areas. For example, Halim et al. (2010) examined science teachers' PCK of selected physics concepts in Malaysia. Chun (2006) conducted a case study in Hong Kong to examine the practice and challenges of School-Based Formative Assessment. Kapambwe (2010) examined the implementation of school-based continuous assessment in Zambia. Thimmappa and Sharma (2003) examined the implication of SBA within the Pacific Island nations. In Solomon Islands, Walani (2008) reported a study on the perceptions of teachers about the use of formative assessment while F. Rodie (2014) reported a study on summative assessment practices in Year nine science. Besides, Kakai (2010) explored the perceptions of science teachers on the SBA of practical work in science education. As well, Lingam and Lingam (2016) looked at challenges and steps to develop school-heads as instructional leaders in SBA. Accordingly, these studies had provided researched based literature by examining a nexus between two or three key research areas. However, there is lack of research information that explored a coherent nexus between the key research areas presented in the conceptual framework for this study.

Hence, it is hoped that the conceptual framework for this study will add another perspective to the already existing wealth of science education literature on: teaching, learning and assessment of scientific concepts; practical work; SBA; and PCK. This study will provide a set of guideline that connects and integrates these key research areas into a coherent conceptual framework. That emphasised, the conceptual framework for this study is further elaborated by discussing and linking the key

research areas. The first key research area to discuss is the notion of understanding scientific concepts.

2.3 Understanding of Scientific Concepts

Understanding scientific concepts is one of the main goals in high school science teaching, learning and assessment in most science education contexts globally (Fleer, 2009; Khishfe & BouJaoude, 2016; Slotte & Lonka, 1999). This is evident in many high school science curriculum documents which emphasise the importance of understanding scientific concepts. Purposely, to prepare learners for further tertiary studies and career paths in science as well as, for every day livelihood in societies that are greatly influenced by science and technology (Uzunboylu & Aşıksoy, 2014). For example, the Australian curriculum for science states that “science provides opportunities for students to develop an understanding of important science concepts and processes” (Queensland Studies Authority [QSA], 2015, p. 1). Similarly, an utilitarian purpose of science teaching in New Zealand for the twenty first century “involves a focus on basic science concepts and principles as they apply in the everyday world” (Gluckman, 2011, p. A-16). Besides, according to the Australian National Curriculum Board [NCB] (2009), science understanding includes science knowledge which “refers to facts, concepts, principles, laws, theories and models that have been established by scientists over time” (p. 6). The Solomon Islands science curriculum also emphasise the importance of learners to develop their knowledge and understanding about scientific concepts (MEHRD, 2011). Hence, it is imperative to understand and differentiate the term scientific concepts commonly used in school science from the intuitive tacit concepts that learners construct from their everyday experiences.

While the term scientific concept is used regularly, the term concept itself is used many times with other terms within science as well. For example; physics concepts, chemistry concepts and biology concepts. Furthermore, the term concept is also used with other terms such as; force concept, concept of light, concept of pressure, and concept of energy, and so on in physics education. Inevitably, the term concept is used many times in science curricula documents. For instance, from a quick review, Tang (2011) revealed that national science and mathematics curricula for countries like the

United States of America (USA), United Kingdom (UK) and Singapore have the term concept(s) appeared “from 14 to 97 times throughout the documents” (p. 109). These curricula documents emphasised the importance for learners to acquire and demonstrate the knowledge and understanding of scientific concepts that they learn in school science.

However, although school curricula documents as well as science teachers prevalently used the term concept in science education, most “would find it hard to articulate a definition” (Tang, 2011, p. 111). As such, Tang (2011) posited that since the term concept is used extensively in curriculum documents, its nature and articulation needed to be unravelled. Subsequently, in tracing literature definitions and usages of the terms concept and conception, Tang (2011) developed a framework that articulates the nature and definition of concept and conception in science learning. Tang (2011) used a multimodal approach by using diverse disciplines to theorise and analyse the meaning and nature of concept in science education. That said, it is imperative for this study to articulate the definition and nature of concept and conception in order to understand the basis for teaching, learning and assessment of scientific concepts. Thus, the definition and nature of concept and conception are discussed next.

2.3.1 Concept and Conception in Science Education

The terms concept and conception may have ambiguous as well as contentious definitions in philosophy and psychology (Lalumera, 2014; Malt, 2010). These two perspectives theorised that, “concept is a theoretical term” (Lalumera, 2014, p. 73). As such, the term concept is part of a theoretical explanation about the science of cognitive construction of an idea (Lalumera, 2014). In addition, Bloch-Mullins (2015) pointed out that, “concepts are constituents of thoughts. They enable us to classify the world into categories” (p. 940). On the one hand, philosophers proposed that concept is an abstract object, independent of the mind while on the other hand, psychologists theorised concept as a mental representation, internal to the mind (Margolis & Laurence, 2007). Subsequently, when examining this theoretical difference, Margolis and Laurence (2007) postulated that “concepts should be identified with mental representations” (p. 588). That is, concepts are mental representations of entities or phenomena. It is alleged that individuals may regard their mental representations of entities and phenomenon as truths about reality. Hence, the mental representations that

an individual construct and hold about reality would set a system of beliefs that are well situated within the holder's schema of thoughts and actions (Remesal, 2011). Accordingly, Remesal (2011) argued that, conception is the organisation of the systems of beliefs that individuals construct and hold as mental representations of reality that they experience.

Science education literature indicated that many science curriculum documents use verbs such as “understand, know, have, use, apply, and develop” (Tang, 2011, p. 111) along with the term concept. For example, learners must be able to understand and apply the concept of force. The use of such verbs tend to indicate that concept is an object or a thing that an individual “can recognise, acquire and possess” (Tang, 2011, p. 111). Along with this, a concept was normally regarded as a stable idea or mental representation of an entity or a phenomenon (Gilbert & Watts, 1983). It was posited that a mental representation is a formation of some structured strings of information, images, situations and actions which can be integrated cognitively to interpret and explain new happenings as well as guide individuals interactions and reasoning about any new and similar entity or phenomena (Driver, 1989; Lalumera, 2014). In other words, mental representations of reality may help individuals to recognise and classify entities into categories as well as, to have the capacity to integrate and apply their knowledge within other situations (Bloch-Mullins, 2015). That means, individuals use their mental representations of entities to recognise and explain phenomena and situations.

However, while concept may be regarded as a stable mental model of an entity or a phenomenon, Wells (2008) and Vosniadou (2008) argued that scientific concepts are not relatively stable and they do not belong to individuals. This argument is in-line with the view that, the term concept can be used with reference to individual's knowledge structure, such as every day concepts, as well as public knowledge systems such as, scientific concepts (Gilbert & Watts, 1983; Wells, 2008). That means, a concept can be referred to as a mental representation that an individual constructed about reality through cognitive development or as a system of knowledge constructed and sanctioned by an organisation.

According to Vygotsky (1987) and Fleer (2009), it is important to differentiate and connect everyday concepts to scientific concepts that are sanctioned and can be

generalised. Vygotsky (1987) asserted that learners developed an idea or a mental representation through their everyday experiences and direct interactions with an entity or phenomena. Basically, Vygotsky (1987) developed a dialectical argument about conception or formation of a mental representation by emphasizing a link between words and verbal thinking which reflects that someone has consciously developed an idea about an entity. That is, when an idea is formed in the mind there are words that are linked to it and those words can be used when speaking and writing to reveal that idea. Besides, Vygotsky (1987) claimed that everyday concepts or ideas that learners formed about entities and phenomena are grounded in their daily life experiences and interactions. These everyday concepts are well situated in the mind, thus greatly influence the learner's conceptions and beliefs about reality.

However, an idea formulated through and from experience as well as direct interaction in everyday life may not be scientific and cannot be generalised to other contexts or situations (Fleer, 2009; Vygotsky, 1987). Learners may construct mental representations from every day experiences and interactions but the mental representations may not be scientific (Fleer, 2009). For example, learners may develop an idea by experiencing that bigger and heavier objects fall faster than smaller and lighter objects when dropped at the same time from the same height above the ground. Although, learners through everyday experience with falling objects may formulate and can reasonably reveal their ideas in words and semiotics, their explanation that heavier objects fall faster than lighter objects may not be scientific. Other researchers refer to learner's conceptions that are different to scientific concepts as "misconceptions... preconception, naïve theories, and alternative frameworks" (Read, 2004, p. 2). Nevertheless, Sneider and Ohandi (1998) prefer to use the term misconception to emphasize the need for learners to make a conceptual change from a conception that is not scientific to one that is scientifically correct.

According to Vygotsky (1987), everyday concepts are spontaneous and constructed during particular instances in everyday life while scientific concepts were constructed over time and are part of a structured body of knowledge. As such, Vygotsky (1987) argued that a mental representation of an entity that is scientifically correct can be constructed through formal learning in school science. However, Vygotsky (1987) and Fleer (2009) asserted that scientific concepts that are formally learnt in schools during

schooling should have some connections to the learner's everyday contexts. Further to that, it is beneficial to connect the learning of scientific concepts with learner's every day or "spontaneous concepts" (Howe, 1996, p. 38). In other words, it is vital to make connections between the formation of concepts from everyday experiences and formation of scientific concepts through formal learning.

However, according to Tang (2011), Vygotsky's terminology of scientific concepts refers more "to the systematic concepts that are gained through formal learning (as opposed to spontaneous concepts) and not the notion of scientific concepts that are commonly found in science curriculum and instructions" (p. 114). Tang (2011) argued that Vygotsky's contentions about scientific concepts was mainly from the stand point of learners' psychological development. In fact, Tang (2011) highlighted that scientific concepts are "more concerned with a broad sociohistorical constitution of knowledge, social subjects, and conceptual framework of a society or institution" (p. 115). Hence, in a broader and discursive system, scientific concepts are defined and sanctioned by an organised society or institution with a set of rules and discourse. In this case the organised society is the scientific community (Tang, 2011). Therefore, scientific concepts that are formally learnt in school science are collaboratively constructed overtime and sanctioned by the scientific community.

Wells (2008) alleged that scientific concepts are institutionally accredited by the interrelated organisations within the scientific community. Hence, although concepts maybe formulated or constructed by an individual within the community, the concepts are further proved, scrutinized and formally documented according to the binding historical practices and rules of conduct within the scientific community (Tang, 2011; Wells, 2008). As such, it can be argued that the scientific concepts that are found in science curricula were collaboratively produced, heavily scrutinized, documented and institutionally sanctioned within the scientific community. So scientific concepts are not determined and defined by a single discipline such as Physics, Chemistry or Biology but by the broader scientific community that consists of many interrelated systems of disciplines (Tang, 2011; Wells, 2008). Added to that, Wells (2008) asserted that a scientific concept is not a single idea but a systematic structure of ideas that are interrelated, connected and is shared within the scientific community.

Along this line of argument, Treagust and Duit (2008) portrayed scientific concepts as mental constructs that are collaboratively shared by a community. Additionally, they asserted that the conception of scientific concepts is basically the formulation of mental models that represent external entities that are formally learnt in school science. That implies that, the understanding of scientific concepts in science curricula documents should be accorded to what is known, accepted and sanctioned by the scientific community. Historically, professional scientists over many generations had developed the scientific concepts to increase their understanding as well as to develop possibilities for their actions within the scientific community (Wells, 2008). Thus, scientific concepts were produced as “cultural artefacts... and they do not belong to particular individuals... but are available for all to use” (Wells, 2008, p. 346). That means, scientific concepts belong to the scientific community and teachers, learners as well as individuals can learn and use them on a social plane (Tang, 2011). Subsequently, science teachers should develop better understanding of scientific concepts in school science. In this regard, it is significant for this study to explore both the trainee and practising science teachers’ understanding of physics and scientific concepts in the context of practical work.

However, in order to understand and subsequently teach, learn, assess and use scientific concepts it is also proper to further outline the nature and construction of scientific concepts from a representation framework (Tang, 2011).

2.3.2 Representation Framework of Concept and Conception

Wartofsky (1979) argued that the primary role of mental representations in understanding scientific concepts should be placed on the activity of representing concepts using models. According to Wartofsky (1979), a model is “a putative mode of action, a representation of prospective practice, or of acquired modes of action.” (p. xv). In other words, the mode of actions should be commonly used and accepted to represent the meaning and understanding of scientific concepts. From a representation perspective, Tang (2011) theorized that modes of actions that can be used to represent the understanding of scientific concepts include; “speaking, writing, drawing, and gesturing” (p. 128). Added to that, Roth and Tobin (1997) stressed that scientific concepts can be represented in equations, graphs, tables of values that are connected with verbal and written descriptions, interpretations and explanations. That means, the

language, literacy and semiotics used in science curricula texts can be deconstructed into modes of actions that learners can learn and enact to enhance as well as communicate their understanding of scientific concepts.

Nevertheless, Roth and Tobin (1997) inferred that learners' difficulty in understanding scientific concepts in school science is associated with the making of connections between the "multitudes of translations across ontological gaps" (p. 1088). The multitudes of ontological gaps comprised of the related systems of ideas, inscriptions, equations, graphs, table of values and semiotics that are *priori* to connect and construct a particular scientific concept (Roth & Tobin, 1997). Hence, to construct understanding of a particular scientific concept it is vital to understand and connect other system of ideas that are represented in many different modes such as graphs, tables of values, equations, semiotics and verbal descriptions that composed the scientific concept. That said, this study is premised on the basis that it is significant for science teachers to develop the understanding that scientific concepts are a system of ideas that are connected.

Many times science teachers fail to figure out why learners find it difficult to understand scientific concepts. Even teachers may find it difficult to understand and translate the associated system of ideas, language and semiotics that construct a scientific concept (Roth & Tobin, 1997). For example, the concept of force is connected to the concept of acceleration and mass. The connection can be represented in an equation, graph, table of values, diagrams and so on. Besides, the concept of acceleration is also related to the concept of velocity and displacement. Hence, to understand the concept of force, learners have to first construct the ideas encompassing acceleration and mass. But before that learners should understand that the concept of acceleration is related or connected to the concept of velocity and displacement. These related concepts are arranged in certain ways according to a set of rules or conventions that the scientific community agree upon and use. According to Roth and Tobin (1997) science teachers need to develop such understanding in order to make meaningful deconstructions of scientific concepts into forms that learners can comprehend and reconstruct cognitively as well as demonstrate audibly and visibly.

As mentioned earlier, Tang (2011) theorised a framework using a representation approach to deconstruct scientific concepts. According to Tang (2011), scientific

concepts are written in science curricula documents and materials for teachers and learners to deconstruct their meanings into intelligible representation human actions and practices in school science. Using a representation approach, Tang (2011) developed a theoretical framework that defines the nature of concept as:

an assemble of words, inscriptions, and objects that have to be actively made through human actions and practices, what a person ‘knows’ as a concept is then precisely what he or she can explicitly do in terms of speaking, writing, gesturing, drawing, manipulating objects and so on (p. 130).

This theoretical framework implies that a scientific concept can be deconstructed into and constructed from a collection of words, inscriptions and objects that teachers teach as well as learners can learn and enact through various interrelated modes of actions.

That being said, when introducing a new scientific concept teachers should be able to unpack a scientific concept, analyse and identify its related representation entities and connections (Tang, 2011). For example, Tang (2011) proposed that to unpack a scientific concept from a science curriculum and textbook text, it is important for teachers to examine and analyse the linguistic and visual structures that learners can read, visualise and enact through means of representations. In other words, science teachers should have developed the understanding and ability to unpack scientific concepts into related representations, entities and connections. In view of that, this study used survey items and interview questions that probed into trainee and practising science teachers’ views on how they can unpack, introduce and teach physics concepts.

On this aspect of unpacking scientific concepts in school science, it is vital for this literature review to briefly outline the epistemology of scientific concepts or the nature of science (NoS) and scientific methods (Leach, 1998).

2.3.3 Nature of Science

According to Leach (1998), NoS is related to the epistemological and socio-historical aspects of scientific body of knowledge and processes within the scientific community. Basically, NoS has no simple definition (Parkinson, 2004). However, according to Miller (2004) NoS relates to how individuals, groups and different communities of

disciplines within the scientific community socially interact in order to theorise, experiment, formulate and construct scientific concepts and processes. As such, according to Miller (2004), NoS involves the sociocultural and constructivist epistemology of scientific knowledge, skills and the process of enquiry. This involves the different types and levels of claims scientists make, the kind of reasoning scientists use to undertake in order to formulate connections between data, interpretations and explanations as well as the role of the scientific community in analysing, examining and sanctioning scientific knowledge (Parkinson, 2004). That said, while NoS has no simple or single definition, it can be understood by its features.

As one of many features, NoS portrays that scientific knowledge is understandable and reliable for use at a particular time since it is tentative and subject to change with new findings or reviews over time (National Science Teacher Association [NSTA], 2000; Parkinson, 2004). However, although tentative, scientific knowledge is reliable for a particular time and space because its construction requires overwhelming evidences as well as strong reliability and validity over time. These can be enhanced by precision in techniques, instrumentation and repeated rigorous processes within a natural setting or in a laboratory setting (Parkinson, 2004). Such a rigorous process can be messy and there is no one set of rules or an algorithmic procedure that actually underpinned a step-by-step scientific method (Wellington, 1998, Osborne, 2015). As such, science teachers should develop the understanding that although scientific knowledge is reliable, it can also be tentative.

According to the NSTA (2000), another feature of understanding NoS is encompassed in the following premise:

Although no single universal step-by-step scientific method captures the complexity of doing science, a number of shared values and perspectives characterize a scientific approach to understanding nature. Among these are a demand for naturalistic explanations supported by empirical evidence that are, at least in principle, testable against the natural world. Other shared elements include observations, rational argument, inference, scepticism, peer review and replicability of work (NSTA, 2000, para, 2).

In this feature, NoS portrays scientists as ordinary social individuals who also have personal attitudes and attributes, opinions and predispositions (Wellington, 1998). However, the difference is scientists ask and find answers to hard questions. Subsequently, they are innovative, creative and work within a sociocultural, historical, political and authentic contexts of the scientific community (Wellington, 1998). As such, although scientists work in different disciplines of science which differ from one another with respect to the kind of phenomena they investigate and the processes they employ, there is a conventional understanding about what makes an investigation valid and reliable within the scientific community (Parkinson, 2004). As such, science teachers should understand that scientist are also individuals who work within the sociocultural context of their community of practice.

Basically, Latour and Woolgar (1979) described an account of the social construction of scientific facts that took place in science laboratories. They observed how scientists socially construct scientific facts in a laboratory setting. While they recognised that scientists and technicians in the laboratory wrote in a similar way, they also noticed that some activities were not connected to some sort of generic transcription or inscription. Scientists and technicians were doing more “coding, marking, altering, correcting, reading, and writing” (Latour & Woolgar, 1979, p. 49). There were expensive inscription devices that transform material substance into inscriptions such as graphs, diagrams and table of values. Scientists later organised and systemized the inscriptions into what seemed like a process of “literary inscription” (Latour& Woolgar, 1979, p. 52). In other words, laboratory activities involved the process of transforming substance materials into inscriptions of codes, marks, diagrams, values that are later organised systematically and presented as literature with a meaningful language. The transforming process went through different levels of scrutiny and the interpretation of the inscriptions into a meaningful scientific fact in literature were exhaustive. While this can be understood within the scientific community, science teachers can understand the features that portray the NoS.

Understanding the features of the NoS is crucial for science teachers (Akerson, Cullen & Hanson, 2009; Gallagher, 1991; Hodson, 1985). Such an understanding would help influence science teachers beliefs and views about science teaching, learning and assessment in science classrooms (Handelsman, Miller & Pfund, 2007). To improve

science teachers' use of NoS, it is also essential for them to have a knowledge and understanding of the effective pedagogical practices associated with the NoS (Schwartz & Lederman, 2002). This assertion was supported by a study conducted on 17 K-6 elementary science teachers in Atlanta, USA (Akerson et al., 2009). Using pre-test and post-test at their summer workshops on the NoS, they found that the science teacher participants enhanced their teaching and assessment practices in their science classrooms. Nevertheless, they recommended that the concept of NoS should be integrated into the science teacher training education as well as ongoing professional learning within a community of practice in schools and science classrooms.

This notion of community of practice is in-line with the view to establish science classrooms that integrates the dimensions of cognitive, epistemic and sociocultural process (Duschl, 2008). In fact, Duschl and Grandy (2013), suggested that learners are required to study or engage in the common practice of science. That is, science classrooms should provide learners with learning environments that depict the basic activities that scientists engage in (Osborne, 2014). Osborne (2014) go on to assert that, "only then will they begin to understand how scientists establish credibility for the claims that they advance" (p. 180). Given the account described by Latour and Woolgar (1979), the learning environment in laboratories can depict the sociocultural, cognitive and epistemic processes. This would involve the sociocultural interactions whereby learners and teachers can collaboratively experience the NoS which encompasses cognitive and epistemic processes of science. Such an approach would form a community of practice whereby learners and science teachers not only teach and learn theoretically but they also practise the processes within their learning environment.

However, Webb (2007) pointed out that the transfer of the NoS knowledge into science classroom practices is complex. Such a transfer is influenced by many other contextual and personal factors. This includes class size and classroom management, the limitations of the curriculum and schools, time, other concerns for motivations and ability of learners as well as teacher's experience (Lederman, 1999). As such, Duschl (2008) suggested that there is a need to rethink the concepts and designs for teaching, learning and assessment in science education. According to Osborne (2015), practical

work is one of the activities in science classrooms that offers an opportunity for learners to:

experience phenomena themselves – an experience for which there is no substitute... second... it offers... the opportunity to experience the activity of enquiry – although this is predominantly limited to the testing of scientific ideas (p. 16).

In other words, practical work provides an opportunity for learners and science teachers to experience and practice the NoS. This link between practical work in school science and NoS provides a backdrop to gauge trainee and practising science teachers' views on the purpose of teaching and assessment using practical work.

2.4 Nature of Practical Work

Science education literature overwhelmingly emphasised the importance of practical work in school science (Abrahams & Reiss, 2012; Bennett, 2003; Harrison, 2016; Millar, 2004). According to Millar (2002), practical work “seems the natural and right thing to do” (p. 53). Over 200 years practical work was seen as an activity to exercise learners' senses and this has been emphasised in the United Nations Science education guide (Harrison, 2016). As well, many science teachers and science curriculum documents emphasise the use of practical work in school science as crucial to the teaching, learning and assessment of scientific concepts and skills (Donnelly, 1998). However, science education literature has used the terms laboratory work (lab work), experiments, investigations, field work and practical work to refer to similar kinds of activities carried out in school science. These terms may be used interchangeably or may be used to refer to the same kind of activities (Hodson, 1998). As such, it is significant to define the term and nature of practical work. This will be followed by outlining the purpose of practical work and how it is essential to teaching, learning and assessment in science education.

2.4.1 Definition of Practical Work

Many science education literature used the terms laboratory work, experiment, investigation and practical work in reference to similar types of school science

activities even though they may have distinct descriptions (Hodson, 1998). In fact, Hodson (1998) as well as Abrahams and Reiss (2012) pointed out that the term practical work is mainly used in Australia, New Zealand and European science education literature while North America generally use the term laboratory work and experiment “virtually as synonyms” (Hodson, 1998, p. 153). Since it is commonly used in European science education literature, Abrahams and Reiss (2012) emphasized that they use the term practical work as an overarching term. They suggested that, the term practical work:

refers to any type of science teaching and learning activity in which learners at some point, working either individually or in small groups, are involved in manipulating and/or observing real objects and materials (p.1).

Similarly, the Science Community Representing Education [SCORE] (2008) defines practical work as learning experiences in which learners can also interact with secondary sources of data such as observing the stars, taking photos of the Earth’s landscape and geography in order to understand their natural environment better. In other words, practical work is commonly used to refer to any science teaching, learning and assessment activity that involves learners to experience the handling and observing of real objects and phenomena.

Practical work as science activities are not characterized by the location that they are conducted in but by the type of experience that learners would involve in (Abrahams & Millar, 2008). These types of school science activities can be undertaken in school laboratories, inside or outside a classroom or beyond the school precinct, in a natural ecological environment or at home (Miller, 2004). According to Abrahams and Reiss (2012), practical work provides an opportunity wherein learners would learn school science by tangible experience and practice.

Practical work involves firsthand experience in which the five human senses of touch, smell, taste, hear and sight can be used to handle and observe phenomena, objects and organisms (Harrison, 2016; Hodson, 1998). For example, the experience of seeing and feeling how the forces of magnets attract or repel each other; hear and see the test for the popping sound of oxygen; seeing micro-organisms like plants cells using microscopes as well as making connections with simple electrical circuits. Basically,

these experiences do not occur in normal everyday lives of learners. Therefore, such practical work in school science can be seen as an opportunity for learners to learn and experience science which associates with developing the understanding of the NoS.

However, Osborne (2015) asserted that practical work is not all about experiencing phenomena and manipulating objects or material substances, it is a cognitive activity. According to Osborne (2015), “the defining feature of science is that, it is a set of ideas about the material and living world” (p. 16). In fact, Oakeshott (1933) pointed out that science begins with a world of scientific ideas. As such, it is crucial for science teachers to be clear about the science ideas that learners supposed to experience and construct in practical work. Bell (2005) stated that practical work is a thinking activity wherein learners and teachers constructed understanding and not solely to manipulate objects and observe. Given the notion that science is a set of ideas, practical work provides an opportunity for learners to learn by experience the understanding of constructing and verifying scientific ideas with their science teachers.

Learning by experience with material substances encompasses the notion of establishing procedural understanding of constructing scientific knowledge. Hence, “one particular set of ideas that is essential to the doing of all practical work is encapsulated by the concept of procedural knowledge” (Osborne, 2015, p. 20). Practical work provides the opportunity for learners to experience the procedural understanding of making meaning, collecting and interpreting data as well as constructing their understanding of scientific knowledge (Hodson, 1998). Basically, “procedural understanding has been used to describe the understanding of ideas about evidence, which underpin an understanding of how to proceed” (Glaesser, Gott, Roberts & Cooper, 2009, p. 597). Engaging learners in practical work would help them develop a broader understanding of epistemic and procedural ideas that guide the practice of science (Osborne, 2014). Practical work provides the opportunity for the learners and science teachers to experience and rationalise the messiness of epistemic processes in science. This is one of the features of NoS.

For the purpose of this literature review, practical work in science education is regarded as an overarching term. Practical work refers to school science activities which provide learners the opportunity to learn through hands-on, social interaction and cognitive experiences. Practical work also provides the opportunity for learners to

develop their cognition and thinking processes in constructing procedural knowledge and conceptual understanding in science. In other words, practical work enables learners to experience the NoS which encompasses the notion of sociocultural and epistemic understanding of science. As such, practical work involves a spectrum of activities that can be carried out not only within the laboratories or school precincts but also in the natural settings outside of the school context. While the term practical work is used in this literature review and thesis as an overarching term, the terms such as laboratory work, experiments, investigations and field work are also used at times to emphasize their contexts. That said, it is significant for this study to identify both trainee and practising science teachers' definition and purpose of practical work.

2.4.2 Purposes of Practical Work

This study sought to explore and document the views and experiences of trainee and practising science teachers about the practice of using practical work to teach and assess learners' understanding of physics concepts in the science SBA curriculum. The views and experiences of the participants were analysed and synthesized with the literature review discussed in this chapter. Subsequently, this study sought to develop a set of guidelines that can be used to inform and enhance science teachers' PCK in teaching, learning and assessment of physics concepts using practical work in SBA.

In essence, the purpose of practical work is related to the aims of science education as a whole (SCORE, 2011). Recently one main focus of science education in the western world as well as the globe revolves around the notion of scientific literacy (Allchin, 2011; Duschl, 2008; Hodson, 1998; Laugksch, 2000). This is associated with the goal to develop learners' life-long learning ability in science for everyday use in their societies which are increasingly influenced by science and technology (Allchin, 2011; Gluckman, 2011). In addressing such a goal, science education has multiple aims that can be summarised into two main areas. One is to help learners understand the established body of scientific knowledge and second, to develop learners' understanding on the NoS (Millar, 2004). The emphasis on these two areas is to develop learners' scientific understanding, knowledge and skills for further studies and career paths in science as well as for scientific literacy.

While these two aims have overlapping elements, the second aim for the NoS is closely related to the purposes of practical work. That is, the second aim encompasses:

an understanding of how scientific enquiry is conducted, of the different kinds of knowledge claims that scientists make, of the forms of reasoning that scientists use to link data and explanation, and the role of the scientific community in checking and scrutinising knowledge claims (Millar, 2004, p. 1).

These understandings, knowledge and skills can be addressed within three teaching, learning and assessment categories in science education (Hodson, 1998, 2014). The first category is ‘learning science’. This category includes learning and developing conceptual and theoretical scientific knowledge. The second category is ‘learning about science’. This category develops the understanding about the complex interactions science has with technology, socio-cultural and historical contexts as well as economic development and global issues regarding the natural environment. The third category is about ‘doing science’. This category involves the learners’ practical engagement in science inquiry as well as developing procedural knowledge in solving socio-scientific issues and problems (Hodson, 1998, 2014). Aligned to these categories of teaching, learning and assessment in science education are the purposes of practical work.

For over a century, the purposes of practical work were purported to enhance learners’: “understanding of scientific concepts; interest and motivation; scientific practical skills and problem solving abilities; scientific habits of mind, and understanding of the nature of science” (Hofstein & Lunetta, 2003, p. 38). Basically, these century over purposes of practical work can be classified into three main learning domains. That is, for learners’ cognitive, skills and affective developments in science (Wellington, 1998). In other words, the purposes of practical work include the understanding of scientific concepts and knowledge; procedural and manual skills; and attitude and motivation to do science. Subsequently, the purposes of practical work can be discussed in aligning these three learning domains in relation to the three categories encompassing the aims of science education.

Cognitive domain is in-line with the category of 'learning science'. This involves the purpose of using practical work to teach, learn and assess scientific concepts and theories by experience. While this purpose is imperative, Osborne (2015) cautioned that scientific ideas were well researched and historically established. Hence, scientific theories and concepts cannot be readily and easily reconstructed from observation as well as experimentation in school science. However, science teachers can teach and learners can learn scientific theories and concepts theoretically. Subsequently, learners can further construct and affirm their understanding of scientific concepts by employing hands-on experience or by illustrations, verification and observation of material substances and phenomena. Although Osborne (2015) argued that more evidences are needed to prove the success of practical work, Millar (2004) claimed that practical experience can aid the understanding of scientific concepts. Basically, hands-on and practical experience can help learners to observe at the same time cognitively construct and affirm their understanding of scientific concepts (Millar, 2004). For example, learners can theoretically learn Hooke's Law in physics classes but by doing hands-on experiment they can verify or affirm their understanding by making connections between the objects, phenomena and associated inscriptions. Apart from hands-on experience science teachers can also demonstrate using real objects to illustrate the phenomena while learners observe and cognitively interpret and construct their understanding.

Skills domain in practical work is associated with developing learners' manipulative or manual skills in handling objects or instruments as well as the development of procedural skills and knowledge (Hodson, 1996; Wellington, 2005). While the development of manipulative and manual skills are associated with how to use scientific apparatus and objects, procedural skills and knowledge are strongly related to scientific enquiry. This is in-line with the category of doing science. According to Hodson (2014), in doing science, the learners' would engage in first-hand experience to plan and carry out scientific investigations by themselves. The emphasis is not so much about learning the methods used by scientists but more on the procedural skills and knowledge to carry out investigations. That is, knowledge and skills to proceed and "investigate phenomena, test and develop understanding, solve problems and follow interests" (p. 2546). The focus here is shifted from teaching, learning and assessment of 'what' to 'how' and 'why' of science (Duschl, 2008; Wellington, 2005).

The emphasis is on learners' conceptual, contextual and procedural understanding as well as knowledge and skills to make decisions when carrying out investigations in school science.

The affective domain of practical work plays an important and positive role in influencing learners' "attitudes towards science, their keenness to do science and perhaps even their self-esteem i.e. self-belief that they can actually do some science" (Wellington 2005, p. 106). The affective domain is related to the category of learning about science which aimed at developing learner's awareness about the sociocultural and historical aspects of science. Subsequently, learning about science should make learners motivated, excited, interested and enthusiastic in science (Wellington, 1998). Besides, learning about science provides the opportunity for learners' to develop their understanding about science as a practice for investigating phenomena and happenings as well as for constructing concepts and establishing facts. Learning about science would also help learners to appreciate the history and development of scientific knowledge which also includes the awareness of the socio-cultural and contextual interactions of the different science fields within the scientific community (Hodson, 2014). Subsequently, learning about science promotes the awareness and the understanding of how and why science has value in the pressing global socio-scientific issues. In this regard, practical work provides an avenue for learners to develop the comprehension and interest in constructing and deconstructing claims associated with socio-scientific issues (Gott & Duggan, 2007).

The three purposes of developing learners' cognitive, skills and affective domains along with the three categories of learning science, doing science and learning about science cannot be achieved in one single science practical work (Gott & Duggan, 2007; Hodson, 2014; Wellington, 1998). Besides, not all purposes can be achieved or approached in the same way and attempting to reach diverse purposes in one practical work may not be effective (Hodson, 2014). Basically, the three domains along with the three categories have different learning outcomes as well as different emphasis in learning, teaching and assessment planning and practice (Millar, 2004). However, while the boundaries of the domains and categories are not self-evident or may overlap for planning purposes, it is essential to understand and identify the different levels of practical work which intend to achieve different learning outcomes and purposes

(Millar, 2004; Osborne, 2014). This is to ensure that a practical work is designed and planned to achieve what it intended to achieve. Hence, it is important for this literature review to outline the different levels of practical work that can be designed for different purposes and learning outcomes.

Levels and Learning Outcomes of Practical Work

Basically, Branchi and Bell (2008) and Tamir (1991) provided a similar continuum comprising four different levels of practical work while Millar and Abrahams (2009) outlined three types of practical work in school science.

According to Branchi and Bell (2008) the first level is the “conformation inquiry” (p. 26) which corresponds to Tamir’s (1991) level 0. This level of practical work is aimed at confirming or reinforcing a previously learned concept, theory or to practise certain hands-on and observation skills. Learners are basically provided with a question and a set of procedure to follow with predetermined results. This is usually termed as a ‘cookbook or recipe’ practical work (Clarkson & Wright, 1992; Llewellyn, 2005). Subsequently, the second level is the “structured inquiry” (Branchi & Bell, 2008, p. 26). At this level, learners are asked to provide explanations for their results. Hence, learners have to demonstrate some knowledge and understanding of scientific concepts. This is similar to Millar and Abrahams’ (2009) Type A practical work on illustrating scientific ideas. This level or type of practical work intends to help learners develop as well as affirm their knowledge and understanding about the natural world in relation to scientific facts, concepts, theories and relationships (Millar & Abrahams, 2009). These two levels of practical work correspond to learning about science which intends to develop learners’ appreciation and knowledge on the relationships science has with everyday livelihood (Hodson, 2014).

With increasing difficulty, the third level of practical work is “guided inquiry” (Branchi & Bell, 2008, p. 27). At this level learners are provided with a question but they themselves have to plan and design a procedure to carry out the investigation. This level of practical work requires a good understanding about processes and concepts in science. This is similar to Type B practical work which involves the practice of using procedures and skills (Millar & Abrahams, 2009). Learners need to have basic understanding of scientific concepts and procedures. Subsequently, the

fourth level is “open inquiry” (Branchi & Bell, 2008, p. 27) which corresponds to level 3 of practical work according to Tamir (1991). At this level, learners are asked to formulate their own questions, design and conduct their own investigation as well as communicate the explanation for their results. This is similar to Type C practical work which focuses on developing learners understanding about the NoS (Millar & Abrahams, 2009). Learners are given the central role in identifying problems and developing a plan as well as carry out the investigation, gather, interpret and discuss their results along with a scientific conclusion. These two levels of practical work correspond to ‘learning science and doing science’ which intend to develop learners’ conceptual and procedural understanding in science (Hodson, 2014).

Consequently, science teachers should have an explicit knowledge and skills of teaching, learning and assessment strategies that are associated with the different levels, purposes and learning outcomes of practical work (Osborne, 2014). Science teachers need to develop a coherent knowledge and understanding that links the aims of science education, the purposes of practical work, learning outcomes to the different levels of practical work. According to Osborne (2014), this is an essential aspect to the teaching practice in science education. While science teachers need a deeper content knowledge of the subject they also need to enhance their understanding and knowledge on epistemic processes involving different levels of practical work in science. Consequently, for the purpose of this study, both trainee and practising science teachers’ views on the purposes of practical work in school science were explored.

Additionally, it is significant for this literature review to outline the teaching, learning and assessment strategies that can be utilised for different levels, purposes and learning outcomes of practical work. This nexus is imperative for the effectiveness of employing practical work in school science.

2.4.3 Teaching Strategies for Different Learning Outcomes

The practical work with learning outcomes to do with identifying objects, observables and phenomena has less cognitive demand than the learning outcomes to understand scientific concepts and theories (Millar & Abrahams, 2009). The learning outcomes on how to identify and use objects as well as observation can be achieved without doing authentic or real science when doing practical work (Millar, 2004). For instance,

learners may be able to identify, use and recall objects as well as observe and remember the descriptions of a phenomenon by either observing pictures, diagrams, videos and demonstrations or having a simple hands-on experience. That said, learners should be able to appreciate as well as understand that scientific practice is more complex than just identifying and being aware of objects and phenomena. Learners should cognitively develop the understanding and awareness that the domain of objects and observables have links to the domain of ideas and complex interactions (Hodson, 2014). Hence, other types of practical work and teaching strategies can also be utilised.

According to Hodson (2014), science teachers need to add a wider range of practical work for learners to construct the understanding about how science is connected to the world around them. For example:

historical case studies, simulations and dramatic reconstruction; role playing... and debating; reading and writing activities that emphasize the key distinctions between the private language of personal experience and the public language of science; computer-based activities; research laboratory visits and interviews with scientists (Hodson, 2014, p. 2551).

These ranges of practical work can enable learners to develop some understanding about as well as appreciate the history, philosophy and sociocultural milieu of science practice. Learners can understand how science plays an important role in their everyday livelihood. The range of practical work outlined can be regarded as level one and level two practical work whereby learners can learn, appreciate as well as make connections to scientific facts, concepts and theories (Hodson, 2014; Osborne, 2014).

The learning outcome to learn scientific concepts and theories require significant input from science teachers (Millar & Abrahams, 2009). This is related to learning science which focuses on the development of learners' conceptual and theoretical knowledge in science (Hodson, 1998, 2014). From a sociocultural view of learning, learners as individual rational beings have developed their own fragmented concepts and theories of nature from their everyday experiences (Vygotsky, 1987). This includes their sociocultural conceptions of various natural interactions, artefacts, political, historical, economical, geographical, language and religious milieu (Duit & Treagust, 2003). However, the everyday conceptions may not be scientific and they can be

misconceptions in comparison to sanctioned scientific concepts and theories (Vygotsky, 1987). As such, learners may not be able to fully use their own preconceived ideas to further develop scientific concepts while doing practical work (Millar & Abrahams, 2009). Consequently, support from science teachers is required in order to facilitate the reconstruction and restructuring of learner's preconceived ideas using practical work experience (Hodson, 2014).

According to Millar (2004) scaffolding for teaching and learning in practical work is about making contextual and conceptual links between learners everyday conceptions to what is practically experienced and the intended learning outcomes. Typically, Vygotsky (1987) posited that scaffolding is associated with the sociocultural theory of teaching and learning whereby science teachers play a joint role in constructing scientific concepts during practical experiences. It is a temporary support from science teachers to enable learners to make links with what they experience in the domain of objects and observables to what they are intended to construct in the domain of scientific ideas (Millar & Abrahams, 2009). Besides, scaffolding is strongly situated when objects and languages used in the practical work are socio-culturally and contextually meaningful to learners as well as science teachers. The aim for such scaffolding is to construct links from what is already known from everyday objects, language and sociocultural contexts to scientific concepts and contexts.

To maximise the effectiveness of teaching, learning and assessment of scientific concepts, scaffolding or temporary assistance from science teachers should be intentional, purposeful, situated and socially collaborative (Bell, 2005; Vosnaidou, 2002). With scaffolding learners and science teachers are both seen as active participants in the collaborative construction of knowledge through practical experiences (Stone, 1993). As such, scaffolding is an ongoing process of communicating ideas between learners as novices and science teachers as experts. Seen as the experts, science teachers are the ones that provide guidance and support to dynamically navigate intentional learning from what is intended to be experienced to what is intended to be learnt. The dynamics and effectiveness of such intentional scaffolding depends very much on science teachers' content knowledge as well as the choice and skills of teaching, learning and assessment strategies.

However, one of the challenges science teachers face in scaffolding during practical work for learning scientific concepts is the lack of known scaffolding strategies (Kwalkar & Vijapurkar, 2013). Basically, scaffolding for conceptual learning during a practical work is seen as an interactive process guided by science teachers asking questions and providing feedback as well as feedforward to learners' responses. Science teachers play an important role in generating the interaction which potentially leads learners to cognitively link what they already know and what they experience in practical work to construct intended scientific concepts (Hodson, 2014).

The interaction involves the science teachers asking probing questions and providing progressive feedbacks and feedforwards to respective responses as well as questions from learners. Hence, science teachers need to develop the knowledge and skills to identify and ask lower and higher level as well as open or closed-ended questions when scaffolding during practical work (Kwalkar & Vijapurkar, 2013). The lower level and closed-ended questions has less cognitive demands on learners than higher and open-ended questions. Studies indicated that, the kind of questions asked when scaffolding also influenced learners' thinking as they engage in the process of constructing scientific concepts in practical work (Chin, 2007). Hence, scaffolding by asking higher level and open-ended questions in practical work is cognitively demanding for learners. That means, learners are required to provide related as well as coherent arguments and explanations of the phenomenon investigated (Kwalkar & Vijapurkar, 2013). Such a teaching strategy is imperative for conceptual learning.

Basically, the aim in asking higher level and open-ended questions when scaffolding for conceptual learning in practical work is to elicit learners' existing conception of what is experienced (Kwalkar & Vijapurkar, 2013). Their kind of conception can be demonstrated through their level of articulation which includes the words, language and semiotics they use in their response. This process would help learners to elaborate and reflect on their own thinking. As well, by using sociocultural collaboration during practical work, learners would also learn from other learners' articulation. Such collaboration would challenge and resolve incoherent views in the construction of scientific concepts during practical work (Chin, 2007). It is the role of science teachers' to assess the level of learners' articulation and decide on how to proceed progressively using guided scaffolding. This interactive process would progressively

challenge and guide learners' to evaluate their own conceptions. Added to that, learners can compare their conceptions by collaborating with their peers and guided by their science teachers in order to construct the intended scientific concepts that are practically observed and experienced.

The learning outcome of developing procedural knowledge or the understanding of the NoS can be experienced using open inquiry or level 3 practical work (Branchi & Bell, 2008; Tamir, 1991). This type of practical work contributes to learners' development in doing science (Hodson, 1998, 2014). It "stimulates and reflects the type of research and experimental work that is performed by scientists, and demands high-order thinking capabilities" (Zion & Mendelovici, 2012, p. 384). Learners are provided with variety of issues and are challenged to make decisions as well as design their own plans to investigate and find solutions. With open inquiry learners have the onus to determine the purpose and the questions to be investigated. However, with sociocultural views of learning, learners are encouraged to collaborate with peers to critique as well as evaluate their decision-making and procedural designs (Haigh, France & Forret, 2005). As learners, making the right decisions may be difficult. Besides, there are various pathways to reach a solution (Treagust & Duit, 2008). Hence, social collaboration provides an environment wherein learners can evaluate and modify their decision-making and designs using the evidences and ideas they progressively put together (Glaesser, et al., 2009). This type of practical work provides an opportunity for learners to challenge their conceptual and procedural understanding in doing science as well as to experience the NoS (Hodson, 2014). That is, with open inquiry learners can be able to experience and develop a basic understanding in the epistemic processes in science.

However, there are various challenges for science teachers in facilitating open inquiry teaching, learning and assessment strategies in practical work (Shedletsky & Zion, 2005; Zion & Mendelovici, 2012). The effectiveness of open inquiry is a challenge since the learning outcomes such as the development of procedural understanding can be "imprecise and difficult to measure" (Millar, 2004). Furthermore, "most science teachers view inquiry as difficult to manage, and believe that inquiry instruction is possible only with above average students" (Windschitl, 2002, p. 115). Studies indicated that, science teachers who lack pre-service and ongoing experience in conducting open inquiry practical work also lack procedural understanding and skills

(Shedletzky & Zion, 2005). As such, they may have difficulty in identifying the sequence to proceed as well as lack the knowledge to facilitate and scaffold their learners in open inquiry (Windschitl, 2002). While open inquiry practical work is challenging for science teachers, there are strategies that can be employed to achieve what is intended (Shedletzky & Zion, 2005). Therefore, science teachers should develop their knowledge, understanding and skills in these strategies.

Although learners play the central role in open inquiry, its effectiveness depends mainly on the ability of science teachers to facilitate as well as scaffold their learners through every stages of decision making. According to a study conducted by Zion and Mendelovici (2012), the cognitive ability of the learner as well as science teachers' experience, content and procedural knowledge in science is crucial in the inquiry process. Further to that, science teachers should be able to recognise and be familiar with their learners' cognitive, skills and affective capabilities. With such familiarity, science teachers can provide appropriate scaffolding at the initial stage in formulating questions for investigation and progressively at other stages that learners need to make decisions to proceed (Zion & Mendelovici, 2012). In fact, the more complex and challenging the practical work is, the more difficult it is to be assessed, especially in relation to the notions of effectiveness and manageability (Osborne, 1998). Accordingly, this study explored trainee and practising science teachers' views on how they effectively teach and assess scientific concepts in school science.

Identifying the Effectiveness of Practical Work

Effectiveness in practical work is encompassed in the choice of teaching, learning and assessment strategies that can best achieve the specific learning outcomes and purposes of practical work (Millar & Abrahams, 2009). In other words, the effectiveness of practical work lies in the nexus between purposes along with specific learning outcomes and the specific choice of the teaching, learning and assessment strategy to achieve what is intended. Basically, Millar and Abrahams (2009) argued that in order to address the effectiveness of a practical work, its purpose and learning outcomes must be clearly identified and articulated. As such, a choice of a teaching and assessment strategy for a practical work can be framed in a way that learners' achievements of specific learning outcomes can be made visible, audible as well as measurable.

Millar and Abrahams (2009) outlined two senses of effectiveness in practical work. They are Effectiveness 1 (One) and Effectiveness 2 (Two) as depicted in figure 2.2. Effectiveness One is associated with what the learners are ‘intended to do’ compared to what they ‘actually do’ in the practical work (Millar & Abrahams, 2009). That means, practical work is more effective when learners actually do what was intended for them to do. Effectiveness Two is associated with what the learners are ‘intended to learn’ compared to what they ‘actually learn’ from practical work. Effectiveness 2 is maximised when learners actually learn what they were intended to learn (Millar & Abrahams, 2009).

The emphasis for effectiveness is encompassed in the notion that doing science must go along with thinking science (Millar, 2004). As such, designing practical work for effectiveness involves a choice of teaching, learning and assessment process that addresses the learning outcomes as well as choices to link the doing and thinking in science. These two senses of effectiveness can help guide science teachers to understand as well as design and conduct practical work that is effective to achieve what is intended. This is in-line with the purpose of this study to bridge the gap between what is intended and what is attained in the SBA of practical work curriculum.

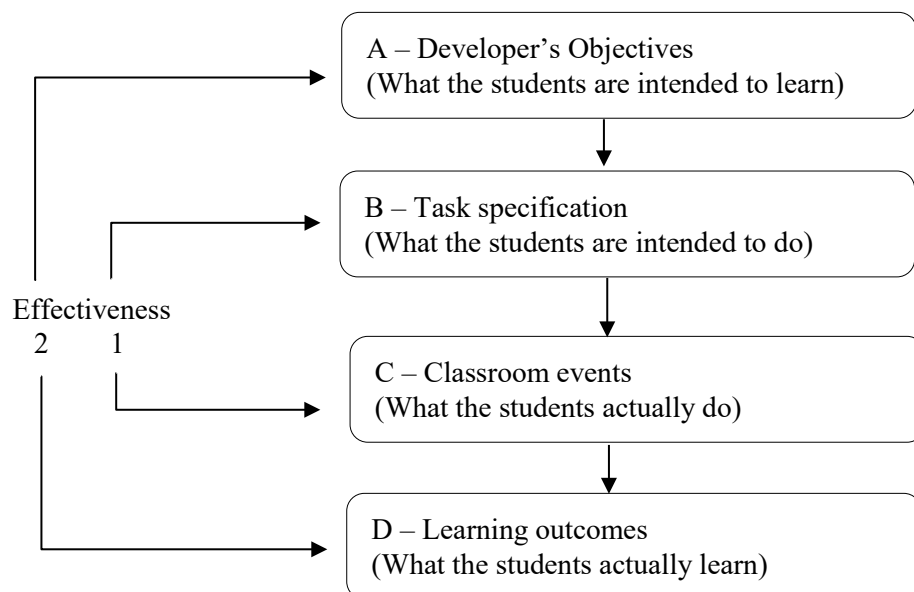


Figure 2.2. “Stages in the development and evaluation of a teaching and learning activity – and their relationship to two senses of effectiveness” (Millar & Abrahams, 2009, p. 60).

In essence, this study premised that the SBA of practical work is an avenue wherein teaching, learning and assessment of scientific concepts and skills can take place and effectiveness of practical work can be addressed. In particular, the practice of using practical work to teach and assess learners' understanding of scientific and physics concepts.

2.5 Nature of School-Based Assessment

The key element of effectiveness in teaching and learning process for practical work is assessment (Abrahams, Reiss & Sharpe, 2013). It is argued that assessment can be used to determine the effectiveness of teaching and learning strategies in school science practical work (Cheung, 2016). Generically, the main purpose of assessment in education is to make decisions “about what is relevant evidence for a particular purpose, how to collect the evidence, how to interpret it and how to communicate it to intended users” (Harlen, 2005, p. 207). Besides, assessment in education is encompassed in the notion that it is a “social practice, an art as much a science, a humanistic project” (Broadfoot & Black, 2004, p. 8). The decisions about what to assess, how to assess, when to assess, why we need to assess, who to assess and what strategies to employ is a humanistic practice that reflects a particular sociocultural context (Bell, 2007). As such, assessment in education and science education has a social value to its stakeholders as much as users. Bell (2007) suggested that assessment in education is also a political enterprise, therefore the decisions and the use of assessment results as a product must be convincing to its shareholders. That said, most of the assessment in school science takes place between the science teachers and their learners in the school environment. Thus, science teachers and their learners take the central role in producing the assessment results that would effectively fulfil the intended to purposes and learning outcomes.

Studies on assessment in education and science education has indicated that assessment has multiple purposes (Bell, 2005). Out of many assessment purposes, science education literature extensively discussed two main purposes for assessment. Namely - assessment of learning, called summative assessment and assessment for learning, called formative assessment (Bell, 2005; Cheung, 2016; Crooks, 2002). While summative assessment intends to prove what level learning has taken place,

formative assessment intends to help learners learn what is intended during the process of teaching and learning (Bell, 2007). Given these two distinct purposes and the nature of assessment, studies have proposed that SBA can be utilised to serve the dual purposes of both summative and formative assessments in science education (Bell & Cowie, 2001; Fok, Kennedy, Chan & Yu, 2006).

Many different contexts have utilised SBA for different purposes in various school subjects. For example, in Queensland, one of the States in Australia have had used a system of moderated SBA after they abolished public examinations (Maxwell, 2004). Their SBA was aimed to broaden the scope of assessment strategies from the traditional paper-and-pencil examinations (Maxwell, 2004). Similarly, the national assessment systems of New Zealand was “enhanced with effective school-based assessment that allows teachers to focus on improvement decisions” (Hattie & Brown, 2008, p. 189). This included the decisions for “improving learning, reporting progress, providing summative information, and improving programs” (Bell & Cowie, 2001, p. 4). Other geopolitical and sociocultural contexts like Hongkong (Cheung, 2016), Malaysia (Malakolunthu & Hoon, 2010) and Singapore (Chong, 2009) had also replaced their assessment systems from one-shot written examinations to course work SBA. Similarly, Solomon Islands (the context of this study) had introduced SBA in science education in the late 1990s.

The shift to SBA was underpinned by many rationales (Maxwell, 2004). The technical rational relates to the notion that “more valid assessments should increase both the fairness of the testing process and public confidence in that process” (Kennedy, 2013, p. 1). Basically, the rationales for SBA were underpinned by the constructivist view of progressive continuous assessment as well as for the assessment for multiple purposes (Bell & Cowie, 2001; Cheung, 2016; Maxwell, 2004). As such, many SBA systems are used to progressively assess other vital aspects of learning that were not possible to assess using paper-and-pencil examination. For example, HongKong and Singapore used the SBA of practical work to assess practical skills in science education (Cheung, 2016; Chong, 2009). Similarly, the SBA of practical work in the Solomon Islands science education is employed to assess science practical skills that are not possible to assess in written examinations (MEHRD, 2010). With the SBA schemes, science

teachers take a crucial role in making decisions, designing and implementing the assessment activities at the school as well as classroom level.

This study premised that SBA can be used as a teaching, learning and assessment strategy for different assessment purposes and learning outcomes of practical work. Hence, the next subsections will discuss the summative and formative purposes of SBA that can be utilised for different learning outcomes of practical work. In saying that, the terms summative and formative are used mainly to describe the purpose for which the assessment is carried out. The terms do not exclusively describe the task itself since one assessment task can be used for either or both summative and formative assessment purposes (Bell, 2007).

2.5.1 Assessment for Summative Purpose

Sadler (1989) argued that assessment for summative purpose encompasses the notion of summing up or summarizing what is attained after learning has taken place within a specific period of time. Hence, a summative assessment result provides an indication of what the learners have learnt after a specific period of teaching and learning. The specific periods can be identified by a topic in a subject, school terms, semesters or an academic year. The summary information from summative assessment is mainly used to inform the learners of what they have achieved as well as provide a report to parents, teachers, the school administration and other stakeholders such as the ministry of education (Harlen & James, 1997). Given different time periods, summative assessment may take place on one occasion as in one-shot national external examinations at the end of the semester and year or continuously as internal assessments administered by a teacher throughout a period of time.

One of the aims of SBA was to provide continuous summative assessments throughout the year instead of one-short examination at the end of an academic year (Cheung, 2016; Maxwell, 2004). With such continuous summative assessments, cumulative marks from each individual summative assessment tasks are aggregated at the end of a specific teaching and learning period, usually at the end of an academic year or course. In addition, continuous summative assessment can employ different tasks to assess a wider range of learning outcomes such as practical skills in school science (Bell & Cowie, 2001; Cheung, 2016). In fact, continuous summative assessment is

used for practical work in the context of SBA in Hongkong and Singapore. For example, Yung (2012) pointed out that in Hongkong, one-shot external practical examination of science subjects at the end of Advanced Level (AL) were replaced by “Teacher Assessment Schemes (TAS)” (p. 125) as SBA. Similarly, Singapore implemented the “Science Practical Assessment (SPA) scheme...to replace the former one-time practical test administered at the end of General Certificate Examination O – and A – level science courses” (p. 125). Actually, Yip and Cheung (2005) claimed that SBA removes the disadvantages of one-shot examination. Similarly, Maxwell (2004) pointed out that SBA lightens the pressure of one-shot examination that both learners and teachers likely to face at the end of semester or academic year.

According to Cheung (2016), the use of SBA as a continuous summative assessment to assess learners’ practical skills in science has little doubts compared to a one-shot practical skills test at the end of a long period. Given the number of learners in one science classrooms it is also a challenge to assess learners’ practical skills in a one-shot practical examination. Hence, using continuous summative assessments in SBA can alleviate the challenge and doubt in administering practical skills assessment in a large class size using one-shot examination (Cheung, 2016). With continuous summative assessment tasks science teachers can take time to watch over several groups of learners as they perform the tasks in different practical work for assessment throughout the year. Different types of practical work can also be used at different times to assess different practical skills (Yung, 2001). For example, various practical skills can be assessed in different practical work such as laboratory experiments, field excursions and open inquiries. Besides, with continuous summative assessments, learners can also keep their assessment results as portfolios (Bell, 2005).

The assessment of practical skills in science appeared to vary a lot in different countries (Abrahams et al., 2013). For example, in analysing the assessment of practical skills for the ten top countries that did well in the Program for International Assessment (PISA), Abrahams et al. (2013) found that some countries directly assess practical skills while others assess indirectly. Countries that “performed well in terms of their science PISA results, such as China, Singapore, New Zealand and Finland” (p. 16) directly assess their learners’ practical skills. Other countries like Australia, England and Scotland assess their learners’ practical skills using indirect assessment

methods. Abrahams et al. (2013) found that in China, ranked first in 2009 PISA in science, science teachers directly observe and assess between two to four learners in practical examinations. Science teachers directly observe the abilities of learners to scientifically select, use and look after instruments as well as correctly follow practical procedures. While in Australia, ranked 10th in 2009 PISA in science, teachers assess learners' practical skills indirectly through their completed written reports that indicated their abilities to measure, collect, interpret as well as make inferences and scientific conclusions. Whether the assessment is direct or indirect, this study is premised on the view that SBA can be utilised for continuous summative assessment of the practical skills.

Practical work with learning outcomes concerning the development of manual and procedural skills can be enhanced and assessed using the continuous summative assessment. A study conducted by Hoe and Tiam (2010) in Singapore indicated that learners preferred the SBA of practical skills because science teachers can assess them more accurately during the individual practical work. As well, learners have more opportunities in SBA to improve and demonstrate their enhanced practical skills progressively after each consecutive practical activity. Having many practical works to assess practical skills over a period of time is also an avenue for learners' enculturation into science (Hodson, 1998). Besides, with continuous summative assessments science teachers can generate a progressive understanding about as well as familiarise with learners' cognitive, skills and affective capabilities in performing science practical work. This is significant for science teachers when scaffolding for the development of conceptual understanding as well as procedural skills and knowledge in open inquiry (Zion & Mendelovici, 2012).

Continuous summative assessment in SBA can also be utilised for teaching and assessing conceptual and procedural understanding in practical work. According to Got and Duggan (2002) conceptual understanding means:

knowledge base of substantive concepts such as the laws of motion...
which underpinned by scientific facts,... procedural understanding...mean
the thinking behind the doing of science and include the concepts such as
deciding how many measurement to take, over what range and with what

sample, how to interpret the pattern in the resulting data and how to evaluate the whole task (p. 186).

This means, conceptual understanding includes the understanding of procedures, equipment, data and drawing conclusions. Gott and Duggan (2002) called the understanding of procedures as the concept of evidence which underpinned by practical skills as well as knowledge of equipment and their uses. With open inquiry practical work, learners are required to use their conceptual and procedural understanding as well as knowledge of equipment and uses (Gott & Duggan, 2002). As such, learners can be assessed for their conceptual understanding as well as procedural understanding and knowledge of the investigation itself (Hodson, 2014). This means, learners should be able to demonstrate their understanding of scientific concepts as well as concepts of evidences, processes and equipment. These understanding can be demonstrated and assessed by their abilities to develop a hypothesis; design procedures; use equipment to collect appropriate data; analyse and interpret results and draw scientific conclusions (Gott & Duggan, 2002).

However, continuous summative assessment of conceptual and procedural understanding in practical work is complex and demanding for both learners and science teachers (Abrahams et al., 2013; Got & Duggan, 2002). Most practical work used for assessing learners' conceptual and procedural understanding were carried out indirectly through written reports (Abrahams et al. 2013). For example, in France, learners' practical work are assessed in four areas. First area, is a written explanation for the choice of apparatus and methods that links to the hypothesis. This requires conceptual understanding or knowledge of scientific facts as well as procedural knowledge. Second area is the assessment of learners' ability in using the equipment correctly which involves practical skills. Third area is the assessment of learners' ability to select, record and present results with various inscriptions, graphs, tables and words. The fourth area is the assessment of the learners' ability to write an argumentative conclusion (Abrahams et al., 2013). The third and fourth areas require both the conceptual and procedural understanding. It is about making a link between the domain of objects and observables to the domain of ideas (Abrahams & Millar, 2009; Osborne, 2014). Basically, these four areas of assessment were meant to reflect

learners' understanding of concepts, procedures, equipment and uses as well as the ability to make links between objects and ideas.

However, for summative assessment to occur in SBA, the process of teaching and learning should have been taken place first. As Salder (1989) expressed, summative assessment is conducted to prove that learning has taken place prior to the assessment. In this regard, trainee and practising science teachers' views on summative assessment in SBA was explored in this study. In addition, SBA can also be used for formative assessment or assessment for learning (Bell, 2005; Cheung, 2016).

2.5.2 Assessment for Formative Purpose

Science teachers can use formative assessment during the process of teaching and learning to recognise and respond to learners' learning needs in order to improve learners' learning (Bell & Cowie, 2001). Practical work in SBA may serve a formative purpose when it provides information that can be used by science teachers and learners to improve the teaching and learning process in real time. Using the information provided from learners' responses, science teachers should be able to reflect on their own teaching and adjust their teaching to progressively address the learning needs of the learners (Black & William, 1998). The assessment information gathered for formative purposes can be interpreted to identify a gap between the learners' actual level of performance and what is intended to be learnt or performed. Subsequently, science teachers can interactively devise an appropriate action to help learners to close that gap during learning (William & Black, 1996). That said, it is how the assessment information that is provided during the teaching and learning process is used that determines the nature of formative assessment (Bell & Cowie, 2001). According to Dun and Mulvenon (2009), formative assessment is not defined according to an inherent characteristic of an assessment activity rather it is defined by the use of the information generated during the teaching and learning process.

Science teachers can use planned and interactive formative assessments in school science (Bell & Cowie, 2001). On the one hand, a planned formative assessment involves teachers' prior planning of assessment activities that can be used for formative purposes in the whole class. A science teacher may plan to use different assessment strategies to elicit information about their learners' learning levels. For

example, before introducing a topic a science teacher may plan to ask the learners to write what they know about the topic on a piece of paper. The teacher may interpret the written responses and make an informed judgement about the learners' level of understanding. Subsequently, science teachers can act on the interpreted information to improve the learners' learning by providing further related learning activities and approaches (Chun, 2006). The planned formative assessment involves a whole class approach.

On the other hand, Bell and Cowie (2001) explained that interactive formative assessment involves a one-on-one interaction between science teachers and their learners. Unlike planned formative assessment, interactive formative assessment arises during the teaching and learning process. Basically, science teachers cannot predict exactly what would arise that needs attention. As such, science teachers may not be able to plan detailed strategies for interactive formative assessments (Chun, 2006). However, with informed knowledge, skills and experience science teachers can recognise the level of learner's performance. That is, during the process of teaching and learning science teachers may be able to gather information from what a learner writes and verbally or non-verbally express. Using the gathered information science teachers should be able to make informed judgement on the level of learners' performance and determine the implications for the learners' learning with regards to achieving the learning outcomes (Bell & Cowie, 2001). Subsequently, science teachers can make appropriate responses specifically to enhance their learners' learning to achieve the learning outcomes during the teaching and learning process.

The important aspect of planned and interactive formative assessment is the process of providing feedback and feedforward or scaffolding by a science teacher or collaboratively amongst learners themselves (Bell, 2005). According to Cheung (2016), the worth of formative assessment in SBA for practical work is yet to be fully recognised. Besides, Nott and Wellington (1999) stated that most aspects of learning the NoS is experienced and not taught. Hence, formative assessment should be used in practical works that are intended for the purposes of experiencing the NoS. Science teachers and learners should see and use these kinds of activities as learning science rather than about getting marks for summative purposes and grading. As such, for the purpose of learning science, formative assessment is used to inform learners' level of

performance and learning as well as to inform science teachers about their teaching strategies (Bell & Cowie, 2001). Basically, formative assessment involves a lot of quality feedback and feedforward between science teachers and learners during the process of conducting practical work.

Science teachers providing quality feedback and feedforward can help clarify learning outcomes for learners as well as help to guide their learning, thus help them to improve their learning. Cowie (2005) defined feedback as “information that gives the learner the opportunity to see how well they are doing or have done and they might do next to enhance their performance and knowledge” (p. 200). Basically, feedback should describe the qualities of the learners’ performance in relation to the intended learning outcomes. Hence, quality feedback should include the information about the learners’ learning processes and strategies that will help them figure out how to make improvements. A quality feedback should foster learners’ self-efficacy, making connections between learners’ performance and the effort they put into it. Subsequently, quality feedback should also include feedforwards. Science teachers should be able to identify learners’ learning strengths and weaknesses and appropriately provide scaffolding for learners to progress towards the learning outcomes (Bell, 2005; Moreland & Jones, 2000). Essentially, quality feedback and feedforward can help motivate and encourage learners to close the gap between their actual level of performance and the intended learning outcomes.

There were evidences that learners’ performance did improved when they were provided with quality feedback and feedforward in formative assessment (Bell, 2007; Black & William, 1998). For example, when reviewing 250 articles from 160 different journals, Black and William (1998) found that providing quality feedback in formative assessment did help improve learners’ learning as well as their standards of performance. However, a recent study by Kawalkar and Vijapurkar (2013) on scaffolding for science inquiry indicated that, science teachers are faced with a challenge of providing quality feedback and feedforward when teaching science inquiry. Science teachers are challenged on how they supposed to play their roles as facilitators in helping learners to develop scientific conceptual and procedural understanding through practical work. Kawalkar and Vijapurkar (2013) found that traditional science teachers used interactive formative assessment in their classroom

by asking many questions that learners already knew. Kawalkar and Vijapurkar (2013) pointed out that science teachers should employ an interactive formative assessment that stimulates learners' thinking capacity as well as to engage learners in thought provoking discussions that would move them towards constructing conceptual and procedural understanding.

Formative assessment for conceptual and procedural understanding in school science can be explained from sociocultural and social constructivist perspectives of teaching and learning (Bell & Cowie, 2001). Science teachers can facilitate the teaching and learning of conceptual and procedural understanding in the classroom through progressively asking questions and providing feedbacks and feedforwards to learners' responses (Kawalkar & Vijapurkar, 2013). This encompasses the notion of effective scaffolding whereby teachers should facilitate the social construction of scientific concepts and procedural understanding in open inquiry practical work as outlined in subsection 2.4.3. In this regard, this study view formative assessment as a sociocultural and social constructivist process of interaction between teachers and learners as well as between learners themselves, especially, for the purpose of teaching, learning and assessment of conceptual as well as procedural understanding in school science. Hence, for the purpose of this study, trainee and practising science teachers' views and practices regarding formative assessments in the SBA of practical work was explored.

That being said, it is also significant to ensure that the quality of the assessment practices in the SBA of practical work can be trustworthy and adds value to learners' achievement (O'Farrell, 2002).

2.5.3 Quality of School-Based Assessment of Practical Work

While there are many aspects to enhance the quality of assessment in education, the two essential ones are validity and reliability (Black & William, 2006). According to Harlen (2005), validity and reliability in educational assessment are not exclusively independent of each other in practice. They may have overlapping interpretations as well as consequences (Black & William, 2006). However, there are significant differences between the reliability and validity of summative assessment and formative assessment (Bell, 2007; Brookhart & Nitko, 2008; Stobart, 2006). As such,

it is important for this literature review to differentiate the reliability and validity of the assessment for summative and formative purposes in the SBA of practical work.

Reliability and Validity of Summative Assessment

The reliability of summative assessments is encompassed in the notion of consistency and accuracy in learners' assessment scores as well as, whether the assessment results are comparable and dependable (Brookhart & Nitko, 2008; Harlen, 2005). According to Harlen (2005), the reliability of summative assessment results can be determined and presented in the form of test scores, summary of grades or marks. Basically, the notion of consistency is associated with the view that when the same learners repeated or different learners do an assessment activity at different times or the same time, the results should have strong similarities (Harlen, 2005). Additionally, consistency is also evident when different teachers assess the same assessment activities at the same time or at different times in the same place or different places but still produce comparable results (Brookhart & Nitko, 2008; Harlen, 2005). That said, the notion of reliability or consistency is an essential component of summative assessment.

However, consistency in summative assessment in the SBA is heavily influenced by both learners and science teachers. For example, Brookhart and Nitko (2008) explained that physical, mental and emotional conditions of learners when they do the assessment activities at different times can affect the consistency of their performance. Similarly, the personal conditions of science teachers when they mark the assessment activities can influence the consistency of the assessment results. That means, consistency in summative assessment is associated with how the assessment results are generated more than the assessment instrument or activity (Harlen, 2005).

Consistency can be increased by allowing the learners to do similar assessment activities several times in order to gauge their true level of performance from their average scores. Corresponding to that, science teachers' ability to assess the assessment activity consistently at different times is also a prominent factor for increasing the reliability (Black & William, 2006). That said, the consistency in marking the SBA of practical work for continuous summative assessment is a challenge for science teachers. While some assessment activities are carried out in different schools, they are assessed by different science teachers who may have

different abilities. Hence, to maximise consistency in continuous summative assessment in the SBA, science teachers should have similar training and develop a comparable knowledge as well as skills to assess the practical works in different schools (Green & Johnson, 2010).

The validity of summative assessment is encompassed in the notion of fitness for purpose or whether the assessment activity actually assesses what it intended to assess (Stobart, 2006). This is similar to the notion of Effectiveness 1 and 2 in practical work discussed in the later part of subsection 2.4.3 (Millar & Abrahams, 2009). In fact, Harlen (2005) identified and explained various forms of validity which include: “face validity, concurrent validity, construct validity, consequential validity” (p. 247). These forms of validity are well explained by Harlen (2005). However, for the purpose of this study, validity of summative assessment for the SBA of practical work lies in the design of the assessment activities. That means, validity is determined by the design of the assessment activity such that learners know what is assessed and able to demonstrate their level of performance accordingly. This is a form of construct validity (Harlen, 2005). According to Green and Johnson (2010), construct validity is increased when the assessment activities and instructions are familiar to both the teachers and learners. With the SBA of practical work, construct validity can be maximised by using language, inscriptions, artefacts and procedures that are familiar to both the sociocultural context of learners and science teachers.

It is the purpose and learning outcomes of the practical work that determines the interrelationship between reliability and validity (Harlen, 2005). Basically, Harlen (2005) claimed that increasing the validity by designing appropriate practical work to assess learning outcomes that demand higher level of reasoning may decrease their reliability. This is because some of the high level learning outcomes are complex and may be difficult to identify and assess. However, both the reliability and validity of summative assessment in the SBA of practical work for high level learning outcomes in open inquiries can be increased. This can be addressed by clearly outlining the learning outcomes and marking rubrics for the practical work for both learners and science teachers (Cheung, 2016; Green & Johnson, 2010). As well, science teachers’ skills, knowledge and understanding in administering and assessing high level learning

outcomes in open inquiry should be enhanced. However, for the purpose of inquiry practical work, formative assessment can also be utilised.

Reliability and Validity of Formative Assessment

When assessment information is used for formative purpose, the validity is paramount while reliability is of less concern (Bell, 2007; Harlen, 2005). According to Black and William (2006), the concerns regarding reliability are much different when assessment information is used for formative purposes. For formative purposes, the assessment information that science teachers gathered from learners' performance during the teaching and learning process is chiefly used to improve learners' learning in order to achieve the intended learning outcomes. As such, the assessment information gathered has less significance for the purpose of comparing scores between learners for consistency. Bell (2007) described that formative assessment is a sociocultural activity and is contextually bounded within the process of teaching and learning. That is, the interaction between teachers and learners is subjective to the language, inscriptions and artefacts used within the sociocultural context of the learning environment. Besides, the interaction whereby teachers may provide feedback and feedforward is dynamic and can change into different shapes and forms during the process of teaching and assessment. However, the effectiveness of this dynamic process lies in the expertise of science teachers and it is more concerned with the notion of validity.

Validity of formative assessment is associated with the level of feedback and feedforward that teachers provide during teaching and learning process that evidently improves learners' learning to achieve the learning outcomes (Green & Johnson, 2008). In other words, validity in formative assessment hinges on the effectiveness of scaffolding that teachers provide to learners in order to close the gap between what is intended and what is achieved during the teaching and learning process. That said, for practical work, the learning outcomes are mainly for the understanding of scientific concepts, procedural knowledge as well as manual skills (Hodson, 2014). Subsequently, the validity of formative assessment for learning new concepts is embedded in the kind of scaffolding that science teachers provide for learners to make a conceptual change from prior misconception in order to construct, assimilate and accommodate new scientific concepts (Kawalkar & Vijapurkar, 2013).

Equally important for validity in formative assessment is the aspect of trustworthiness. Cowie (2000) explained that, trustworthiness involves trust and respect that learners have towards their science teachers to provide appropriate and worthwhile feedback and feedforward. When learners trust their science teachers, they will not only be motivated but also willing to collaborate and socially interact in the process of scaffolding (Cowie, 2000). Subsequently, learners may have confidence in and treat scaffolding during practical work experiences in science as a worthwhile process that would develop their conceptual and procedural understanding in science.

However, facilitating formative assessment and providing progressive feedback and feedforward during practical work is complex and highly demanding for both learners and teachers (Bell & Cowie, 2001; Cheung, 2016; Kawalkar & Vijapurkar, 2013). Providing quality feedback and feedforward is a professional skill that science teachers may develop over time in their teaching careers as well as by enhancing their PCK (Bell, 2005; Cheung, 2016; Hodson, 2014). Recent studies suggested that teacher training and ongoing professional learning should place more emphasis on the development of science teachers' PCK (Cheung, 2016; Hodson, 2014; Kind, 2009; Osborne, 2014). Given this context, this study had the aim to enhance science teachers' PCK for use in and improve the quality of the SBA of practical work in school science.

2.6 Nature of Pedagogical Content Knowledge

This study premised that science teachers need to enhance their PCK to effectively facilitate the SBA of practical work. Many recent studies have investigated the significance of science teachers' PCK for effective use in the process of teaching, learning and assessment in science education (Berg, 2015; Halim & Meerah, 2002; Jones & Moreland, 2003; Kind, 2009). In their analysis on current trends in the framing of teacher quality, Knight and Duschl (2015) highlighted the need for teachers to have a deep understanding of PCK as well as the skills to guide learners' thinking process. They emphasised that "quality teaching practice involves a transition to a more complex view of teaching behaviours tied explicitly to content associated with complex learning outcomes that may not be apparent on standardised achievement tests" (p. 459). In other words, the art and practice of teaching is increasingly composite with complex learning outcomes whereby assessment is shifting from

psychometric tests to dynamic educational assessments. Although this is the case, Osborne (2014) identified that little has been done to develop science teachers' procedural and epistemic knowledge to carry out teaching, learning and assessment that encompassed complex learning outcomes in science inquiry.

Many other rigorous and detailed studies have clearly pointed out the significance of PCK in science education (Kind, 2009; Osborne, 2014). So far, innovative materials were developed to support teachers' content knowledge as well as PCK for learners' misconceptions but rarely for science inquiry (Fazio, Tarantino & Sperandeo Mineo, 2014). Hence, there is a need for science teachers to enhance their PCK in order to facilitate learning experiences that engage learners in various integrated practical work with complex learning outcomes such as, developing conceptual and procedural understanding. That is, a PCK that encompasses effective strategies to transform complex content knowledge into familiar language and inscriptions that learners of diverse as well as unique capabilities and sociocultural milieus can comprehensively deconstruct as well as reconstruct (Moreland et al., 2006). This includes PCK on the nexus between content knowledge, curriculum, pedagogy, assessment, inquiry and learners' diverse capabilities (Park & Oliver, 2008). Subsequently, it is essential to outline the models of PCK that can be used to enhance science teachers' practice in the SBA of practical work for conceptual and procedural understanding.

2.6.1 Models of Pedagogical Content Knowledge

Although there is an overwhelming agreement on the significance of PCK, defining and identifying what it comprises is not simple (Kind, 2009). As such, Kind (2009) said that it is a "hidden concept" (p. 170) with "elusive nature" (p. 198). Initially, Shulman (1987) proposed seven categories of knowledge components and understandings that teachers should have for effective teaching. Out of the seven, Shulman highlighted that it is worthy to give special attention to PCK. In fact, Shulman (1987) defines PCK as:

the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by students (p. 15).

Shulman (1986) emphasised that PCK incorporates the ability to present subject matter into “most useful forms of representations... most powerful analogies, illustrations, examples, explanations, and demonstrations... that make it comprehensible to others” (p. 9). Subsequently, Lehane and Bertram (2016) argued that PCK is the defining knowledge that distinguished science teachers from scientists. While scientists have considerable subject matter knowledge, science teachers possess the knowledge to effectively teach and assess subject matter in school science. Despite these affirmative views, over the years some scholars in education as well as science and mathematics education critiqued, interpreted and constructed several conceptual models of PCK.

Many scholars had derived different conceptual models of PCK based on their interpretation of Shulman’s original seven categories of teacher knowledge. For example, based on Shulman’s initial views, Morine-Deshimer and Kent (1999) modelled how the seven categories of teacher’s knowledge are connected and on the whole contributed to make PCK special. This connectedness is depicted in figure 2.3.

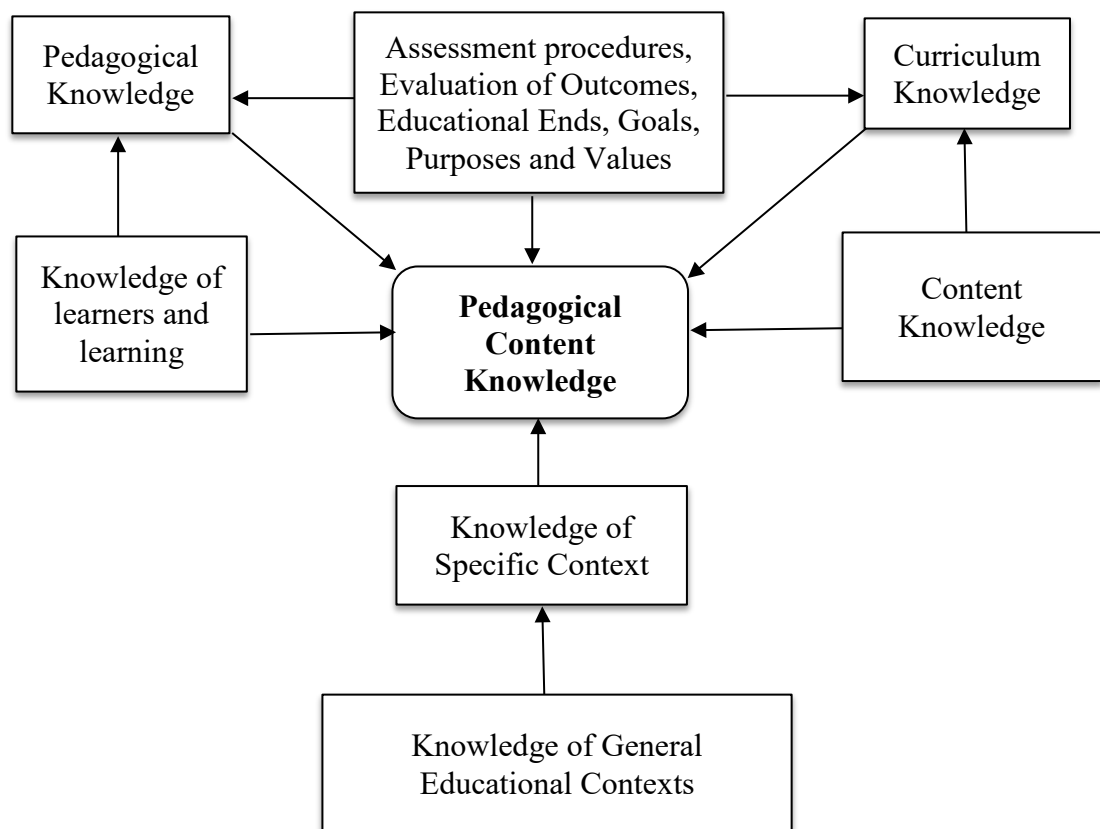


Figure 2.3. Seven categories contributing to PCK (Morine-Dershimer & Kent, 1999, p. 22).

There were other models that were reviewed, analysed and critiqued by scholars such as Gess-Newsome (1999), Jang (2012), Kind (2009) as well as Simsek and Boz (2016). Subsequently, these scholars agreed that PCK has no universally accepted conceptual model and the boundaries of the knowledge components are not clearly defined. At times, different terms were used to refer to the same knowledge components (Simsek & Boz, 2016). However, despite the subtle differences and formless nature, scholars often placed special attention on four knowledge components that Shulman proposed as fundamental to PCK. The four components are “knowledge of representations of subject matter, student learning difficulties, subject matter knowledge, and knowledge of educational context” (Jang, 2012, p. 24). These four knowledge components are often emphasised in most of the conceptual models of PCK.

Gess-Newsome (1999) proposed two models that fundamentally reconceptualised the nature of PCK. Namely, the “integrative model and transformative model” (p. 10). For the integrative model, PCK is the combination of content, pedagogical and contextual knowledge. The knowledge components exist separately and PCK “does not exist as a domain of knowledge” (p. 11). It is the intersection of the knowledge components during the course of teaching, learning and assessment process in the classroom that presents PCK. As such, each knowledge component is acquired separately and PCK lies in the teachers’ ability to combine them to make teaching, learning and assessment effective. For transformative model, Gess-Newsome (1999) proposed that PCK is:

the synthesis of all knowledge needed in order to be an effective teacher...
transformation of subject matter, pedagogical, and contextual knowledge
into a unique form – the only form of knowledge that impacts teaching
practice (p. 10).

These two models are presented in figure 2.4: Transformative model in diagram (a) and integrative model in diagram (b).

Basically, Gess-Newsome (1999) used an analogy from chemistry to differentiate the two models. On the one hand integrative model is like a mixture of chemical substances. Each original substance maintains its individual properties in the mixture and can be separated by physical means. Likewise, teachers’ knowledge components are combined when teaching but maintain their original features. On the other hand,

transformative model is like a compound whereby individual substances lost their features and a new substance is formed with new features. Analogically, for transformative model a new knowledge component is formed from synthesising the original knowledge components (Gess-Newsome, 1999). Hence, PCK is regarded as a new knowledge component with a new definition.

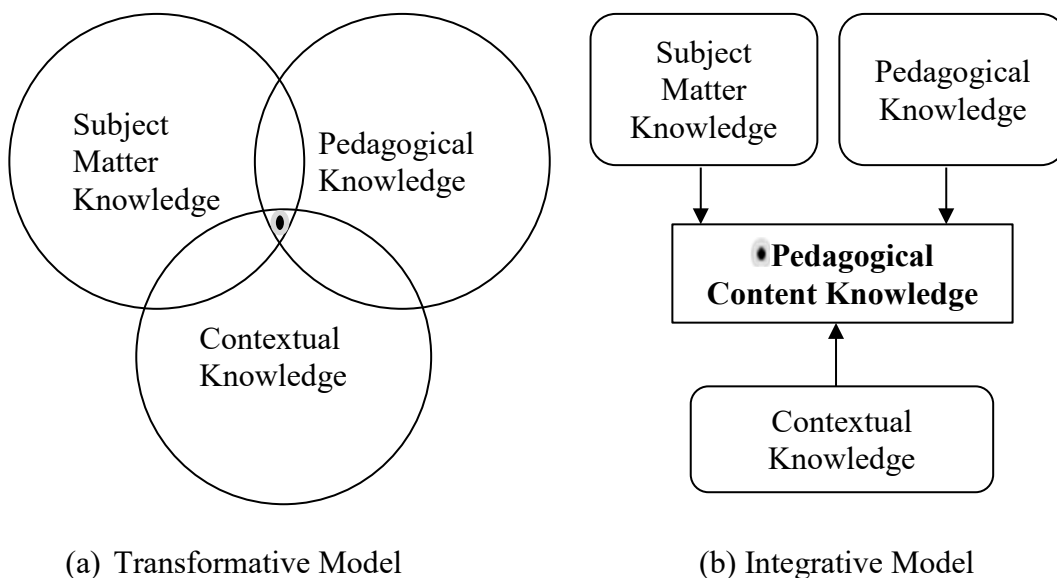


Figure 2.4. Two models of teacher knowledge, ● = knowledge needed for classroom teaching (Gess-Newsome, 1999, p. 12).

Different conceptual models have evidently showed that from a theoretical perspective, PCK is a complex concept. As well, this literature review has indicated that there is a lack of clarity to clearly identify the specific knowledge components required in general or for specific subjects. As such, it is still a dilemma to say whether PCK has a “structure specific to each subject... or a more general structure applicable to each course” (Simsek & Boz, 2016, p. 802). Although, this is evident in many literature discussions, there is still a growing trend that shows the significance of PCK studies in different fields of discipline in teacher education. Jang (2012) suggested that PCK is specific to topics and subjects. In other words, the combination or intersection of content and pedagogical knowledge is specific to subjects. Hence, it is regarded as different from general knowledge of pedagogy.

Studies were conducted to identify whether PCK has a specific structure for subjects such as mathematics, technology, chemistry, biology and physics (Simsek & Boz, 2016). For example, scholars such as Jones and Moreland (2003), Graham (2011) and

Voogt, Fisser, Roblin, Tondeur and Braak (2013) provided theoretical considerations as well as literature analysis for understanding Technological Pedagogical Content Knowledge (TPACK). While their review indicated different understandings about TPACK, Voogt et al. (2013) found that a good technology content knowledge will enhance the development of TPACK. Likewise, Hauk, Toney, Jackson, Nair and Tsay (2013), Hurrell (2013) as well as Simsek and Boz (2016) provided theoretical arguments on PCK in mathematics. In a similar vein, scholars such as Halim and Meerah (2002), (Etkina (2010), Keller, Neumann and Fischer (2017) provided discussions on physics PCK. Keller et al. (2017) found that physics teachers' PCK has positive impact on learners' academic achievement as well as motivation.

For the purpose of this study, this literature review outlines the PCK framework that focuses on improving physics teachers' teaching knowledge and practice. Particularly, for enhancing learners' achievement in school physics as well as other science subjects. That said, Etkina (2010) presented a scholarly description of PCK programs and practices to prepare high school physics teachers at the State University of New Jersey in the United States of America. According to Etkina (2010), it is imperative to emphasise that PCK is a personal construct. Nevertheless, while some scholars argue that individual teachers may progressively construct their personal PCK over their years of teaching, others argue that some aspects can be developed during teacher training programs (Etkina, 2010; Grossman, Schoenfeld & Lee, 2005). Actually, studies indicated that experience science teachers are more aware of the complexity of practical work which may confuse learners (Clermont, Borko & Krajcik, 1994). However, being experienced does not guarantee that a science teacher has developed effective teaching strategies as well as have a deep conceptual knowledge or can recognise learners' misconceptions (Berg & Brouwer, 1991). As such, for the purpose of this study, it is significant to outline a physics PCK that needs to be emphasised for trainee and practicing science teachers.

Using a transformative model, Etkina (2010) portrayed a structure of physics teacher's knowledge which comprises the three pillars of teacher knowledge. That is, content knowledge, pedagogical knowledge and PCK. Within these three pillars lie some of the teacher knowledge components that are commonly emphasised in literature on PCK. According to Etkina (2010), content knowledge in physics consists the

orientation towards teaching physics and knowledge of physics concepts, theories and relationships as well as the NoS. Pedagogical knowledge encompasses the knowledge of brain development, cognitive science, collaborative learning as well as classroom management and school regulations. Pedagogical content knowledge consists of the knowledge of physics curriculum, learner’s preconceptions and misconceptions as well as knowledge of effective teaching and assessment strategies. This structure of physics teacher’s knowledge as portrayed by Etkina (2010) is presented in figure 2.5.

With the transformative structure, PCK is the intersection of content and pedagogical knowledge. According to Etkina (2010), the transformative aspect of PCK encompasses physics teacher’s knowledge about: physics curriculum; learners’ difficulties with physics concepts; learners’ prior conceptions; representations and instructional strategies as well as assessment methods. Hence, with physics PCK a physics teacher should understand physics content and curriculum, understand learners’ difficulties in physics, make informed decisions on teaching and learning strategies as well as plan and conduct appropriate assessment techniques. In this regard, many studies had developed surveys and questionnaires that explored and examined physics and science teachers’ PCK.

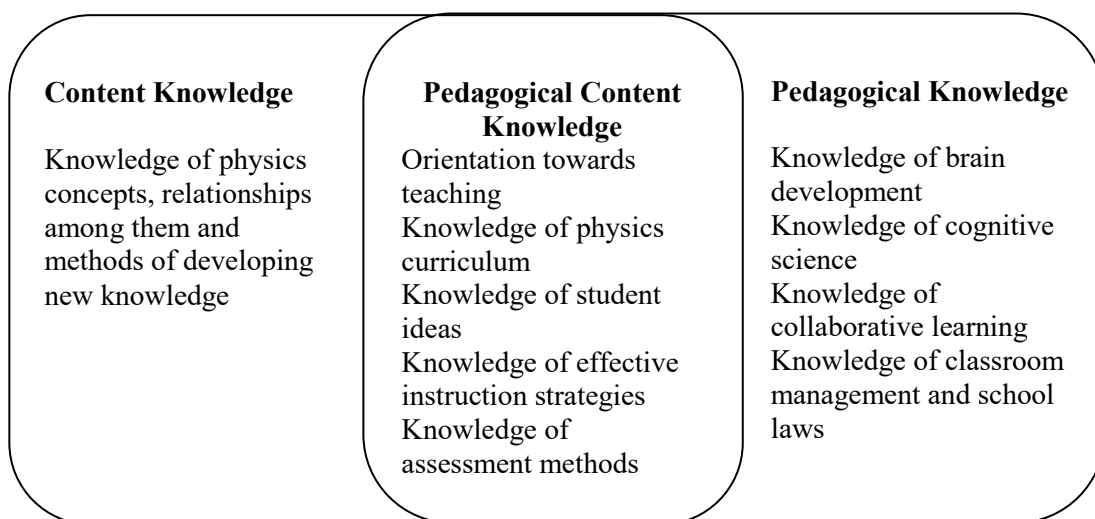


Figure 2.5. The structure of physics teacher knowledge (Etkina, 2010, p. 020110-2).

Many surveys developed scales consisting statements or items representing the different knowledge components. For example, Halim and Treagust (2006) devised a Pre-Service Science Teachers’ PCK survey questionnaire into scales which comprised

of statements regarding teachers' knowledge of teaching, learners' understanding, content and purpose, and multiple representations. Similarly, Jang (2012) developed survey statements with scales comprising science teacher's knowledge of science curriculum, learners' understanding of science, instructional strategies and assessment of scientific literacy. While these studies use the transformative structure more commonly, teachers' content knowledge component is usually explored and examined distinctively using physics concepts items. For example, Maries and Singh (2013) used the Force Concept Inventory (FCI) developed by Hestenes et al. (1992) to explore the PCK of physics instructors and teaching assistants.

According to Baxter and Lederman (1999), PCK is a highly complex construct. Hence, it requires combination of approaches to examine what teachers know, what they do and the reasons for their actions. In fact, to study PCK, many researchers in education have developed several methods and techniques such as "paper pencil tests (in particular, multiple-choice exams), concept maps, pictorial representations, interviews and multiple evaluations" (p. 147). However, although, there are several methods and techniques to assess trainee and practising science teachers' PCK, survey was the most appropriate method for the purpose of this study which was to examine the trainee and practicing science teachers' views and perceptions.

For the purpose of this study, the survey statements and interview questions that were developed to explore science teachers' physics PCK were adapted and derived from other studies as well. Accordingly, statements regarding the knowledge of teaching, learning and assessment of scientific and physics concepts were adapted from the pre-service science teachers' PCK survey questionnaire (Halim & Treagust, 2006). These scales were from an integrative model. A similar approach was taken by Tuan, Chang, Wang and Treagust (2000) in developing an instrument to assess learner's perceptions of their science teachers' knowledge. Additionally, statements on PCK were also derived from the TPACK survey which was developed by Schmidt, Baran and Thompson (2009). The statements were structured in-line with the transformative model. This was also vital for measuring participants' transformative views about PCK in comparison to the integrative model. In addition, for the purpose of this study, four items were adapted from the FCI (Hestenes et al., 1992). The compilation of the survey

statements and scales to explore science teachers' PCK in physics for this study is presented in detail in subsection 3.7.3 in Chapter three.

That being said, this study sought to develop a set of guidelines that can be used to inform and enhance science teachers' PCK to teach and assess physics and scientific concepts in the SBA of practical work.

2.6.2 Enhancing Teacher Pedagogical Content Knowledge

According to Osborne (2014), many science teachers have received little training to develop an explicit knowledge of scientific practice that is associated with conceptual, procedural and epistemic understanding. Etkina (2010) asserted that “one cannot learn physics by just listening and reading but needs to engage in the active process of knowledge construction” (p. 020110-2). In-line with the aims and purposes of practical work, experiencing the active processes in scientific practice is significant for physics teachers' PCK. As alluded to earlier, many scholars suggested that PCK is a personal construct and it develops over time through practice as well as reciprocal reflection and enactment to improve (Etkina, 2010; Wongsopawiro, Zwart & Van Driel, 2017). In other words, PCK can be enhanced as physics teachers continue to experience, reflect on their own teaching practice and in turn make improvements over their years of teaching. However, studies also indicated that knowledge components of PCK can still be enhanced during teacher training. This may also include the development of conceptual and procedural understanding for teaching, learning and assessment in school science (Osborne, 2014; Berg, 2015).

Etkina (2010) suggested that if physics teaching and learning in school science encompasses the understanding of learners' preconceptions, misconceptions, reflections and collaboration with peers then trainee physics teachers need to act as learners during their teacher training. That means, physics trainee teachers should mimic classroom experiences with their peers in their teacher training courses. This is what Etkina (2010) called the “clinical practice” (p. 020110-2). Similarly, Berg (2015) emphasised that trainee teachers should develop their scientific knowledge, skills and understanding through demo experiences during teacher training courses. In other words, the construction of the knowledge components for PCK can be acquired by actively experiencing the process during demo teaching and learning. According to

Etkina (2010), clinical practice can be tailored into teacher training courses by way of using microteaching strategies with peers. Hence, trainee science teachers can plan and execute their lesson plans while their peers act as their learners during “microteaching practices with artificial class environments” (Kartal, Ozturk, & Ekici, 2012, p. 2757). Although such microteaching experience is different from actual teaching of high school learners, the strategies practised and many experiences during microteaching are significant to physics teachers’ PCK development (Berg, 2015; Etkina, 2010; Kartal et al., 2012).

Microteaching provides the opportunity for trainee science teachers to develop the understanding and experience the process to coherently link the aims of curriculum, intended learning outcomes for lesson plans and choices of teaching, learning and assessment activities required to maximise effectiveness. This facet requires a deep understanding of physics concepts, theories and relationships as well as an informed knowledge about the sequences of the physics curriculum (Etkina, 2010). The developmental aspect of curriculum is crucial for lesson planning as well as for outlining learning outcomes for specific lesson plans. Besides, with deep understanding of concepts and curriculum sequence trainee teachers should also be able to progressively plan how to deconstruct, present, identify and assess physics concepts using different modes of representations (Tang, 2011). That means, training teachers should develop the understanding of sequencing and presenting scientific concepts progressively. In other words, knowing what, when to present and how to identify as well as assess starting from simple ideas to construct more complex concepts.

However, De Jong (2000) identified that trainee science teachers usually lack self-confidence not only in their content knowledge but how to meaningfully translate abstract scientific concepts into forms that are comprehensible for learners of diverse backgrounds. Besides, identifying learners’ preconceptions can be challenging (Berg, 2015). In order to deconstruct physics concepts into forms that are comprehensible, it is helpful for trainee teachers to understand and experience the construction of scientific concepts in school science themselves. As noted in subsection 2.3.2, the primary role of mental representations in understanding scientific concepts encompassed the ability to represent the concepts into forms and models that are

contextually familiar to both learners as well as trainee teachers (Wartofsky, 1979). The forms and models may include the kind of words used, diagrams, graphs, tables of figures, equations as well as gesturing and analogies (Tang, 2011). Subsequently, training teachers should develop knowledge on how and why these different forms and models can be synthesised and reconstructed to formulate a scientific concept. With these forms and models, trainee teachers can also develop the understanding and skills to identify learners' preconceptions or misconceptions. That is, training teachers can identify and recognise learners' demonstrations of the forms and subsequently assess by providing feedbacks and feedforwards.

According to Berg (2015) another generative knowledge and skill that teacher should develop is the use of formative assessment. Trainee science teachers can develop their formative assessment strategies during their microteaching process as well. As such, not only they develop the understanding to identify preconceptions and misconceptions but also to provide scaffolding and attempt remediation (Berg, 2015). Understanding formative assessment is important for scaffolding for learners' conceptual and procedural understanding in science (Etkina, 2010). Basically, formative assessment can be integrated into the process of teaching and learning of scientific concepts, context and skills (Green & Johnson, 2010). Trainee teachers can develop the understanding and skills for formative assessment during their microteaching practice. Besides trainee teachers should develop the knowledge, understanding and skills to facilitate learners' learning along different pathways depending on their preconceptions. The pathways can start with different but familiar everyday words, artefacts and analogies or multiple-representations (Mann & Treagust, 2011).

After all, teacher training courses should lay the foundation for continuous professional learning. Hence, progressive development of practising and experienced physics teachers' PCK is also crucial (Kind, 2009; Wongsopawiro et al., 2017; Yung, 2012). Retrospect to the purpose of this study, the enhancement of science teachers' PCK is significant for use in the SBA of practical work. That said, a study was conducted by Wongsopawiro et al. (2017) to identify the pathways that high school science teachers' may take to progressively enhance their PCK over time. Wongsopawiro et al. (2017) employed the "interconnected model of teachers'

professional growth (IMTPG)” (p. 191). The IMTPG was developed by Clarke and Hollingsworth (2002) to study the improvements in teachers’ knowledge as a result of their active participation in professional learning as well as teaching experiences. According to Clarke and Hollingsworth (2002), teachers’ professional enhancement is a result of reciprocal relationship of reflection and enactment between four factors or domains, namely: (1) personal domain - teacher’s knowledge, beliefs and attitudes; (2) external domain - external information and support; (3) domain of practice – trying out new activities; and (4) domain of consequence – new conclusions from effective outcomes in classroom practice (Clarke & Hollingsworth, 2002). As science teachers act and then reflect on one of the factors they may subsequently respond by making improvements in other factors.

Wongsopawiro et al. (2017) found that the development of practicing teachers’ PCK is personal, contextual and non-linear. Basically, with minor refinements to the four factors in the IMTPG, Wongsopawiro et al. (2017) found that the domain of consequence or effective outcomes in the classrooms and external domain or external support impacted the development of PCK for experienced and practising teachers. For example, Wongsopawiro et al. (2017) found that teachers enhanced their knowledge on instructional strategies when they were provided with information and professional support from external sources like literature and university lecturers respectively. Added to that, Wongsopawiro et al. (2017) found that action research can be an avenue to stimulate the enhancement of teachers’ PCK. As such, they suggested that action research whereby teachers evaluate and improve their own teaching through their learners’ performance should also be included in professional development modules. This view of using reflective action research was also raised by Halim et al. (2014).

Wongsopawiro et al. (2017) emphasized that external information and facilitators as well as peers are crucial in enhancing practising teachers’ PCK. In fact, Yung (2012) suggested that teachers should play a proactive role in developing their PCK with their peers. Hence, while focusing and reflecting on own practices teachers should also take time to consult, share as well as review the practices of their peers. This is in-line with the notion of a community of practice within a school or cluster of schools. Having a community of practice, teachers can establish collaborative professional learning

environments that integrated sociocultural and constructivist practices. For example, Duschl (2008) highlighted the sociocultural and constructivist environments whereby science teachers can interact with each other to develop conceptual, procedural and epistemic understanding in science. Such approach promotes epistemological and sociological processes in learning science as well as developing science teachers' PCK associated with the NoS (Duschl, 2008). Practising science teachers within a community of practice can further enhance their PCK with external information and expert facilitators from the universities.

In sum, enhancement of science teachers' PCK for use in the SBA of practical work is complex but can be addressed through teacher training courses as well as ongoing practising science teachers' professional practice and learning. The PCK components can be integrated into teacher training courses. The courses should focus on developing deep conceptual and procedural understanding in science. Added to that, trainee science teachers should engage in microteaching or clinical practises during their teacher training courses to develop the knowledge of: curriculum; learners' preconceptions and misconceptions; effective teaching, learning and assessment strategies. While trainee teachers can develop foundational knowledge in teacher training courses, practising science teachers should continue to develop their PCK through action research, establishing communities of practise and use of external information and facilitators.

2.7 Summary of Chapter Two

This chapter had provided a review of literature regarding the key research areas that underpinned the conceptual framework for this present study. First, the notion of understanding scientific concepts, which can also be narrowed down to the understanding of physics concepts, was discussed. This literature review highlighted that scientific concepts are sanctioned by the scientific community after a rigorous process of constructing and scrutinizing data, reports and other compositions of scientific ideas. Subsequently, the conception of scientific concepts is regarded as a cognitive mental representation that can be deconstructed into visible, audible and measurable forms, representations and analogies that learners can learn and

understand. In turn learners should be able to reconstruct as well as demonstrate their understanding of scientific concepts within their sociocultural contexts.

Science as well as physics are pragmatic high school subjects, and as such, practical work is a vital component for teaching, learning and assessment of scientific concepts, relationships and theories. Besides, practical work aims to develop learners' conceptual and procedural understanding, skills as well as interest and motivation. There are different levels of practical work with different purposes and learning outcomes. With these different levels, the effectiveness of a practical work lies in the link between what is intended and what is achieved. However, the teaching, learning and assessment using practical work can be complex depending on their levels and learning outcomes. Higher levels of practical work with learning outcomes related to conceptual and procedural understanding and the NoS can be complex.

It was emphasised that, by using the dual purpose of SBA, different levels and learning outcomes of practical work can be addressed respectively. This can be done by using continuous summative and formative assessments. On the one hand, manual skills can be demonstrated and assessed directly through performance or indirectly through written reports. Additionally, summative assessment can be utilised for the assessment of learning which goes towards grading. On the other hand, formative assessment can also be utilised for the teaching and learning process of developing conceptual and procedural understanding in open inquiry. This requires the ability of teachers to carry out quality scaffolding with effective feedback and feedforward.

Given the review of literature, this study premised that in order for science teachers to develop the ability to scaffold and make connections between the understanding of scientific concepts, purpose of practical work and the use of SBA, they need to enhance their PCK. This can be done during teacher training courses and through ongoing professional learning environments. Subsequently, both trainee and practising physics as well as science teachers in general need to develop their personal knowledge of: scientific and physics concepts as well as relationships; curriculum sequence and content; learners' preconception and misconceptions; teaching, learning and assessment strategies as well as contexts in science.

Recently, not many studies had explored science and physics teachers' perceptions in relation to the nexus of the key research areas discussed in the conceptual framework of this literature review. Hence, this study was designed to explore and document both trainee and practising science teachers' views and experiences on the teaching, learning and assessment of scientific and physics concepts in the SBA of practical work, particularly, in the sociocultural context of Solomon Islands science education. Subsequently, the research design for this study is presented next in Chapter Three.

CHAPTER THREE

Research Design

3.1 Chapter Overview

The previous chapter presented a review of the key areas in literature that outlines the conceptual framework for this study. This chapter specifically discusses the research design underpinning this study. Firstly, Section 3.2 introduces this chapter followed by reiterating the research purpose and research questions in Section 3.3. Then Section 3.4 outlines the current research perspectives in educational research that are relevant to this study. This is followed by Section 3.5 and Section 3.6 which discuss the research design specific to this study. The chapter then leads on to the description of data gathering and data generation in Section 3.7 followed by data analysis in Section 3.8. Subsequently, Section 3.9 presents the quality of this study while Section 3.10 highlights the ethical considerations that guided the whole research process for this study. Finally, a summary for this chapter is presented in Section 3.11.

3.2 Introduction

This introduction will begin with some clarification of nomenclature. In this study, the term research design is used in this chapter instead of methodology. Research design is used because the process of research is “more like constructing a complex design than merely executing a correct procedure” (Lesh, Lovitts & Kelly, 2000, p 19). In fact, research conducted in education has reached a point where it is more analytical than it has been in the past with the emphasis and effort being more keenly now to produce valid explanations (Labaree, 2003). Educational research has developed more focus on “people, places and processes broadly related to teaching and learning – and its purpose – the improvement of teaching and learning systems and practices for the betterment of all concerned and society at large” (Mutch, 2005, p. 18). This also includes investigating issues and environments relating to educational policies and structures (Donmoyer, 2006). As such, educational research has moved now into

investigating dynamic, complex and multifaceted environments within school systems, classrooms and workplaces (Lesh & Lovitts, 2000). With such a wide range of dynamic and complex educational foci research design could also be complex and multifaceted. Hence, it is important to explain the research design for this study.

For this study, “research design is governed by the notion of fitness for purpose” (Cohen et al., 2007, p. 78). Research design is “an action plan” (Yin, 1994, p. 19). The action plan legitimates and logically maps out the steps beginning from the research purpose and research questions to the theoretical framework which underpin the research design in order to fulfil the research purpose (Yin, 1994). Hence, it is significant to reiterate the purpose and objectives for this study.

3.3 Purpose and Objectives

This study sought to explore and document the views and experiences of trainee and practising science teachers about the school-based assessment (SBA) of physics concepts in science education in Solomon Islands. In particular, the use of practical work for the SBA of physics concepts within the Solomon Islands School Certificate (SISC) and Solomon Islands National Form 6 School Certificate (SINF6SC). The views and experiences given by the study participants were used as the baseline data that were analysed and synthesised with respect to the literature review discussed in chapter two to generate the outcomes for this study.

The outcomes are then used to construct a set of contextual guidelines to enhance science teachers’ physics pedagogical content knowledge (PCK) for use in practical work in the context of science SBA curriculum. The guidelines can be used as a framework for ongoing professional learning as well as, to further contribute to the improvement of science teacher training programs in Solomon Islands as well as in the broader global context where appropriate. The set of guidelines can also be used as a reference to enhance trainee and practising science teachers’ PCK for use in other high school science subjects in science education. The outcomes from this study may also be used as a guide to help improve other school subjects in education not only in Solomon Islands but the South Pacific region as a whole.

Having this purpose, the following research questions were proposed to be investigated. The research questions were tailored specifically to probe into the

contextual views and experiences of the trainee and practising science teacher participants in Solomon Islands.

The research questions were as follows:

1. What do trainee and practising science teachers know and understand about scientific and physics concepts in science SBA?
2. How do trainee science teachers view and experience their learning and assessments of physics concepts?
3. How do practising science teachers view and experience their teaching and assessing of physics concepts?
4. What do trainee science teachers suggest as ways to improve their learning, understanding and assessment of physics concepts in the SBA?
5. What do practising science teachers suggest as ways to improve their understanding, teaching and assessment of physics concepts in the SBA?

These research questions were examined using multiple research perspectives. As such, in order to specify the multiple research perspectives that underlie the research design for this study, it is imperative to discuss the key research perspectives.

3.4 Research Perspectives

It is argued that the “educational world is a messy place, full of contradictions, richness, complexity, connectedness, conjunctions and disjunctions” (Cohen et al., 2007, p. 167). With this kind of argument, research in education needs to be multidimensional and heavily argumentative and researchers need to investigate issues relating to education using multiple perspectives (Donmoyer, 2006; Labaree, 2003). Besides, researchers in education should be free to choose from multiple research perspectives in order to establish a research design that could address the purpose of their study (Donmoyer, 2006; Cohen et al., 2007; Creswell, 2008). In other words, the purpose of this study is fundamental to establish a legitimate research design that is underpinned by well-founded research perspectives in education. As such, it is essential to understand the research perspectives in education that underpinned the research design employed to fulfil the purpose of this study.

There are many research perspectives in the field of education (Creswell, 2012). Based on the research perspectives, “science education researchers, like any other social science researchers, strive to establish the credibility and validity of their studies” (Treagust, Won & Duit, 2014, p. 13). It is common for science education researchers to classify their studies amongst three traditional research perspectives; namely positivist, interpretive and critical perspectives (Dammak, 2015; Lather, 2006). These three research perspectives are basic belief systems that researchers in education can legitimate their claims about the knowledge they investigated (Guba & Lincoln, 1994; Kuhn, 1970). The beliefs are basic in a sense that educational researchers can accept them “simply on faith (however well argued)” (Guba & Lincoln, 1994, p. 107). In this regard, researchers in science education can base their research design on a single research perspective or multiple research perspectives (Donmoyer, 2006; Treagust et al., 2014). As such, it is imperative to describe and distinguish the three traditional research perspectives that are commonly employed in educational research.

The three research perspectives are based on three different “ontological, epistemological and methodological assumptions” (Coll & Chapman, 2000, p. 12). These are three philosophical assumptions that researchers can logically make about: the existence of knowledge (*ontology*), how to construct knowledge (*epistemology*) and the processes of acquiring knowledge (*methodology*) (Coll & Chapman, 2000; Guba & Lincoln, 1994; Ladyman, 2007; Lather, 2006). There are various and sometimes contentious explanations and descriptions about these three types of philosophical assumptions that underlie each of the research perspectives (Guba & Lincoln, 1994; Kuhn, 1970; Ladyman, 2007). Nonetheless, it is argued that, to fulfil a study purpose, a researcher’s choice of research methods and analysis should be legitimated by a set of belief system or a research perspective (Yazan, 2015). In saying that, not many contemporary research studies are committed to any particular research perspective based on the philosophical assumptions (Treagust et al., 2014). As stated earlier, researchers in education may choose a single or multiple research perspectives that they can use to legitimate their research design in order to fulfil the purpose of their study. Hence, in order to make claims that legitimate the research design chosen for this study, the three types of philosophical assumptions for the three common research perspectives are briefly summarised and tabulated in Table 3.1.

Table 3.1

A Brief Summary of the Philosophical Assumptions of the Three Research Perspectives

Philosophical Assumption	Positivist Perspective	Interpretive Perspective	Critical Perspective
Ontology	Knowledge is single, objective and realistic.	Knowledge is multiple, subjective and is socially constructed.	Knowledge is subjective and influenced by ideological interests.
Epistemology	Knowledge can be discovered, measured and verified.	Knowledge is generated through communication and interpretations.	Knowledge is decided collaboratively and mediated within social groups.
Methodology	Researcher controls and observes data mainly through quantitative methods such as surveys.	Researcher interacts to elicit rich explanations through qualitative methods such as interviews.	Researcher facilitates and encourage change through action research, dialogic and dialectical methods.

Note. The brief summary comprises simple and common descriptions adapted from Cohen et al. (2007), Guba and Lincoln (1994) and Lather (2006).

The research design for this study was underpinned by multiple research perspectives comprising predominantly positivist and interpretive assumptions. In fact, Morse (2003) also affirmed that, “by using more than one method within a research program, we were able to obtain a more complete picture of human behaviour and experience” (p. 189). Hence, this study was underpinned by multiple research perspectives to explore and document the participants’ views and experiences to generate a general trend from a deductive (positivist) approach with complementary rich subjective explanations from an inductive (interpretive) approach. The multiple research perspective is further explained in Section 3.6.

In essence, the research design for this study was framed to provide the blueprint for the whole research process, starting from the research purpose and questions through to the methods as well as instruments used for the collection and analysis of its research data. Subsequently, underpinned by the multiple research perspectives, the research design for this study was framed as a case study.

3.5 A Case Study Design

Framed as a case study design, this study sought to explore and document the views and experiences of trainee and practising science teacher participants about the SBA of physics concepts. This explored phenomenon is within a bounded real-life context throughout all the high schools in Solomon Islands (Yin, 1994). It encompasses various systems of human participants, school curriculum as well as educational organisations and structures. These systems of human participants and educational organisations such as the high schools are scattered and isolated from each other due to the geographical context of the Solomon Islands archipelago highlighted in subsection 1.7.1. Hence, it was not practical as well as challenging to involve all the practising science teachers from all the high schools given the timeframe and limited finances for this doctoral study. However, the purpose of this study to explore and generate a general trend with rich interpretations and descriptions regarding the phenomenon investigated was possible within a case study design (Yin, 1994).

Despite the differences in their epistemological discussions, seminal researchers in case study, Merriam (1998), Stake (1995) and Yin (1994) shared the notion that ‘a case’ is a temporary bounded system within a broad and contemporary real-life phenomenon and context. For instance, Stake (1995) described a case as “a specific, a complex functioning thing, an integrated system which has boundaries and working parts” (p. 2). More specifically, Merriam (1998) suggested that, “a case can be a person, a program, a specific policy or a unit around which, there are boundaries” (p. 27). Merriam (1998) further conceived a “case as a phenomenon of some sort occurring in a bounded context” (p. 27). Subsequently, she argued that, as long as case study researchers can specify a phenomenon and identify the boundaries around what they are going to investigate, they can call it a case. Even “when the boundaries between phenomenon and context are not clear and the researcher has little control over the phenomenon and context” (Yin, 2002, p. 13). That means, a bounded system may or may not have clear boundaries between the investigated phenomenon and its context.

Nevertheless, bounded may also mean that a “case is separated out for research in terms of time, place, or some physical boundaries” (Creswell, 2008, p. 476). A case

can also be bounded by “the participants’ roles and functions” (Cohen et al., 2008, p. 253). In essence, case studies are in-depth exploration of temporary bounded systems (Creswell, 2008; Stake, 1995; Yin, 1994). For this study the case under investigation was temporarily bounded by the phenomenon itself as well as a selected number of participants from the two cohorts of science teachers. One cohort being trainee science teachers at the Solomon Islands National University (SINU) and the other were practising science teachers at 21 different high schools in Solomon Islands. These school institutions were bounded within convenient geographical locations that were accessible to the researcher, given the limited time and resources allocated for this doctoral study.

This case study was situated within the three case study designs that Yin (1994), Stake (1995) and Merriam (1998) described in the literature. Yin (1994) stressed that from the outset, it is paramount to develop a logical sequence of steps for a case study. This should include a considerable set of detailed and structured steps for the design. In doing so, less alteration is required during the data collection and analysis process. If major alterations were required when data collection has already started then the researcher should go back to step one and conceptualise the research questions again and then redesign the case study right from the start (Yin, 1994). That means, Yin’s case study design is less flexible during the study process. However, given the context of this study, some flexibility was required.

Conversely, Stake (1995) designed a case study that is more flexible. The flexibility enables a researcher to make major alterations during the process of data collection and analysis. The main concern for Stake’s case study design is the initial conceptualisation of the research problem and questions. This should guide a researcher towards what to observe as well as, tease out what is needed to be collected and analysed, especially within complex and conflictual human contexts (Stake, 1995). In fact, Stake (1995) asserted that such a case study design is progressively focused. That means, there is less step by step plan to follow and changes can be made during the process of data collection and analysis. The research problem and a set of research questions at the outset should “help structure the observations, interviews, and document reviews” (Stake, 1995, p. 20). Even though this flexibility does not require much initial preparation with a set of logical steps, the process during the collection of

data and analysis can lead to confusion and much ambiguity (Yazan, 2015). That said, some logical sequencing was significant for this study in order to avoid confusion and ambiguity when collecting and analysing data.

Unlike the two extremely opposite designs by Yin (1994) and Stake (1995), Merriam (1998) provides a case study design that is in between the two. Her design provides a step by step process that initially includes conducting the review of the literature, constructing a theoretical framework, articulating the research problem, sharpening the research questions and purposefully selecting a sample (Merriam, 1998). Purposeful sampling allows the researcher to “select individuals and sites for study because they can purposefully inform an understanding of the research problem and central phenomenon in the study” (Creswell, 2007, p. 125). However, while Merriam’s case study design is logically sequenced and sampled purposefully like Yin’s case study design, there are some degrees of flexibility like Stake’s case study design. The flexibility occurs, when a researcher decides on what data to collect next in order to generate an emerging theory during the data collection process (Merriam, 1998). As such, although Merriam’s case study design is logically sequenced and purposeful there is flexibility regarding the decision on what type of data to collect next during the data collection process. This was suitable for this study since other appropriate forms of data were collected, for example, field notes and other written documents.

In summary, this case study was designed purposefully to capture as much as possible from different sources of data about the case or phenomenon that was explored in its real and complex context (Yazan, 2015; Yin, 1994). The design for this case study combined some aspects from each of the three case study designs described earlier. This case study was designed with elements that purported to support and serve its purpose. Hence, the design for this case study was based on a logical sequence and connection from the research problem to research questions, intentions, data collection and analysis as well as the theoretical basis to interpret the findings (Merriam, 1998; Yin, 1994). While logical sequencing from the start to the end is less flexible for alterations during the data collection and analysis process (Yin, 1994), there were some degree of flexibility for this case study. Not the flexibility to change the purpose and research questions during the study process but for the use of multiple research

perspectives, methods and data as well as, to use embedded multiple case study instead of a single case (Yin, 1994; Yazan, 2015).

3.5.1 Embedded Multiple Cases

The decision as to whether to have a single case or multiple cases depends on the overall intention of a researcher (Merriam, 1998; Stake, 1995; Yin, 1994). As the name suggests, a single case study may consider and focus only on an individual participant, an institution, an organisation, an event or a particular occurrence of an educational experience or a specific program and process involving a particular social group (Merriam, 1998; Stake 1995). For example, a single case study may focus on a student, a teacher, a school leader or a group of students, teachers, school leaders, or can be a school or a school program (Cohen et al, 2008). Generically, a single case study is eminent, “where the case represents a critical test of existing theory, where the case is a rare or unique event, or where the case serves a revelatory purpose” (Yin, 2002, p. 44). A revelatory case study is usually employed to explore a phenomenon with a subject of interest that has never been studied before (Bengtsson, 1999). Additionally, a researcher may be limited to use a single case study when other cases are not available to either produce predicted similar results (literal replication) or contrasting results (theory replication) (Tellis, 1997). These two replications are less concerned with the quantitative logics or sample size but more about the qualitative logic, or a theoretical framework. Although a theoretical framework can be used as a basis to make generalisation to other cases or new cases, the strength to make conclusion and generalization from a single case study is not high (Yin, 2002). Hence, the two cohorts of trainee and practising science teacher participants were selected as multiple cases to strengthen the conclusion for this study.

This multiple case study also utilised the embedded case study design (Yin, 1994). The embedded design provided an opportunity to collect and analyse other complex but relevant variables that would enhance a rich and in-depth understanding about the phenomenon (Yin, 2003). In employing the embedded design, other significant factors can be incorporated and used for data interpretation and analysis, for example, the years of experiences and qualification levels of participants. The rural and urban contexts as well as the three types of schools involved in this study. The embedded design was used to ensure different sub-levels of analysis were provided “within the

subunits separately (within case analysis), between the different subunits (between case analysis) or across all of the subunits (cross-case analysis)” (Baxter & Jack, 2008, p. 550). In this regard, this case study was sought to explore the views and experiences of science teacher participants about teaching, learning and assessment of physics concepts in the SBA of practical work. Hence, this study was designed to analyse the significant variables within the sociocultural context of the phenomenon as well as the similarities and difference between the two cohorts (cases) of participants.

3.5.2 Explorative Focus

This embedded multiple case study was explorative. Basically, the research problem and research questions provided a guide to determine whether this embedded multiple case study design was explorative, descriptive or explanatory (Yin, 2002). An explorative case study design is an initial study that seeks to understand what and how about a phenomenon that has not been examined before. Hence, an explorative case study primarily seeks to understand what is there to understand. This is different to a descriptive case study that seeks to provide additional information about a phenomenon, or an explanatory case study that mainly intends to understand patterns of causes and effects (Yanzan, 2015). This study was the first of its kind in Solomon Islands. Hence, this embedded multiple case study was predominantly explorative. However, the descriptive and explanatory nature of this study is evident in the discussion of findings in Chapter Six. The discussion situates the results of this study within the existing literature and conceptual framework outlined in the literature review in Chapter Two (Baxter & Jack, 2008). The main intentions of this embedded multiple case study were to explore and develop a set of guidelines to enhance science teachers’ PCK for the SBA of physics concepts, and to lay an initial framework for future studies in science education in Solomon Islands as well as the Pacific region.

As discussed so far, this study was guided by a case study design that included embedded multiple cases with an explorative focus. While these features are imperative to the research design of this study, this thesis will continue to use the term ‘this study’ to refer to the integrated features of this case study design. In saying that, this study favoured a mixed methods approach.

3.6 Mixed Methods Approach

Basically, “case studies can be based on any mix of quantitative and qualitative evidence” (Yin, 1994, p. 14) and “regardless of whether one favours qualitative or quantitative research, there is a strong and essential common ground between the two” (Yin, 2002, p. 15). As such, this study favoured the flexibility of employing both quantitative and qualitative methods as well as, to generate quantitative and qualitative sets of data for the same research questions at the same time (Yin, 2009). This approach is suitable for a case study researcher who intends to explore, examine, evaluate and contribute to improve an existing knowledge or practice within a specific group or organisation (Yin, 2009). In saying this, some authors in science education research have had a dilemma in “whether to regard mixed methods as a separate research paradigm or as a research design” (Treagust et al., 2014, p. 13). As such, many researchers who employed mixed methods approach try not to commit to a particular research perspective that is based on a distinct set of philosophical assumptions (Creswell, 2012, Treagust et al., 2014). Instead, they focus more on strengthening the practical aspects of their research design which involves a mixed methods approach as a means of collecting and analysing data (Treagust et al, 2014). However, a mixed methods of using both quantitative and qualitative approaches can also be viewed through the philosophical lenses of both positivists and interpretive perspectives respectively (Yazan, 2015). The philosophical lenses were significant for making claims for the results from this study (Mackenzie & Knipe, 2006).

A mixed methods approach was used to provide quantitative analysis for the statistical results as well as in-depth and rich qualitative results analyses from the perspectives of the participants. The role of multiple research perspectives is essential to enhance the research methods and the type of data collected (Mackenzie & Knipe, 2006). Furthermore, mixed methods of data collection provide the ability to triangulate data, investigate internal consistency and reliability. They also allow, via the combination of variables and methods, to provide a rich and more comprehensive data set than any one single method would allow. For example, participants may only respond to items on a survey, and may not have the opportunity to provide clarification, which is possible in an interview situation.

On the one hand, in order to provide a general trend or casual relationships from participants' views and experiences, broad statistical measurements and analyses are usually required (Yin, 1994). This can be addressed within the positivist epistemological perspective which primarily favours quantitative methods and data. This can be addressed by using research instruments such as surveys (Yin, 1994). On the other hand, to generate in-depth interpretations about a given phenomenon with rich subjective descriptions and analysis, interpretive epistemology is favoured using qualitative methods and interactive data collection using means such as interviews (Merriam, 1998; Stake, 1995). As a matter of fact, "mixed methods, like all research approaches, need to be viewed through a critical lens while at the same time recognising as valid its contribution to the field of research" (Mackenzie & Knipe, 2006, p. 10). Thus, in considering the purpose of this study, a mixed methods approach was employed to explore a general trend as well as to document an in-depth knowledge and interpretation that were subjective to the research participants in their real life contexts.

A mixed methods approach provides a more comprehensive picture of the phenomenon under investigation (Creswell, 2008). This would not be possible when only one method was used. Morse (2003) explains that, when a researcher combines and use a number of research approaches within a particular study, a more complete picture of human views and experiences can be obtained. Mixed methods was used instead of a single method, to provide multiple perspectives and data that can be used to complement each other. Along with the embedded design, mixed methods allowed the researcher to explore data at different levels within the study that were equally important for analysis (Tashakkori & Teddlie, 1998). Analysis from one data set can provide other significant aspects of the study that the other data set might not be able to provide and indicate. As such, although quantitative and qualitative approaches are seen as distinct and contradictory to each other, they are often regarded as complementary to each other (Creswell, 2008). Actually, Creswell (2012) asserted that, mixed use of both quantitative and qualitative methods and sources of data enable mixed methods researchers to thoroughly triangulate, validate and make stronger knowledge claims as stated earlier. For this reason, mixed methods approach was used for this study.

However, while there are different kinds of mixed methods approaches, triangulation mixed methods was favoured for the purpose of this study.

3.6.1 Triangulation Mixed Methods

This study specifically employed a “triangulation mixed methods” (Creswell, 2008, p. 557) since both the quantitative and qualitative data were collected “concurrently” (p. 557). That means, the quantitative data were collected alongside the qualitative data. The order of when and which method was administered was not a concern since both of the data sets collected were seen as research evidences of the same phenomenon but from two separate sources (Yin, 1994, Creswell, 2008). With the triangulation mixed methods, both data sets were also analysed separately. However, the results from the analysis of both data sets were interpreted and validated comparatively. Inferences were made to see whether the data and results from both methods support or contradict each other (Creswell, 2008). In fact, Creswell (2008) represented the triangulation mixed methods design with the diagram in figure 3.1.

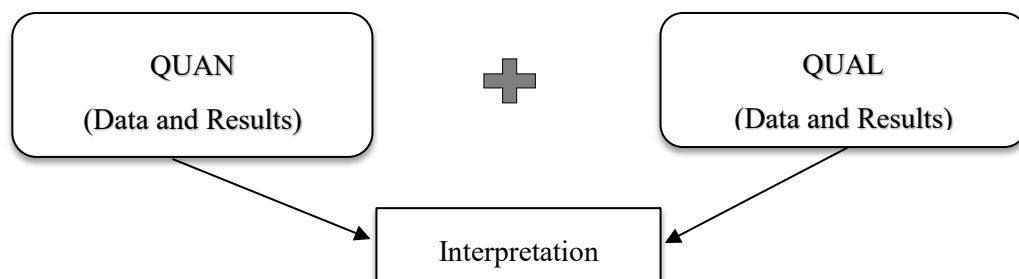


Figure 3.1. Triangulation mixed methods design (Creswell, 2008, p. 557).

Basically, the concept of triangulation was derived from a strategy that is commonly used in navigation and military to geometrically locate exact positions of an object using multiple reference points (Smith, 1975). Likewise, mixed methods researchers, can use multiple viewpoints collected from different sources of data to improve their accuracy in making interpretations on the same phenomenon. Further to that, triangulation is a means to cross check in order to validate that, what is shown in the results is of an emerging trend and not because of the methods used (Denzin, 1978). That means, even when two distinct research methods were used, both of the data collected can be triangulated to cross check whether they are compatible and

comparable. The cross checking can also happen within a single method for internal validity or between two methods for external validity (Yin, 1994).

The diagram in figure 3.2 depicted an overall view of the research design for this study.

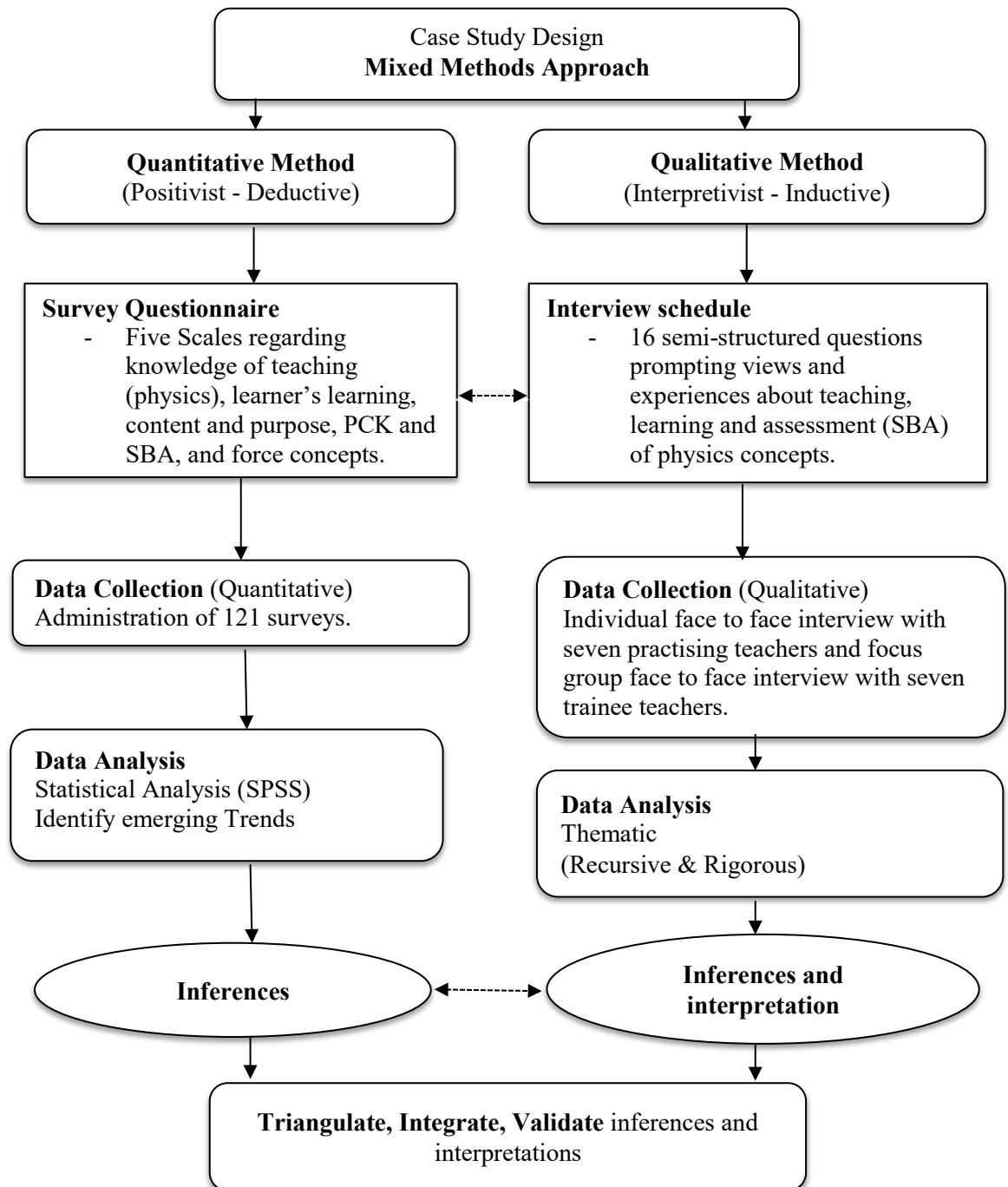


Figure 3.2. An overview of the research design for this study.

In essence, “the effectiveness of triangulation rests on the premise that the weakness in each single method will be compensated by the counter-balancing strengths of

another” (Jick, 1979, p. 604). Hence, by employing triangulation mixed methods with the concurrent approach, both the quantitative and qualitative data were complementary such that:

Quantitative scores on an instrument from many individuals provide strengths to offset the weakness of qualitative documents from a few people. Alternatively, qualitative, in-depth observation of a few people offers strength to quantitative data that does not adequately provide detailed information about the context in which individuals provide information (Creswell, 2008, p. 557).

The quantitative data were collected using a multiple response survey instrument. This method of data collection provided a deductive approach to the data collection which involved a positivist perspective (Cohen et al, 2008). The quantitative data from this study were also used to explore the reliability, internal consistency and validity of the survey responses. In addition, qualitative data were collated using in situ face to face individual and focus group audio recorded interviews. This inductive approach involves an interpretivist perspective (Creswell, 2008). As such, this study used triangulation to develop a deeper understanding of what and how things were viewed and experienced by participants. Mainly to provide a rich interpretation and observation of the same phenomena through complementary research methods and data generation (Creswell & Clark, 2007; Yin, 1994).

3.7 Data Generation Procedures

The data generation procedures for this study consisted of several basic steps which included methods and instruments that were employed to collect, record and generate both quantitative and qualitative data (Creswell, 2003). Hence, this section describes the data generation procedures for this study with respect to: the selection of the entire sample (cases and participants); the selection of the instruments used to collect and record the quantitative and qualitative data as well as the researcher’s diary and field notes from the situation.

3.7.1 Selection of the Whole Sample

The entire sample for this study was purposefully selected in order to incorporate other significant subunits of analysis within the focus of the study and to develop general trends and in-depth understanding about the views and experiences of the participants within their lived bounded systems (Cohen et al., 2008; Yin, 2003). To ensure external validity, schools were purposefully selected to represent a range of school organisations (Creswell, 2003). The schools were also bounded by their geographical locations which were convenient and accessible to the researcher. Basically, the selected sample was convenient in terms of visiting multiple sites as they are geographically distributed and difficult to access, requiring many hours on open boats crossing the sea and in long and arduous road trips by vehicles as described in subsection 1.7.1. Added to that, it is significant to note that the term convenient also refers to the fact that the participants were socio-culturally and personally convenient to the researcher, having been a science teacher in Solomon Islands himself.

The selected school organisations included the SINU and 21 high schools. The SINU and 19 high schools are located in and around the capital city, Honiara on the island of Guadalcanal, while the other two high schools are on the island of Malaita, Solomon Islands. The school organisations were selected in order to invite both trainee and practising science teacher participants for this study. The SINU is the only national university in Solomon Islands that provides Bachelor's degree, Diploma and Certificate of Teaching in science for trainee science teachers. As such, apart from geographical convenience, the SINU was obviously selected. Besides, while the 21 high schools were also bounded by geographical convenience their selection could represent other high schools in Solomon Islands sociocultural and geopolitical contexts (Yin, 2003; Zainal, 2007).

The 21 high schools were selected amongst the three types of high schools in Solomon Islands. The high schools included four National Secondary Schools (NSS), two Provincial Secondary Schools (PSS) and 15 Community High Schools (CHS). These three types of high schools were described in subsection 1.7.3. For relevant analysis, the three types of high schools were also selected to represent rural and urban contexts. Thus, two NSS, one PSS and one CHS are rural schools while the other two NSS, one PSS and 14 CHS are urban schools. Added to that, five of the 21 schools and the SINU

are boarding schools for both male and female learners while the rest of the high schools are day schools.

To further contextualise the research locations for this study, sample photographs of the different types of high schools are presented in figure 3.3 (the School of Education Campus, SINU); figure 3.4 (NSS, Urban context); figure 3.5 (CHS, Urban context); and figure 3.6 (CHS, Rural context).



Figure 3.3. Photo of the SINU School of Education Campus, Honiara.



Figure 3.4. Photo of one urban National Secondary School (NSS).



Figure 3.5. Photo of one urban Community High School (CHS).



Figure 3.6. Photo of one rural Community High School (CHS).

The science teacher participants from the SINU and 21 high schools were selected on the basis that they have had views on and experiences with the Solomon Islands SBA of high school physics concepts. Subsequently, participants were invited on voluntary basis to participate in both the quantitative and qualitative data collection process. Letter of invitation with participant's information sheet was given to their respective Principals and Head of Science Department. As a result, a total of 124 participants

responded for the quantitative data, out of which, 14 participants gave consent to provide the qualitative data on voluntary basis.

There were 250 high schools with 3,357 teachers in Solomon Islands when the sample for this study was selected in 2015 (MEHRD, 2015). There was no government or other statistics on the total number of science teachers to make a comparison with regards to the size of the whole sample in this study. Nevertheless, according to the contextual knowledge and experience of the researcher, there are usually an average of two science teachers per high school. Hence, it can be assumed that there were at least 500 science teachers within the 250 high schools in 2015. As such, it can be assumed that this study involved 8.4 percent of high schools and 21.8 percent of high school science teachers in Solomon Islands. Added to that, out of the 124 respondents 92 were males and 32 were females. Table 3.2 provides a brief description of the types of schools and the total number of science teachers who participated in completing the survey for this study.

Table 3.2

The Whole Sample Including, Types of Schools and Number of Participants

	Types of Schools				Participant (Gender)		
	Rural	Urban	Day school	Boarding	Male	Female	Totals
NSS	2	2	0	4	12	2	14
PSS	1	1	1	1	6	4	10
CHS	1	14	15	0	27	9	36
SINU	0	1	0	1	47	17	64
Totals	4	18	16	6	92	32	124
			22			124	

Note. N = 124 respondents for the survey from a total of 22 school organisations which included SINU and 21 high schools.

3.7.2 Invitation to Participants

The process of inviting the trainee and practising science teacher participants was undertaken according to the ethics approval for this study from the Human Research Ethics Committee at Curtin University (see Appendix D1). Upon arrival in Solomon Islands, permission was also sought from the Ministry of Education and Human Resources Development (MEHRD) to carry out this study with participants from the SINU and high schools. Under the Solomon Islands ‘Research Act 1982’ the researcher had to complete a ‘Research Application Form RA’ in order to have research permit to conduct educational research in Solomon Islands involving schools and its human participants (Research Act, 1982). As required in that research application form, other relevant documents were also attached. Relevant documents included the ethics approval form from Curtin University, the research proposal for this study, participant’s information sheet and researcher’s curriculum vitae (see Appendix E for copies of relevant documents). This process was undertaken not only in adherence to the Curtin University ethics approval but also in accordance with the research act 1982 and MEHRD research protocols. It took a week to get the research permit from the MHERD (see Appendix D2 for research permit from MEHRD).

Trainee Science Teacher Participants

The trainee science teacher participants at the SINU were invited through a formal process as advised by the SINU research committee. Accordingly, a letter attached with the research permit, the participant’s information sheet, the research proposal and the researcher’s curriculum vitae was hand delivered to the Dean of Studies for the School of Education (SOE). This process was undertaken to seek permission to conduct this study with trainee science teachers at the SINU. Permission was granted in writing a week later after the SINU Research Committee met to discuss the proposal for this study. The SINU approval was granted with amendments, particularly, to ensure that the SINU trainee science teacher participants were informed and safe from any harm. Furthermore, it was requested that a copy of this thesis be submitted to the SINU School of Education and Humanities for the purpose of being permanently stored in their library collection upon completion. Subsequently, the researcher was advised to further consult the Head of Science Department (HSD) with regards to

inviting the trainee science teachers (see Appendix D3 for a copy of the approval letter from SINU research committee).

Upon receiving the research permit from the SINU research committee, the researcher consulted the HSD for further arrangements to invite the trainee science teachers. The HSD was keen and showed great interest in providing assistance to invite the trainee science teachers. As such, with the information sheet for this study, the HSD agreed to convey the invitation to trainee science teachers on voluntary basis. The trainee science teacher participants who were invited were doing their Diploma and Bachelor of Teaching programs and were at different years into their programs of study at the SINU. Basically, the invitation to participate in this study was given after the HSDs formal lectures. As agreed, the HSD invited the participants on voluntary basis and their willingness to complete and hand in their surveys was seen as their informed consent. Without giving the exact total number of trainee science teachers for all the different science teaching programs, the HSD said that about 90 percent of trainee science teachers willingly completed and submitted their surveys. A brief demography of the trainee science teacher participants is presented in Table 3.3.

Table 3.3

Number of Trainee Science Teacher Participants and Their Programs of Study

Programs of Study	Male	Female	Pre-service	In-service	Totals
Diploma	25	11	22	14	36
Degree	23	5	16	12	28
Totals	48	16	38	26	

Note. N = 64, Pre-service = 38, In-service = 26.

Practising Science Teacher Participants

Permission to involve practising science teacher participants was sought through education authorities (EA) that oversee the selected high schools for this study (see Appendix E1 for a copy of the letter). A letter attached with relevant documents such as the research permit and the information sheet outlining the aims and significance of this study was also delivered by hand to the Chief Education Officers (CEO) of each EA. In reality, delivering by hand was commonly regarded as the most effective and

efficient means to get prompt responses in Solomon Islands context. Hence, upon receiving and reading the letter with the attached documents, two CEOs promptly responded by verbally giving permission and assurance that the researcher could go ahead and directly liaise with respective school principals. Another CEO for a church EA actually granted the permission to involve their high schools and science teachers in writing. The response in writing took a couple of days. In another vein, upon receiving and assessing the letter and relevant documents, the CEO of the EA that oversees high schools in Honiara, verbally gave permission and vowed to inform their high school principals by way of sending them a circular.

After completing the research protocols and receiving the approvals, the researcher went to the respective high schools and further consult with each of their principals. The principals were kindly asked to invite their practising science teachers to participate in this study. As such, further verbal clarification and elaboration was given alongside the information sheet about the research aims, significance and the nature of the practising science teacher participants' involvement in this study. For most of the high schools, the principals verbally invited their practicing science teachers. Following the invitation through their principals, participants were always reminded that their decision to take part in this study was on voluntary basis. Subsequently, informed consent forms were provided to be signed by the participants. However, most of the participants verbally expressed that they gave their informed consent by willingly participating in this study. A brief demography of the practising science teacher participants is presented in Table 3.4.

Table 3.4

Number of Practising Science Teachers and Their Level of Qualifications

Level of Qualification	Male	Female	Certified	Qualified	Total
Certificate	1	1	1	1	2
Diploma	20	9	28	1	29
Degree	23	5	22	6	28
Postgraduate	1		1		1
Total	45	15	52	8	

Note. N = 60, Certified (Trained Teachers) = 52, Qualified (Not Trained Teachers) = 8.

Table 3.4 only provides the level of qualification and not what kind of qualifications. According to MEHRD (2017), a certified teacher was a trained teacher while a qualified teacher has a qualification but was not trained to teach. That being clarified, this study involved 52 certified and eight qualified practising science teachers.

3.7.3 Collection of Quantitative Data

The generation of quantitative data for this study included the construction of the survey instrument and its administration procedures. Initially, a pilot study was conducted prior to the actual construction of the survey for this study. Hence, a brief description of the pilot study is outlined followed by the description of the actual survey instrument and the administration of the quantitative data for this study.

The Pilot Study

The pilot study was conducted in October 2014 in Honiara, Solomon Islands. It was conducted to try out the proposed survey questionnaire that was developed for collecting the quantitative data for this study (Baker, 1994). As such, it was a small scale study with small sample population of nine practising science teacher participants from three high schools and ten trainee science teacher participants at the SINU. This sample population was within 15.3 percent of the whole sample population for this main study. According to Baker (1994), this sample size was reasonable. In particular, the pilot study was conducted as a trial run in preparation to the actual study, mainly to test the survey questionnaire in order to figure out “whether there is a possibility that worthwhile results will be found” (Anderson, 2004, p. 12). That means, although the pilot study did not guarantee any success or failure in the use of the tested instrument in the actual study, it provided an indication for construct validity of the instrument (Simon, 2011).

The original survey for this study was developed using the first four scales described in the next subsection on ‘the survey instrument’ and the whole 29 items of the Force Concept Inventory (FCI). As such, the pilot study was conducted in order to check and address whether: the instructions were easy to follow; items were ambiguous or not, there were typing errors and or omissions; the survey can be easily administered and participants can reliably complete without fatigue or pressure (Anderson, 2004;

Simon, 2011). Given these following purposes, the pilot study was not conducted to check major statistical and analytical processes and results. But mainly to validate the construct and the suitability of using the survey for the purpose of the main study.

That said, the responses from the sample of 19 participants in the pilot study were significant and valuable in redesigning the actual survey instrument used for the main study. Majority of the participants indicated that the survey was too long since it included the 29 items in the FCI. Added to that, majority of the participants found that the FCI items were difficult. As one participant expressed that not all science teachers graduated with a good content knowledge in physics. Some participants shared the concern that they were anxious of getting the answers to FCI wrong. This was despite the fact that the instructions were seeking for perceptions. While, these brief indicators were found in the pilot study, there was a consensus view about the appropriateness and timeliness of the survey content in science education in Solomon Islands. In particular, the fact that the survey items provoked the majority of participants in the pilot study to reflect and reassess their own PCK and the SBA of physics concepts.

Given these brief but significant indicators from the pilot study, it was decided that it was necessary to modify the survey instrument before the actual study was undertaken. The researcher decided to only include four out of the 29 items from the FCI to be included in the main survey as the fifth scale. The reason to choose the four items are explained later in the subsection on ‘the survey instrument’. Added to that, the design and the structure of the survey was modified with colours and was printed on one A3 size paper that was folded in half. The resulting survey instrument is described next.

The Survey Instrument

The survey instrument for this study consisted of relevant demographic items, five scales which comprised 54 items and a blank space at the end for participants to write any comments they consider relevant to the survey and this study. The survey instrument was constructed using scales and items from three different survey instruments. As described in subsection 2.6.1, the items for the first three scales of the survey were adapted from the Pre-Service Science Teachers PCK Survey questionnaire which was developed by Halim and Treagust (2006). The items for the fourth scale were derived from PCK items adapted from the TPACK survey which

was developed by Schmidt et al. (2009) while items for the fifth scale were selected from the FCI, developed by Hestenes et al. (1992). These different survey instruments were used in other studies and their psychometric properties were validated. Subsequently, some items and scales were purposely selected and adapted for this present study, basically, to capture both trainee and practising science teachers' PCK. The first three scales were from an integrative model of PCK while the fourth scale was from a transformative model and scale five was selected mainly to capture participants' content knowledge on Newtonian force concepts.

The items for the first three scales were specifically adapted from the section on knowledge of teaching and learning science from the Pre-Service Science Teachers PCK Survey questionnaire (Halim & Treagust, 2006). The first scale contained 15 items (statements) regarding science teachers' knowledge of teaching. The second scale contained 12 items regarding the knowledge of learner's understanding and the third scale consisted of 13 items regarding the knowledge of content and purpose. The items considered to have strong correlation between items since the Cronbach Alpha values for the scales were above 0.60 (Halim & Treagust, 2006). Basically, only the subject in the original statements was changed from science to physics. As such, the statements in the original survey were about science teachers' knowledge and perceptions about science as a subject while for this study, the subject was physics. Although the subject was changed the construct of the statements as well as the scales were similar. A similar approach was taken by Tuan et al. (2000) in developing an instrument to assess learner's perceptions of science teachers' knowledge. Table 3.5 provides some examples of the rephrasing of statements from the Pre-service Science Teachers PCK survey questionnaire for items in scales one, two and three for the survey used in this study. The OS1 is an example of an original statement in scale one while S1 is its rephrased statement in this study. Likewise for OS2 – S2 for scale two and OS3 – S3 for scale three.

The fourth scale in the survey for this study contained 10 items that were constructed to capture participants' views and experiences relating to PCK as a transformative model. As discussed in subsection 2.6.1, while PCK is regarded as an important teacher knowledge, its boundaries are unclear as well as its constructs are not well defined and articulated (Gess-Newsome, 1999; Voogt et al., 2012). Hence, on the one

hand, some researchers opted to investigate the content knowledge and pedagogical knowledge separately and then combine the result as an “integrative model” (Gess-Newsome, 1999, p. 11) of PCK. On the other hand, other researchers used the “transformative model” (p. 12) as depicted in figure 2.4 (a). With the transformative model, PCK is a synthesised construct of knowledge that defines science teachers’ knowledge regarding content knowledge that deals with the pedagogical, curriculum and assessment processes (Schmidt et al., 2009). In other words, transformative PCK is “about pedagogy, students, subject matter and the curriculum gained in formal schooling and practice and beliefs teachers hold about these issues” (Voogt et al., 2012, p. 12). Hence, for the purpose of eliciting views and experiences regarding science teachers’ transformative PCK, the fourth scale in the survey for this study had also adapted the transformative model PCK statements from the TPACK. The PCK items have high correlation and the Cronbach’s alpha for this knowledge domain was 0.85 ((Schmidt et al., 2009). Basically, the responses in scale four are comparatively important to the responses in scale one, two and three for the survey of this study.

Table 3.5

Examples of the Rephrased Statements from the Adapted Surveys

Scales	Statements
OS1	I am confident in using familiar everyday examples to explain scientific concepts.
S1	I am confident in using familiar everyday examples to explain physics concepts.
OS2	In my future teaching, I will use knowledge of students’ preconceptions of a scientific concept.
S2	In my teaching, I use knowledge of learners’ preconceptions of physics concepts.
OS3	In my future science teaching, I will use the knowledge of how scientific theories or principles have been developed.
S3	In my physics teaching, I can use the knowledge of how physics theories or principles have been developed.
OS4	I know how to select effective teaching approaches to guide student thinking and learning in science.
S4	I can choose effective teaching approaches to guide learners thinking process of physics contents.

Note. OS1 = original survey statement in scale 1; S1 = scale 1 in the survey for this study.

In retrospect, the TPACK survey has seven knowledge domains or scales, namely; “technology knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and finally, technological pedagogical content knowledge (TPACK)” (Schmidt et al., 2009, p. 128). In their literature review, Voogt et al. (2012) found that 11 studies have adapted the TPACK framework. For example, Chai, Koh, Tsai and Tan (2011), Koehler and Mishra (2008), as well as Lee and Tsai (2010) had adapted parts of the TPACK framework with similar scales and items. Likewise, the derivations for the transformative PCK items or statements in the fourth scale for the survey of this study were adapted from the transformative PCK statements that were developed in the TPACK survey (Schmidt et al., 2009).

The transformative PCK statements in the TPACK represents its own domain of synthesised knowledge (Voogt et al., 2012). The PCK domain or scale has eight items (statements) that are associated with technology teachers’ knowledge of selecting effective pedagogical and assessment processes to teach and assess content knowledge. Hence, based on the PCK constructs in the TPACK, 10 PCK statements were meticulously constructed for the fourth scale in the survey for this study. In particular, the 10 items for the PCK scale were rephrased with physics concepts as the content knowledge and SBA as an assessment process along with other pedagogical processes such as multiple representations. An example of an adapted PCK statement from the TPACK that had been rephrased as a PCK statement for the fourth scale in the survey for this study is also given in Table 3.5 as OS4 and S4.

The first four scales in the survey for this study had five-point Likert items that were grouped into four Likert scales (Likert, 1932). In fact, the use of Likert items and scales was first developed by Rensis Likert in his paper entitled “A Technique for the Measurement of Attitudes” (Likert, 1932, p. 2). Likert items and scales were developed to measure psychological attitudes in a way that can be interpreted and described with proper statistical figures just like other scientific measurements (Uebersax, 2006). As such, each Likert item had a range of response point scales whereby participants were asked to indicate as their “preference or degree of agreement” (Bertram, 2009, p. 1). Added to that, multiple Likert items which related to each other are grouped into one Likert scale. Consequently, the first four scales had 50 items and were intended to

measure trainee and practising science teachers' perceptions about their knowledge of: teaching physics concepts; learner's understanding of physics concepts; physics content and purpose and PCK.

Unlike the first four scales, the fifth scale in the survey for this study was constructed to capture participants' content knowledge on Newtonian force concepts. Hence, the fifth scale contained four items that were selected from the FCI (Hestenes et al., 1992). The FCI has 29 multiple-choice problems or items that were designed to capture learners' conceptual understanding of the basic Newtonian concepts of forces in comparison to other alternative concepts or misconceptions. The FCI is not a test to examine participant's knowledge about Newtonian force concepts. However, it is an instrument that was developed to elicit participants' beliefs and conceptions about forces (Hestenes et al., 1992). The FCI 29 items cover six areas of force conceptual understanding, namely, "kinematics, Newton's First, Second, and Third Laws, the superposition principle, and types of forces (such as gravitation, friction)" (Persson, 2015, p. 2). Each of the FCI 29 problems have five multiple choice answers. One of the five multiple choice answers is a Newtonian force concept while the other four are distractors. The distractors are commonly known as the misconceptions (Persson, 2015). These are common sense beliefs or concepts about forces constructed from everyday experiences and own reasoning (Hestenes et al., 1992). Basically, the FCI was used to provide a clear picture of the common trends of misconceptions that were found in participants' beliefs and perceptions of force concepts (Martín-Blas, Seidel & Serrano-Fernández, 2010). That said, the survey for this study only included four items from the FCI in its fifth scale.

The four items were specifically selected as a result of the pilot study that was conducted using all of the 29 items in the FCI. The four items were selected within the areas of Newtonian force concepts that were commonly taught in Solomon Islands high school physics syllabus. They were also used in the SBA of physics concepts over the years (see Appendix B for a sample practical work). The four items covered the areas of Newtonian force concepts which included gravitation, Newton's first and third laws, and friction. These four concepts are also part of the physics curriculum at Year 10, 11, 12 and 13 in Solomon Islands. Hence, the four items were selected from the FCI on the basis that they were familiar to both the trainee and practising science

teachers. Added to that, the four Newtonian force conceptual items were selected to capture participants' content knowledge about alternative force concepts in comparison to the Newtonian force concepts. Other studies revised the FCI items in a similar way and also yielded robust results (Saleh, 2011; Savinainen & Scott, 2002). Subsequently, data collated from the FCI were used as a subunit of analysis in comparison with data collated from the first, second, third and fourth scales in the survey.

Administration of the Survey

The fact that this study involved two cohorts of participants as one of the units of analysis, the survey was divided into two similar versions. One version of the survey was administered to the 64 trainee science teacher participants at the SINU while the other version was administered to the 60 practising science teacher participants at the 21 high schools. The two versions of the surveys were identical in structure and construct as described earlier in the subsection on the survey instrument. However, the main difference between the two survey versions included the tenses of the verbs used in the survey Likert items and some of the demographic items. The Likert items for the trainee science teachers were written in future tense while for the practising science teachers, verbs were written in present tense. As well, the demographic items for the trainee science teachers were tailored to capture other relevant information relating to their status as either pre-service or in-service science teachers. Despite the differences in the verb tenses used in the Likert items and some of the demographic items, the construct of the five survey scales were the same. As such, the data captured from the five survey scales were comparable. To further differentiate the two survey versions, they were printed in two different colours. The table of scales and Likert items in the survey for the trainee science teacher participants had alternate rows filled with faded red colour as a background while the one for the practicing science teachers was filled with faded blue colour (see Appendix C1 and C2 for the samples).

There were not sufficient resources available in the local sites to be visited to print the surveys locally. Hence, the surveys were printed in colour at Curtin University, Perth, Western Australia, prior to the actual data collection in Solomon Islands in the fourth week of April, 2015. The researcher transported the printed surveys to the local sites

in Solomon Islands and later brought the completed ones back to Curtin University in Western Australia.

The data collection process started after research permit was granted by the MEHRD. There after other permissions to carry out this study with the SINU and high school science teacher participants were also granted. This initial process took nearly three weeks. Subsequently, the arrangement to administer the survey with the participants were negotiated during the researcher's first visit to the HSD at the SINU and to the Principals of the high schools. A letter containing basic information on the nature of this study with participant's information sheet was hand delivered. In the letter, they were asked to voluntarily invite trainee science teachers in the case of the SINU and practising science teachers in the case of the high schools. Subsequently, the researcher also verbally elaborated on the aims, significance and the nature of the participant's involvement in this study. Based on the arrangements made in the first visit, the survey questionnaires were then distributed in the second visit.

The surveys at the SINU were hand delivered to and administered by the HSD. As arranged in the first visit, the HSD agreed to invite and distribute the surveys to the trainee science teachers after their formal lectures. The HSD was reminded to emphasise and ensure that participants were asked to complete the survey on voluntary basis with their informed consent. Added to that, their willingness to submit a completed survey was emphasised as their informed consent to voluntary participate. Surveys were also hand delivered to the principals of the high schools in the second visit. Similar to the HSD at the SINU, the principals agreed to take the responsibility to invite and administer the survey to their practising science teachers. As such, the administration of the survey was similar to the ones with the SINU. However, some principals just invited their practising science teachers and allowed the researcher to directly administer the surveys.

Basically, brief instructions with examples were written on the survey forms for the participants to read and follow in completing the survey. Besides, the researcher also took time to provide verbal instructions to the HSD, the principals and the participants on how to respond to the survey Likert items. It was emphasized that participants should indicated alongside each Likert item their preference or degree of agreement by encircling one of the five-point scales. It was also emphasized that there was no

wrong or right choices. Therefore, participants' preferences were based on their views and experiences which were relevant to what was stated in the Likert items. As shown in the survey instruments, the statements were worded in a form that sought to seek participants' own views as well as experiences. On the same note, the participants were instructed to choose their preferred choice when answering the four items in the fifth scale containing the Newtonian force concepts problems. Added to that, participants were provided with a blank space at the end of the survey to write what they perceived about the survey.

3.7.4 Collection of Qualitative Data

The generation of qualitative data for this study included one-on-one interviews and a focus group interview. The qualitative data were generated from a smaller number of participants who volunteered from the larger group for the quantitative data. The intention was to collect more detailed and rich descriptions from each participant regarding his or her views and experiences about teaching, learning and assessment of physics concepts in the SBA of practical work (Cohen et al., 2007). In fact, interviewing was a systematic means of collecting qualitative data from talking and listening to participants voices (Hancock, 2002). Additionally, apart from the participants' actual voices, discourses and rationales about their views and experiences, other qualitative data such as the researcher's diary and field notes away from the situation were also collated.

Interviews were conducted for a small group of both trainee and practising science teacher participants. Both cohorts were interviewed using 16 semi-structured interview questions with the same constructs. The only difference was the tense of the verbs used in the semi-structured questions. Like the two versions of the survey, the interview questions for the practising science teachers had present tense (see Appendix C3) and the questions for trainee science teachers were grammatically structured with future tense (see Appendix C4). This format is common in learning environments research, whereby participants can report on actual and ideal perceptions from their socio-cultural contexts (Rickards, 1998). Added to that, the questions in the interview schedules had similar constructs as most of the statements in the survey instruments. As such, the responses from the interviews and the surveys were regarded as

complementary. That is, responses for similar constructed questions were collected from different sources (Yin, 1994).

Semi-Structured Interview

This study used semi-structured interview to generate qualitative data. Semi-structured interview is categorised between unstructured interview and structured interview. For the purpose of this study, the semi-structured interviews utilised prepared open-ended questions that simultaneously provided flexibility for the participants to voice their views while at the same time sets a sense of control and direction for their responses (Burns, 2000; Creswell, 2012). The semi-structured questions were prepared according to pre-guided themes and topics that allowed dynamic feedback, exploration and clarification of responses in real time. Accordingly, the prepared semi-structured questions for this study were guided with themes relating to teaching, learning and assessment of scientific and physics concepts in the SBA of practical work.

The semi-structured interviews were used in this study to explore more deeply into the participants opinions, beliefs, values and emotions that were expressed in words as well as, with body signals or gestures (DiCicco-Bloom & Crabtree, 2006). In fact, “interview is a flexible tool for data collection, enabling multi-sensory channels to be used: verbal, non-verbal, spoken and heard...and not simply concerned with collecting data about life: it is part of life itself, its human embeddedness is inescapable” (Cohen, et al., 2008, p. 349). The semi-structured interviews were conducted in a way that made the interview process conversational but also purposeful (Villasenor & Etkina, 2007). This was both culturally and academically appropriate in Solomon Islands context. The semi-structured interview was conducted as a “social interpersonal encounter and not merely a data collection exercise” (Cohen, et al., 2008, p. 361). As such, the researcher gradually built a rapport to gain the participant’s trust and confidence. For this study, rapport was built with asking preliminary questions about participants’ brief background, for example, questions about how long the practising science teacher participants have been teaching science in high schools.

While the semi-structured open-ended questions were prepared according to pre-guided themes the order of when the questions were asked was dependent on the researcher and the interviewee’s responses. The pre-guided themes were used as a

guide to explore the participants' views and opinions in detail during the purposeful conversation (Burns, 1994, 2000). At times, the participants found the questions difficult so they just provided a brief response. In such instances, the researcher had provided cues or prompts to encourage the participants to further consider the question and provided more appropriate details. With semi-structured interviews, the researcher also had the flexibility to ask other probing questions to elicit more information relevant to the guided themes (Hancock, 2002). In contrast, sometimes the participants' responses to one open-ended questions did go astray or deviated from the scope of the guided themes. In such situation, the researcher made decisions on what question to ask next and when to ask it, so that the conversation continued to flow within the scope of the guided themes.

The semi-structured open-ended questions were also asked in different orders and not necessarily with the exact wordings for different participants (Burn, 1994). Hence, with the semi-structured interviews, the researcher had some control to smoothly redirect conversation as well as to probe deeper in capturing richer descriptions, explanations and interpretations from the participants. For this study, probing involved the asking of follow-up questions in order to fully understand a response, especially when responses were vague and more specific as well as in-depth information was required. The probing questions were not always planned and at most times active listening and probes such as silence, reasonable eye contact and use of statements such 'can you tell me more' were employed (Creswell, 2012). Basically, the semi-structured interview had provided flexibility for the researcher to tap into the limits of the participants' views and experiences about teaching, learning and assessment of scientific and physics concepts in the SBA of practical work.

For the purpose of this study, the strengths and weaknesses of semi-structured interview were also taken in into consideration when qualitative data were elicited from both trainee and practising science teacher participants. In this regard, Table 3.6 presents a brief summary of the strengths and weaknesses of semi-structure interview. Subsequently, this study had conducted one-on-one semi-structured interviews with practising science teacher participants while a focus group interview was conducted for trainee science teacher participants.

Table 3.6

A Brief Summary of Advantages and Limitations of Semi-Structured Interviews

Advantages	Limitations
Researcher can develop a positive rapport with interviewees in a simple and inter-subjective relationship.	The outcome of conversation depends on researchers' skills and ability as well as, the interviewee's articulacy.
Data validity is high because good rapport can result in eliciting rich and in-depth responses.	One-on-one interview processes can be time consuming and expensive.
Provide multi-sensory channels such that both participants' views and emotions can be expressed and captured.	Researcher's unconscious body languages can interfere with interviewees' responses. Vice versa, interviewee's body signals can be misinterpreted by the researcher.
Complex questions or issues can be clarified and simplified using language familiar to interviewees.	Validity is questionable when participants can change their views after reflection. There is no way of knowing whether it is genuine or not.
Management of confidential and sensitive issues can be negotiated.	Not very reliable since consistency can be difficult with different interviews with different participants.
Researcher can easily record conversations on audio or videos tapes with the interviewees' consent.	Conversations with the same participant cannot be repeated with exact responses if reliability is valued.

Note. Advantages and limitations are summarised from Burns (1994), Cohen et al. (2008) and Creswell (2012).

One-on-One Interviews

In response to the invitation for the one-on-one interviews, seven out of the 60 practising science teacher participants who submitted their surveys volunteered to be interviewed with informed consents. The interviews took place from May to June 2015 in Honiara, Solomon Islands. The times for each of the interviews was prearranged on an individual basis after the seven participants indicated their willingness and informed consent to be interviewed. The times for interview were prearranged such that participant's official duties were not disturbed. Accordingly, most of the interviews were conducted after the participants' formal classes were over for the day. On average, the individual interviews took approximately 40 to 60 minutes. In addition,

each interview was also prearranged to be conducted at a place that was natural as well as familiar and safe for each participant (Brinkmann & Kvale, 2014). For example, some practising science teacher participants chose to be interviewed in their high school's science laboratory while others preferred their own or other classrooms in their schools. The environments and times were conducive for the participants to feel at ease and engage more freely in developing a rapport and conversation with the researcher (Creswell, 2012).

The interview questions for the one-on-one interviews were printed on a single sided A4 sheet of paper (see Appendix C3 for interview questions). The printed interview questions and an informed consent form were issued to the participants who were willing to be interviewed prior to their actual interview conversations. Most of the participants used the printed sheet of interview questions to prepare their thinking by writing some brief answers for the actual interviews. The researcher was flexible in giving each participant a chance to negotiate a length of time that would suit their availability as well as allowing for them to prepare for their prearranged interview items. As such, one-on-one interviews for each of the practising science teacher participants were held at different times and in different weeks. For instance, two participants were interviewed a week after the first visit while another two were interviewed after two weeks. It took a couple more visits within three weeks after the first visit to negotiate and set times for the one-on-one interviews for the last three practising science teacher participants. However, given the printed interview questions, the three participants eventually decided to provide written responses instead of verbal.

In Solomon Islands context, it is not common to look straight into someone's eyes while conversing since it is seen as disrespectful. As such, the one-on-one interviews for this study were conducted side-by-side instead of face-to-face. The interviews were also flexible such that most of the participants had their printed interview question sheet in front of them. Added to that, the participants were given the flexibility to write down their views or likely answers on their interview question sheet. Hence, most of the participants wrote English sentences as their answers on their interview question sheets. However, while the official language of instruction in Solomon Islands is English, the language used during the interview conversations was mainly Pidgin. This

was the main medium of communication with the participants. Pidgin is the national vernacular of Solomon Islands. Other Melanesian Countries like Vanuatu and Papua New Guinea also have a similar national vernacular. Pidgin is also known as broken English. In using Pidgin, the participants were able to articulate their responses and clearly express their views and experiences.

During the conversation, the researcher (A Solomon Islander and native Pidgin speaker) had to rephrase and simultaneously translate the questions into Pidgin as well. As such, the researcher asked the open-ended questions in English and then rephrased the same question in Pidgin. In response, while a couple of participants straight away answer the questions in Pidgin, others did repeat the open-ended questions and then rephrased them again as well for themselves. The researcher assumed that in repeating and rephrasing the open-ended questions while at same time glancing over their pre-written answers, the participants were basically reorganising their thoughts and ideas in preparation to articulate their responses verbally. Some of the participants seemed confident and were articulating their responses at length while other participants were anxious whether they had answered the open-ended questions correctly or not. Those participants continually seek assurance from the researcher on whether they had fully answered the questions or they had missed some important aspects. Such participants were concerned with providing correct responses. However, during the conversations, the researcher continuously reemphasised that there were no right or wrong answers. Instead it was their personal views and experiences with regards to what the questions asked that was important. Further to that, the researcher ensured that participants' everyday vernacular was dominantly used during the conversation.

To minimise repetition and boredom, the researcher was also reflexive to skip some open-ended questions that had be answered when participants responded to other open-ended questions. In other instances where participants' responses were not properly articulated or were not within the scope of the guided themes, other probing questions were asked by the researcher. The probing questions gave a sense of direction as well as, prompted the participants to articulate more details. Added to that, the researcher also provided minimal forms of scaffolding for terms and scientific concepts. For example, some participants tried to express their views and opinions using scientific terms and concepts but had some difficulty in articulating. In such instances, the

researcher provided cues or related words and ideas that helped the participants to reconstruct their own thoughts and expressed their views. By doing so, participants were able to provide richer descriptions and explanations. However, in the process, the researcher was also reflexive to the nature of the social interpersonal interaction such that the researcher avoided the likelihood of dictating the conversation. As well, the researcher continuously monitored and ensured that the participants were not coerced or intimidated.

Focus Group Interview

This study used “focus group interview” (Creswell, 2012, p. 218) to generate the qualitative data for the trainee science teacher participants’ views and experiences about teaching, learning and assessment of science and physics concepts in the SBA of practical work. Out of the 64 trainee science teacher participants at the SINU who submitted their completed survey forms, seven voluntarily took part in the focus group interview for this study. In fact, participants were invited on the basis that they have had views and experiences related to the SBA of physics concepts. Added to that, focus group interview was convenient for the SINU participants because the time for this study’s field trip was coming towards the end. Besides, it was easier to make arrangements with the seven trainee science teacher participants as a group after all their formal lectures were over and they were preparing for their end of semester one exams.

The trainee science teacher participants expressed their willingness and confidence to share their views as well as discuss interactively as a group. Within a focus group interview, the participants were able to share their views in response and in addition to the contribution of others during the group interaction (Cameron, 2005). The shared discussion and interaction was the main aspect of the focus group interview for this study. In essence, “focus groups can be used to collect shared understanding from several individuals as well as to get views from specific people” (Creswell, 2012). First documented in 1926 (Bogardus, 1926), focus group interview was recognised as a method to gather narratives from moderated discussions and interactions between six to 10 individuals within a group (Creswell, 2012).

The researcher was the moderator who introduced the issue or asked the questions to be discussed or answered. Then, as the moderator the researcher invited as well as moderated the discussion and interaction between the individuals in the focus group (Cameron, 2005). Furthermore, various types of questions from structured to unstructured questions were also used in the focus group interview (Cameron, 2005; Creswell, 2012). As discussed earlier, this study used semi-structured interview questions similar to the ones used for the one-on-one interviews for the practising science teacher participants. Likewise, the researcher also provided the printed semi-structured interview questions to each participant prior to the focus group interview.

The researcher proceeded on by providing an overview of the study and its purpose. Followed with a description about the nature of the focus group interviews as well as reemphasizing the role and rights of the participants. It was also stressed that the focus group interview was flexible for the participants to share and discuss their views and experiences with respect to the topics of discussion. Hence, participants were reminded that there were no right or wrong answers. They were encouraged to take heed of each other's views and experiences then reflect and articulate whether they agree or disagree with each other's views during the discussion. That said, one of the purposes of this study was to collect shared views and understanding about the SBA of physics concepts. As such, all participants were encouraged to share and to take their turns, one at a time talking in any order.

The researcher facilitated and moderated the focus group interview by further asking the first open-ended question in pidgin. From this point onwards, participants were asked to take their turns to respond to the open-ended questions. In that way, the researcher was able to write down alongside each of the participants' names the order of who was talking. The discussion of the topics flowed as each participant took turn to respond and contributed by agreeing or disagreeing while at the same time added somewhat different or similar views. Most participants shared their views on every topics and questions for discussion. Besides, some participants talked more and some talked less. As the moderator, the researcher continuously monitored the responses and subsequently decided on when and how to provide probes and cues. Mainly to elicit further clarifications and deeper explanations or to redirect the discussion towards the guided themes of the prepared open-ended questions. Not all open-ended questions

were asked during the focus group interview. Most times, the responses for the earlier open-ended questions also covered the guided themes for the later open-ended questions.

Although, it was a constant challenge to facilitate and moderate the focus group interview the actual voices and views of the participants were elicited and audio recorded. The focus group interview took one hour and thirty minutes and it used two full 45 minutes audio cassettes for recording the actual spoken words during the discussion.

3.7.5 Data Recording

This study employed mixed methods research design involving both quantitative and qualitative data. These two types of data were recorded differently but systematically in a way that both data were securely kept and easily retrieved for analysis by the researcher.

For the quantitative data a survey was used (see subsection 3.7.3). The survey was printed on an A3 paper that was folded in half, comprising four pages. Participants indicated their views to the survey items by writing their responses on the survey forms. The completed survey forms were collected and filed in groups according to the 21 high schools and the SINU. The files were then securely kept in a box at the researcher's accommodation while the researcher continued to collect other data for this study. The researcher used some of the completed survey forms to make initial analysis from participants' responses. Basically, to identify particular responses and trends that the researcher used as a basis to probe and further elicit qualitative explanation, description and interpretation during one-on-one interviews. The completed survey forms were safely stored with the researcher until he physically transported them from Honiara in Solomon Islands, back to Perth in Western Australia for further analysis.

The qualitative data were generated from participants' responses during one-on-one interviews and a focus group interview. As such, an audiotape recorder and blank 45 minutes cassettes were used to capture the actual spoken words of the participants during the interview process (Patton, 2002). The interviewed participants were made

aware of the audio recordings as well as, their rights of privacy and the nature of their involvement. With informed consents the recording was conducted in a way that participant's discomfort was minimized and cultural norms considered. While some participants did not bother and did not take much notice about the recording devices, some occasionally asked whether the recording was going on fine or the cassette was about to be full or the cassette needed to be changed. The researcher at all times consistently monitored the audiotaped recording mainly to see whether the cassette was nearly completed or needed to be changed. The researcher did provide signals and let the participants to know in advance that there was a need to change the cassette and that the conversation was going to be paused for a while.

While the one-on-one interview audiotape recordings were easily recorded, the audiotape recording for the focus group interview was a challenge and had one major limitation. In particular, the two classroom tables used for the participants to sit around were long narrow rectangular tables. As such, when the tables were placed next to each other at the long sides, the combined ends of the shorter sides were still short than the longer sides. So even though the researcher consciously placed the audiotape recorder at the centre of the two tables, the participants who sat at the two ends were still sitting further away from the audiotape recorder. As a result, during the focus group discussion the audiotape recorder did not clearly record some of the actual words spoken by the participants who sat further away at the two ends. Nevertheless, the focus group interview was successful so as the one-on-one interviews.

The audiotape cassettes were coded and labelled accordingly to match with each of the respondents and focus group interview. The researcher safely kept the used cassettes in a secured bag during the field then later carried them from Honiara, Solomon Islands back to Perth, Western Australia for transcribing and analysis.

3.7.6 Diary and Field Notes

To further explore and understand the quantitative and qualitative data, the researcher also gathered other qualitative information using researcher's diary and reflective field notes that were written away from the situation. These field notes were also collected as qualitative data. Basically, the researcher wrote the diary as a log book to record the dates, times and other personal views relating to the process of data collection. In

addition, the reflective field notes were the researcher's perceptions from personal observations and reflections with regards to behavioural and affective cues from the participants and other relevant facts that had defined and described specific situations and backgrounds of their responses. Field notes were also used to qualitatively capture a description of physical, sociocultural and emotional environment that to some extent influenced the context of the participants' livelihood and perceptions. These additional qualitative information were used to help understand, interpret and make meaning alongside the data analysis, especially when answering the research questions for this study.

3.8 Data Analysis

While the quantitative data and qualitative data were analysed separately using different processes, their results were complementary. These two process are described next, starting with quantitative data analysis followed by qualitative data analysis.

3.8.1 Quantitative Data Analysis

The quantitative data for this study were generated from 124 completed survey forms that comprised 60 survey forms from practising science teacher participants and 64 from trainee science teacher participants. The initial step for the quantitative data analysis was to organise and code the responses from both sets of the surveys. To do so, a system of "scoring data" (Creswell, 2012, p. 175) was identified. That means, one common numerical score or value was assigned to each similar response or item on both of the surveys. Apart from the slight difference for the background demographic items of the two surveys, the first four Likert scales and the fifth scale were identical. As described in subsection 3.7.3 (the survey instrument), the five-point response scales for the Likert items had preassigned numerical values. That is, 1 = strongly disagree (SD), 2 = disagree (D), 3 = uncertain (UN), 4 = agree (A) and 5 = strongly agree (SA). Other demographic variables were also assigned with codes of different numerical values. For example, the two variables for gender were assigned, 1= male and 2 = female.

The response data from both sets of the surveys were manually typed and tabulated using Microsoft Excel spreadsheet as a master data set. The response data were first entered as variables for the demographic items and numerical values for the Likert items. As a master data set, the variable and item headings were typed at the top of each columns. Then each participant's responses were typed across in one row under each appropriate column heading. After the initial entry the variables and values for the items were crossed checked again by the researcher for any items that was not yet typed into the master data set. Then the researcher checked the master data grid in the Microsoft Excel spreadsheet for any missing item as part of cleaning the response data.

The actual assigning of codes and scores for the rest of the variables were done in the master data set. As such, most of the actual responses transferred into the Microsoft Excel spreadsheet were replaced with their codes and scores before the data set was further cleaned. The process of cleaning the data involved the thorough search for missing values (Creswell, 2012). From this point, the researcher manually inspect the values in the master data grid to spot gaps for missing values. Most of the missing values that were found in the Likert items were also missing in the original response in the survey form. As such, the researcher decided to type in the value three (3 = uncertain) in place of the missing values in the Likert items (Rickards, 1998). The data cleaning process for the quantitative data was painstakingly carried out by the researcher.

Later the cleaned master data set in the Microsoft Excel spreadsheet was imported into the Statistical Package for the Social Science (SPSS) software for more statistical and graphical analysis (Pallant, 2013). Initially, the quantitative data were analysed mainly for the frequencies of responses for each of the five scales for the whole sample. This analysis provided information with regards to the number of responses for each item within each of the scales (Creswell, 2012). Then, Cronbach's Alpha reliabilities were also calculated for the first four scales to identify the internal consistencies of the responses to each scale. This analysis was significant to determine the general trends of responses with respect to the scale themes. Accordingly, higher values of Cronbach's Alpha reliability indicates that the majority of items were related in construct and concept as well as, it can be inferred that the majority of respondents responded in a similar way for many of the items in one scale (Cohen et al., 2007).

Basically, Cronbach's Alpha reliability values greater than 0.90 are very highly reliable while values between 0.80 and 0.90 are highly reliable, values between 0.70 and 0.79 are reliable, and values between 0.60 and 0.69 are marginally reliable and are acceptable for an exploratory study as this present study (Cohen et al., 2007; Tavakol & Dennick, 2011).

Subsequently, Corrected Item-Total Correlation and Cronbach's Alpha If Item Deleted were also calculated for each item within each of the first four scales. The Corrected Item-Total Correlation analysis was conducted to identify items that were highly or least correlated with other items in each of the first four scales. A value closer to one indicated how close one item is correlated to other items in the same scale while a value close to zero indicated the opposite (Streiner, 2003). The 'Cronbach's Alpha If Item Deleted' indicated how one item would affect the scales Cronbach's Alpha reliability if it was deleted from the scale. Hence, if an item with low correlation was deleted, the Cronbach's Alpha reliability for the scale would increase. The opposite would happen if an item with high correlation value was deleted. This was significant to assess the correlation of responses to the items in scale one as well as, to make inferences on how participants might have responded to each individual item. It was determined that Item – Total Correlation from 0.40 to 1 was significant (Cohen et al., 2007). The results for these additional quantitative analysis were tabulated and are attached in Appendix H. Besides, factor analysis for the first four scales as well as mean score for each of the five scales were tabulated and are attached in Appendix I.

According to research design of this study, the quantitative data were collected and analysed separately from the qualitative data. Hence, the quantitative findings for this study are reported in chapter four of this thesis, separate from the qualitative findings.

3.8.2 Qualitative Data Analysis

The qualitative data for this study were captured using semi-structured interviews with seven practising science teacher participants on one-on-one interviews and a focus group interview with seven trainee science teacher participants. Both interview procedures used a similar set of questions. Hence, a similar process was used to analyse their qualitative data. The process of generating qualitative data from semi-structured interview responses that were recorded on audiotape cassettes was so crucial in

complementing the quantitative data for this study. As such, it was imperative to process the recorded spoken words into a form that can be easily and reliably analysed and synthesised but at the same retained the depth, richness, meanings and interpretations of the participants (Atkins, 1984; Goodson & Choi, 2008).

The qualitative data from the interviews for this study were analysed within the thematic analysis framework (Braun & Clarke, 2006). While thematic analysis is not as well demarcated as grounded theory and content analysis, it has been widely used to analyse qualitative data. According to Braun and Clarke (2006), thematic analysis is flexible, less complex and is used mainly to identify, analyse and report patterns or themes within the qualitative data. In fact, “rigorous thematic approach can produce an insightful analysis that answers particular research questions” (Braun & Clarke, 2006, p. 97). Added to that, by using thematic analysis, the qualitative data for this study were analysed within two perspectives. From an inductive perspective based on recursive and progressive coding of the interview responses as well as from the research questions perspective by checking consistency of information with regards to the pre-guided themes.

For this study the qualitative data analysis started with the painstaking process of translating and transcribing the audio recorded interviews followed by the rigorous process of organising the key themes.

Translating and Transcribing

Following the tenets of analysing the qualitative data from semi-structured interviews, the audiotaped responses were initially transcribed (Creswell, 2012; Draper, 2004). The process of transcribing the participants’ actual spoken words from audio cassette recordings into text form was not a simple task. Nevertheless, the researcher used a transcribing machine that made it possible for the recorded conversations to be transcribed into texts. The transcribing machine had a foot paddle that was used to pause, play and replay, rewind and forward recordings while the researcher listened, translated then transcribed into texts using a computer. Added to that, the transcribing machine enabled the researcher to decrease or increase the playing speed as well as the tone of the sound in order to capture words or phrases that were difficult to hear as well as determine with the normal speed and tone.

The transcribing process for the one-on-one interviews for the practising science teacher participants were done on an individual basis. The researcher played and listened to the audio recorded conversation then translated and transcribed them into text forms. The actual participants' spoken words in Pidgin were painstakingly translated and transcribed into English texts. This was possible because the researcher as the interviewer also speaks and writes Pidgin fluently. It was difficult to capture the spoken words in Pidgin then translating into English while transcribing because "of the sentence structure, use of quotations, omissions and mistaking words or phrases for others" (DiCicco-Bloom & Crabtree, 2006, p. 2006). However, with the versatile fixtures of the transcribing machine, the researcher was able to capture, translate and type the pidgin responses into English texts using Microsoft Word for each participant. The texts were typed in the order they were recorded during the interview conversations. Subsequently, the researcher silently and attentively read and re-read the written texts while at the same listened to the spoken words which were repeatedly replayed in order for the researcher to cross check and verify the translation, the meaning and the interpretations of the responses.

A similar transcribing process was conducted for the focus group interview for the seven trainee science teacher participants. However, the transcribing process was done as a whole document for the recorded focus group discussion. The researcher was able to transcribe the recorded conversation as well as identified the participant's voices by using the written list of names which had numbers indicating the order of the speakers during the recording. Similar to the transcribing process for one-on-one interviews, the researcher listened to the recorded spoken words in Pidgin then translate and transcribe into written texts in a Microsoft word document. Again, the process of cross checking and verifying the written text with the recorded spoken words were painstakingly undertaken. Not only for translation and interpretation purposes but also to validate the accuracy of matching participants' voices with what they said according to the written list of names and the order they contributed during the actual audiotaped conversation.

To further verify and validate the translations, interpretations and meanings from Pidgin to English, another Solomon Islander living and studying at Curtin University was asked to repeatedly listen to the recordings while reading through the transcripts.

This other individual Solomon Islander provided independent verifications and validation that was not bias to the researchers own interpretations and meanings (Strauss & Corbin, 1998). As such, further correction were made with respect to the independent feedback. Finally, like the one-on-one interview, the focus group individual participant's transcripts were separated into each Microsoft word documents. The individual transcripts were printed and were airmailed to each participants that the transcripts belongs to. The participants were requested to further verify and validate their own spoken words, interpretations and meanings and send their responses by email or airmail to the researcher at the Curtin University. Subsequently, the second stage was to organise the verified responses in the transcript into pre-guided themes and emerging themes.

Organisation of Themes

The organisation of themes for this study was guided by the thematic analysis approach which provided a flexible process of identifying themes from the qualitative data presented in the transcripts. With a rigorous thematic analysis, pre-guided themes and emerging themes were insightfully identified at the semantic level with relevant words, phrases and concepts pertaining to the research questions (Braun & Clarke, 2006). This process of organising themes from the heavily argumentative and interpretative qualitative data was highly recursive and reflexive (Cohen et al., 2007). In addition, although hard-to-classify themes and major or minor themes may have presented vital semantics and concepts, classifying them were not simple (Creswell, 2012). Hence, for this study, given the intricate nature of organising different types of themes, the researcher manually evaluated the transcripts using personal reflections and perceptions to initially organise the different themes into pre-guided themes followed by the emerging themes. The pre-guided themes had preassigned words, phrases and concepts within the semi-structured interview questions while the emerging themes were identified from phrases, semantics and concepts that were related to the pre-guided themes as well as the research questions. For example, one pre-guided theme is the 'importance of science education' and one emerging theme is 'develop the ability to solve problems'.

The initial individual transcripts were typed according to the order in which the actual individual interviews as well as focus group interview were conducted. As such, each

transcript was transcribed according to the pre-guided themes that were asked in the semi-structured interview questions. Later, all the responses from each transcript were copied and pasted into a new Microsoft document as a master data file. Each responses were copied and pasted into one group under the pre-guided themes in the master data file. As such, all responses to semi-structured interview question one were grouped under question one as an initial analysis for pre-guided theme one. The responses were pasted with the name of the respondent who the response belongs to. The same process was done for the other semi-structured interview questions. In doing this, the master data file contained all the qualitative responses that were grouped under each pre-guided theme as preassigned with the semantics and concepts in the semi-structured interview questions.

The qualitative data analysis was carried out by creating for each theme a new Microsoft Word document that only contained the responses to one pre-guided theme. This process was done to lessen the burden of identifying emerging themes from within a very large Microsoft Word document. For example, one file contained all of the responses to semi-structured interview question one, another contained all the responses to question two. Hence, names with responding responses were copied and pasted accordingly from the master data file to each new pre-guided theme in separate Microsoft Word files.

Further evaluation and identification of emerging themes were conducted recursively. While electronic means were available, the researcher decided to print hard copies of each Microsoft word file for each pre-guided theme for further thematic analysis. For example, the Microsoft Word file containing the responses to the pre-guided theme on 'the importance of science' asked in question one was printed. Similarly, other Microsoft Word files for other pre-guided themes were printed. From then on, the researcher manually used different coloured pens and codes to identify and thematically analysed similar and slightly different or contrasting ideas or comments that were presented in different Microsoft Word file under different pre-guided themes. The researcher used personal reflections and perceptions to recursively go through the different printed pre-guided themes to manually identify similar semantics and concepts as well as other significant views that emerged under the pre-guided theme transcripts.

Thereafter, the researcher used the electronic Microsoft word files to update the coloured or highlighted quotes and coded ideas. As such, the participant's responses or quotes that had similar themes were grouped together under an emerging theme in a new Microsoft word file. At this stage, only the relevant quotes or responses that indicated the similar emerging themes were copied and pasted with the names of the participants that the quote belongs to. This Word file was then read and reread as well as recursively evaluated to reaffirm the semantics and concepts of the participants quotes under the emerging themes. The emerging themes were then reworded according to the explanation or the construct of the ideas that were presented in the quotes (Cohen et al., 2007). This process was done to name the emerging themes appropriately according to the participants' own expressed words and phrases. As such, the qualitative data analysis for this study was specific for this study. In addition, pseudonyms for participants were used alongside the quotes instead of the participants' real names. Basically, the pre-guided themes and emerging themes were identified to generate appropriate qualitative data analysis that constituted the answers to the research questions. This involved the process of revisiting the research questions and identifying the different types of themes and responses that can be integrated and collated to answer the research questions.

The final qualitative analysis encompassed the process of collating and organising the pre-guided themes and emerging themes with their respective responses or quotes into a chronological order that progressively provided the answers to the research questions for this study. Subsequently, third person narratives using qualitative data from the researcher's written field notes, diary and demographic information were also interwoven into the qualitative analysis. The researcher's third person narratives provided rich descriptions and interpretations to help make sociocultural and contextual inferences from the participants' quotes. The results of this qualitative data analysis process are reported separately as qualitative findings in Chapter Five of this thesis.

3.9 Ensuring Validity and Reliability

This study employed a triangulation mixed methods approach that generated both the quantitative and qualitative data. This approach was favoured since the weaknesses of

one data set are complemented by the strengths of the other data set (Creswell, 2012). However, ensuring validity and reliability of the integrated data was complex and cumbersome. The literature has described many different concepts and terms of validity and reliability that have been used separately for quantitative and qualitative data (Cohen et al., 2007; Lincoln & Guba, 1985; Maxwell, 1992). As such, when integrating quantitative and qualitative data, Onwuegbuzie and Johnson (2006) argued that the use of bilingual nomenclature is appropriate. They recommended that the use of the term “legitimation” (p. 48) is more appropriate than the terms validity and reliability. For the purpose of this study, the concepts of validity and trustworthiness were used to enhance the quality of the quantitative and qualitative data for this study.

3.9.1 Validity

The validity of this study was maximised in order to generate what it intended to generate (Burns, 2000). While there are many different concepts of validity used for quantitative and qualitative methods, this study ensured that the construct validity and cultural validity were maximised.

Construct Validity

Based on its theoretical framework, this study integrated key research areas into a coherent conceptual framework that premised to enhance science teachers’ PCK for use in the SBA of practical work. As such, the construct validity for this study involved the process whereby the concepts and key ideas in the conceptual framework were well translated or transformed into the construct of the items in the instruments used for data collection (Cohen et al., 2007; Drost, 2011). Underpinned by both the quantitative and qualitative methods, construct validity for both – the survey instrument and the semi-structured interviews were examined and validated for the notion of fitness for purpose (Cohen et al., 2007). Subsequently, in order to substantiate the construct validity for the two instruments, a process involving face validity, content validity and convergent validity were employed for this study (Trochim & Donnelly, 2008).

Initially, face validity was used to examine how well the abstract concepts and ideas were translated into the instruments used and whether participants were able to respond

to the items in ways that were intended (Drost, 2011). This involved seeking the opinions from likely participants (Munby, 1997). Therefore, the researcher asked five other Solomon Islands students who were familiar with the SBA of physics concepts and were studying at Curtin University to provide their responses to the survey items and interview questions. Their responses were assessed to substantiate the fitness for purpose. That is, whether they responded in ways that were expected according to the constructs. The face validity was a weak form of construct validity (Drost, 2011).

Subsequently, content validity was also used to assess whether the content of the instruments comprehensively covered the domains they purported to cover (Cohen et al., 2007). That is, to test whether the content domain of the items were theoretically sound and were actually represented in the constructs themselves. This involved seeking the judgements of five other doctoral colleagues and research experts at the STEM Education Research Group at Curtin University. In addition, convergent validity was used to examine whether the survey items in a specific scale were similar to other items of the same scale (Drost, 2011). The purpose was to construct a multiscale survey that can provide a means to determine whether items within the same scale were tapping into the same construct. As well, to check whether each scale was assessing a distinct construct from the other scales in the survey. Similarly, the open-ended questions for the semi-structured interview were constructed with distinct guided themes.

Cultural Validity

Apart from the construct validity one significant research validity that is generally ignored is cultural validity (Jadhav, 2009). As such, this study ensured that cultural validity was not ignored, but instead was a key inclusion. While the validity of an instrument ensures that it is actually measuring what it intended to measure, “cultural validity extends to contextualise validity within the specific community being studied” (Jadhav, 2009, p. 92). It involves the researcher, being sensitive to the cultural values of the participants. “This could include:...identifying and understanding salient terms as used in the target culture;...checking interpretations and translations of data with native speakers; and being aware of one’s own cultural filters as a researcher” (Morgan, 2005, p. 1). Additionally, cultural validity ensures that the researcher is the appropriate person to conduct the research and appropriate participants are selected as

well as, information is translated through culturally appropriate means (Joy, 2003). As such, cultural validity ensures that what is measured is culturally appropriate and adds value to the authenticity and truthfulness of the study.

Being a Solomon Islander, the researcher was not alien to the sociocultural context of this study as well as to the participants. The researcher was aware and sensitive to the participants' circumstances as well as their sociocultural and geopolitical environments (Cohen et al., 2007). That said, the researcher did not occupy a position of influence or status within the sample population, and was well accepted by participants. The sensitivity to the sociocultural context of this study was crucial for its success. It was a way of showing respect and understanding. The participants felt at ease in the comfort of their own lived environments, when they related and identified strongly to researcher. In this environment, the participants were able to freely express their views and experiences with regards to the phenomenon investigated. As a result, the researcher was able develop a better rapport and delve deeper to seek meanings and interpretations in the context. Added to that, the participants were able to relate and make sense of their lives and understand their own experiences (Bishop, 1997).

The researcher being a Solomon Islander was also a bonus. The researcher was also able to translate information in a way that was socially and culturally appropriate to the participants as well as the other gatekeepers. As such, the researcher was able to effectively communicate, co-construct meaning and interpretations as well as analyse and develop inferences from participants' data that were collected in this study. Consequently, the cultural validity of this study ensured that data collected was contextually and socio-culturally appropriate.

3.9.2 Trustworthiness

While trustworthiness is a term used mainly in qualitative research (Guba, 1981), it has the same concept as validity and reliability in quantitative research (Golafshani, 2003). The constructs of trustworthiness in qualitative research are comparable to the quality criteria in quantitative research (Lincoln & Guba, 1985; Shenton, 2004). That is, credibility in qualitative research is comparable to internal validity in quantitative research. Similarly, transferability is comparable to external validity; dependability is comparable to reliability, and confirmability is comparable to objectivity (Shenton,

2004). Actually, trustworthiness ensures that a researcher presents a convincing case that demonstrated “something or someone may be trusted or relied upon to be true” (Bell & Cowie, 1996, p. 11). Over the years both qualitative and quantitative researchers seek to ensure that their research was trustworthy (Guba, 1981; Shenton, 2004). In saying that, the trustworthiness of this study was ensured by addressing the provisions that are outlined next.

The researcher was familiar with the phenomenon investigated as well as the sociocultural context of the participants. So the researcher was in a better position to construct contextual and conceptual interpretations of the participants’ own and multiple constructs. As such, the researcher had confidence to maximise the credibility (internal validity) of the data generated.

The researcher used different forms of triangulation (Cohen et al., 2007; Shenton, 2004). One form of triangulation was the use of different methods such as, surveys, one-on-one interviews and focus group interview. The data from the different sources were triangulated to strengthen the results for this study. In addition, based on the assumption that participant’s views and experiences were subjective, another form of triangulation involved the random selection of participants from several high schools within different contexts as multiple cases (Guba, 1981, Merriam, 1998). Consequently, data were generated from multiple constructions of views and experiences from different contexts. The multiple constructions of views had provided a rich and credible data that can be transferable (external validity) to similar, but diverse cases and or contexts.

The researcher sought the assistance of an independent Solomon Islander in Perth, Western Australia who fluently speaks and writes both Pidgin and English to cross validate the data generated from audio recordings. That involved repeated listening to the recorded interviews in Pidgin while reading the written transcripts in English. By doing that, back translations as well as verification of meanings to the actual spoken words were simultaneously validated. Such process ensured that the data generated was the result of the views and experiences of the participants and not of the researcher (Miles & Huberman, 1994). The researcher used this provision to enhance the confirmability (objectivity) of the generated data.

The researcher airmailed each interview participant their written transcripts for verification and validation purposes. While most interviewed participants indicated that it was not a concern for them to verify the data they provided, the researcher still ensured that trust was established with the participants.

Finally, this study is trustworthy since the researcher has provided a detailed description of the research design and implementation process as well as the result. With such a detail, other future researchers can use the information from this study as a “prototype model” (Shenton, 2004, p. 71). Consequently, future researchers can maximised the dependability (reliability) of the information provided in this present study (Lincoln & Guba, 1985; Shenton, 2004).

3.10 Moral and Ethical Concerns

Moral and ethical concerns were important since this study involved human participants and it used semi-structured interviews that directly explored the views and experiences of the participants’ lives (DiCicco-Bloom & Crabtree, 2006). Hence, even though this study had prior Ethics Approval from the Human Research Ethics Committee of Curtin University (see Appendix D1), there were a number of moral and ethical concerns that were stringently considered before commencing as well as during the process of this study. One key aim was for the researcher to apply at least the same ethical standards that are required in Australia, but in addition add a layer of local participation and engagement with the process to provide local authenticity and consent. Additionally, the moral and ethical considerations were imperative to minimise any negative impact affecting the participants as well as the data collected. The moral and ethical consideration for this study are described next.

3.10.1 Permission and Participant Information

The data generated for this study involved participants from the SINU and 21 high schools in Solomon Islands. Hence, appropriate permissions were sought, in order, from the Ministry of Education and Human Resources Development (MEHRD), education authorities, the SINU, high schools, and the participants themselves. This was in accordance with the Ethics approval from Curtin University and the Ministry of Education Research Act 1982 of the Solomon Islands. When seeking permission,

the research proposal which included the ethics approval, proposed dates for its start and completion, study aims and benefits, research design and details on how the results would be used, was provided. Added to that, sample forms including letters, informed consent forms and survey instruments were submitted for approval (see Appendix E for letters seeking permission for this study).

After permissions were granted, participant information and informed consent forms were provided to the participants through the school principals. The researcher also provided verbal information when the written information was hand delivered to the principals and the participants. Participants were reminded that their involvement in this study was on voluntary basis with their informed consent (see Appendix F1 for participant's information sheet and Appendix F2 for informed consent form). It was made clear to all participants that they could withdraw at any time without prejudice. Particularly, the participants who voluntarily involved in the one-on-one interviews and the focus group interview.

3.10.2 Privacy and Confidentiality

Privacy and confidentiality of the participants and the data that they provided for this study were maximised. All participants invited to complete the surveys were made aware of their rights to no longer be involved or to withdraw at any time without prejudice. They were made aware that pseudonyms would be used instead of their real names such that their anonymity was maximized for them as well as for the information that they provided. Their data would remain anonymous in all reporting of results. With that, the participants' demographic information and profiles were used only for the purpose of this study. Hence, the researcher continuously monitored and took stringent care when recording, storing and analysing data to maximized privacy and confidentiality. To ensure that participants' names were not readily identified, random codes known only to the researcher were used.

All data ranging from completed surveys, audio recorded interviews and field notes to transcripts were kept and stored in locked cabinets in the researcher's locker at Curtin University. Electronic copies were also strictly stored using the concept of "audit trail" (Lincoln and Guba, 1985, p. 319). Using audit trail the researcher was able to re-identify data specific to an individual and destroy it when participation was withdrawn any time during data analysis. This was one of the key components that also

demonstrated the credibility and dependability of qualitative studies. So both the raw quantitative data and qualitative data were coded and filed, such that they could be easily retrieved and cross-referenced with the electronic copy when required. The codes were separated from the raw data to ensure that anonymity was maintained when data analysis was completed.

This study also maximized the anonymity of the high schools by using codes since the high schools were close to each other, thus they can be easily identified by their communities at large. Even more, continuous strict consideration was executed and monitored to maximize the privacy and confidentiality of the trainee science teacher participants since the anonymity of the SINU is not easily addressed because it is the only university in Solomon Islands.

3.10.3 Potential Harm and Dispute Resolution

The researcher continuously monitored and assessed the circumstances and situations surrounding participants' involvement by seeking their opinions with regards to their comfortability during the interactions. Participants were reminded of the rights to voice any discomfort that may negatively influence their participation. Nevertheless, such a potential harm was minimized since participants were made aware initially with their informed consent. That said, there were no disputes during data collection and analysis. However, a mechanism to resolve disputes was in place in case of any dispute. The initial dialogue should be carried out by the researcher. If no resolution was reached then the supervisor would be notified for further consultation. The supervisor's and the researcher's email addresses were provided on the participant's information sheet.

3.10.4 Other Ethical Concerns

One of the other ethical concern for this study was time. Data were collected when participants were also performing their responsibilities as well as studying. Hence, adequate time was given when negotiating and organising time for the administration of surveys and interviews. To overcome some of the time constraints, participants were given options of when to submit their surveys. Two participants were also given the option to submit written responses instead of one-on-one interviews. In fact, it was

anticipated that the number of times and amount of time required for participants to complete the survey, as well as their general willingness to participate, could limit the quality of the data they provided. The researcher ensured that participants did not feel that their time and privacy was invaded or improperly used. As such, the researcher was conscious with time when administering the survey and conducting interviews.

Another ethical concern was the fact that the researcher was a science teacher as well as a Solomon Islander. In conducting the study with science teacher participants in Solomon Islands, the researcher was vigilant to avoid conflicts of interest. Therefore, data were generated from a vantage point of a researcher and not from another science teacher. This led to the ethical concern of biasness. However, the researcher was extremely conscious not to dictate the results, nor coerce participants by means of bribes or influence other interest group to provide favours.

3.11 Summary of Chapter three

Using the notion of fitness for purpose, this study employed a mixed methods approach within an embedded multiple case study design. Hence, this study was bounded by the selected participants' who had views and experiences about teaching, learning and assessment of physics concepts in the SBA of practical work. The participants were also bounded by the convenience of their geographical locations. Given the extreme difficulty in reaching some potential sites, a pragmatic approach had to be undertaken to ensure the study could be completed within the time and resources available. Hence, a triangulation mixed methods approach was used to collect both qualitative and quantitative data independently and concurrently. The two data sets were complementary and were triangulated to confirm reliability and trustworthiness (Creswell, 2012; Yin, 2002).

The quantitative data were generated from 124 survey responses comprising 64 trainee and 60 practising science teacher participants. The survey instrument comprised relevant demographic items and five scales with a total of 54 items. The first four scales contained statements associated with knowledge about teaching, learner's learning and understanding, content and purpose, and PCK for use in the SBA of physics concepts. Each statement in the first four scales had five Likert choices that participants encircled indicating whether they "strongly agree", "agree", "uncertain",

“disagree” or “strongly disagree”. The fifth scale consisted of four Newtonian force concept multiple choice problems that were adapted from the FCI.

The qualitative data were generated from one-on-one interviews with seven practising science teacher participants and a focus group interview with seven trainee science teacher participants. The interview schedule had 16 semi-structured questions that were related to the statements in the scales of the survey. Probing questions were strategically asked during the interview process to elicit in-depth explanations and descriptions as well (Cohen et al., 2007). The interviews were conducted in Pidgin English as guided verbal conversations and audio recorded on voluntary basis with prior consent from participants.

The quantitative data were tabulated using spreadsheets in Microsoft excel software and later converted into SPSS files for statistical analysis. The qualitative data comprised participants’ audio taped interview conversations were painstakingly transcribed and translated into proper English transcripts. Then, a back translation was conducted to verify the qualitative data recorded. The transcripts were typed into word documents and later organised into pre-guided themes and emerging themes using thematic analysis. The constructs of the interview questions were associated with scales in the survey instrument. Hence, inferences from these two data sets were triangulated and synthesised for discussion of key findings.

This study ensured that the morals and ethics in conducting research involving human participants were maximised when seeking appropriate permissions and informed consents from participants, schools, education authorities, SINU and the MEHRD in Solomon Islands. Besides, this study ensured that privacy and confidentiality as well as anonymity of participants were maximised. Other ethical considerations were also heeded to ensure the reliability and validity of the findings were maximised. Subsequently, the quantitative findings for this study are presented next in Chapter Four followed by qualitative findings in Chapter Five.

CHAPTER FOUR

Quantitative Findings

4.1 Chapter Overview

The research design for this study generated both the quantitative and qualitative data as previously discussed in Chapter Three. Subsequently, as described in subsection 3.8.1, this chapter specifically presents the findings from the quantitative data while the findings from the qualitative data are presented in Chapter Five. This chapter begins with an introduction in Section 4.2. Then Section 4.3 reports the main findings from the quantitative data in the order that they were generated from the five scales in the survey instrument for this study. Finally, a brief summary of the quantitative findings is highlighted in Section 4.4.

4.2 Chapter Introduction

This study sought to explore and document participants' views and experiences regarding their pedagogical content knowledge (PCK) in the teaching, learning and assessment of physics concepts in the school-based assessment (SBA) of practical work. Hence, the quantitative findings for this study were generated in order to identify general trends of views and experiences regarding the five knowledge components in the survey for this study. Subsequently, the inferences from the quantitative findings are triangulated with as well as complement the rich qualitative findings presented in Chapter Five to answer the following research questions:

1. What do trainee and practising science teachers know and understand about scientific and physics concepts in science SBA?
2. How do trainee science teachers view and experience their learning and assessments of physics concepts?
3. How do practising science teachers view and experience their teaching and assessing of physics concepts?

4. What do trainee science teachers suggest as ways to improve their learning, understanding and assessment of physics concepts in the SBA?
5. What do practising science teachers suggest as ways to improve their understanding, teaching and assessment of physics concepts in the SBA?

In general, the quantitative findings for this study indicated that the majority of participants had similar views and experiences regarding some knowledge and understanding of teaching, learning and assessment of physics concepts in the SBA of practical work in Solomon Islands science education. In addition, the quantitative findings for the first four scales of the survey showed acceptable Cronbach's Alpha reliabilities indicating that the participants' responses were consistent. However, the participants' responses for the fifth scale were highly inconsistent.

4.3 Results from Quantitative Data

This Section presents the quantitative findings according to the following five scales or knowledge components in the survey, namely:

- 4.3.1 - Knowledge of teaching physics concepts;
- 4.3.2 - Knowledge of learner's Understanding of physics concepts;
- 4.3.3 - Knowledge of content and purpose;
- 4.3.4 - Physics pedagogical content knowledge;
- 4.3.5 - Knowledge of Newtonian force concepts.

The survey for this study was completed by 124 participants that comprised 64 trainee and 60 practising science teachers. Data from the 124 respondents were analysed as a whole using basic statistics in SPSS. Subsequently, there were 124 valid cases (N) and none was excluded for the first four scales in the survey. Besides, with the statistical analysis, inferences were also made by comparing the responses from the two cohorts. Added to that, the responses from scales one, two and three were also compared with responses to scales four as well as scale five.

The first four scales comprised items or statements with corresponding five points Likert options while the fifth scale in the survey contained four multiple choice questions that were extracted from the FCI. Subsequently, the first four scales were

analysed for their Cronbach's Alpha reliabilities or internal consistencies while the fifth scale was basically analysed using the frequency of responses that were correct compared to misconceptions. As such, the reliability statistics for the first four scales are presented in Table 4.1.

Table 4.1

Reliability Statistics for Scales One to Four

Scales	Number of items	Cronbach's Alpha
1 Knowledge of Teaching	15	0.72
2 Knowledge of Learner's Understanding	12	0.66
3 Knowledge of Content and Purpose	13	0.83
4 Pedagogical Content Knowledge	10	0.89

Note. The Cronbach's Alpha for each scale in the survey (N = 124).

This analysis was significant to determine the general trends of responses with respect to the themes in the first four scales. Accordingly, higher values of Cronbach's Alpha reliability indicate that the majority of items were related in construct and concept as well as, it can be inferred that the majority of participants responded in a similar way for many of the items in the same scale (Cohen et al., 2007).

4.3.1 Knowledge of Teaching Physics Concepts

Scale one in the survey for this study consists of 15 statements regarding knowledge that science teachers should have in teaching physics concepts. Subsequently, for the purpose of this study the frequencies of scale one responses for the whole data set of 124 respondents or participants are presented in Table 4.2. This result provides a general trend of how the survey participants responded to the statements regarding their knowledge of teaching physics concepts. Consequently, the higher frequencies of responses to most of the items indicated that the majority of survey participants had similar responses or views and experiences associated with the knowledge of teaching physics concepts in high school. In other words, generally, the quantitative findings for scale one indicated that the majority of participants perceived that they had knowledge of teaching physics concepts in high school. However, specific results in Table 4.2 also indicated a spread of responses for item three and item 14.

Table 4.2

Frequency of Responses for Scale One (N = 124)

Item No	Statements on Knowledge of Teaching Physics Concepts	Frequency				
		SD	D	UN	A	SA
i01	I understand how to use demonstrations to explain physics concepts.	0	5	8	92	19
i02	I understand how to use appropriate diagrams and graphs to explain physics concepts.	0	1	21	81	21
i03	I am able to use computer simulations to help learners understand physics concepts.	10	19	44	42	9
i04	I am confident in using familiar everyday examples to explain physics concepts.	2	1	22	66	33
i05	I am confident in using stories to explain physics concepts.	0	4	23	72	25
i06	Presenting a physics concept in multiple ways to explain the concept are tools for effective physics teaching.	0	5	12	46	61
i07	Physics learning is enhanced when the teacher is good at representing the physics concepts in multiple ways.	0	2	7	38	77
i08	Physics teachers should spent time on developing or finding multiple representations of a physics concept.	0	0	4	39	81
i09	Textbooks or curricular material should embody physics concepts in multiple ways.	0	0	7	56	61
i10	In my physics teaching, I use multiple representations to teach a physics concept.	1	9	17	61	36
i11	I use stories to explain physics concepts in my teaching.	3	4	19	66	32
i12	I use familiar everyday real objects to help learners' understanding of the physics concepts in my teaching.	0	2	4	63	55
i13	Multiple representations of a physics concept can help to explain abstract concepts.	0	3	13	56	52
i14	Multiple representations of a physics concept can lead to misunderstanding of the concept.	16	49	29	22	8
i15	Multiple representations of a physics concept can support physics learning when all the representations show all the information about the concept.	0	2	9	59	54

Note. The sample (N) is 124 cases: 64 trainee and 60 practising science teacher participants.

Although the Cronbach's Alpha reliability of 0.72 for scale one is reliable and indicated that the majority of participants responded in a similar way, it is also significant to identify the items that may have reduced the Cronbach's Alpha reliability for scale one. In other words, the items that participants may have interpreted or understood differently due to its construct or depicted concept. Hence, as described in subsection 3.8.1, Item – Total Correlation Statistics were also calculated as part of the quantitative analysis to identify how items in one scale are correlated to each other (see Table 1H in Appendix H). Consequently, on the one hand, items four, five, six, seven and thirteen had high corrected item-total correlation greater than 0.40 while on the other hand, items one, two, three, eight, nine, 11, 12, 14 and 15 had corrected item – total correlation less than 0.40. Out of the items with values less than 0.400, item three and item 14 had the lowest. Hence, it is significant to analyse item three and item 14.

The majority of participants indicated they were uncertain while many others disagree and strongly disagree with the statement concept in item three. The majority of responses to item three were negative and were uncorrelated to the majority of positive responses to other items with item – total correlation higher than 0.400. For example, for item three, 19 out 124 participants disagree and 10 strongly disagree while 44 out of 124 participants were uncertain as shown in Table 4.2. That is a total of 77 participants or 58.9 percent of participants who were uncertain as well as disagree and strongly disagree with item three. In other words, more than half of the participants indicated that they were unsure or not able to use computer simulations to help learners to understand physics concepts.

This quantitative finding is significant to note in comparison to other findings from this study. For example, as indicated in subsection 5.3.3 in the qualitative findings, one of the important aspects of teaching physics was to develop learners' understanding and skills to use technology. However, although some participants shared the view that teaching and developing learners' understanding to use technology tools is important, the majority of participants indicated that they did not know how to use technology tools for teaching science and physics. This finding is similar to other studies such as Batane and Ngwako (2017) who found that only 10 percent of teachers in their study used technology in their classes. Similarly, Sade (2009) found that even technology

teachers lack some knowledge in using technology tools as well as the definition of technology in the context of high school education in Solomon Islands.

Similar to item three, the majority of responses to item 14 were negative compared to the responses to other items in scale one. Although, the responses to item 14 were uncorrelated to the majority of responses to other items, the responses indicated that participants took time to read the statement and made a decision that supported their views in relation to other items in scale one. In fact, it is significant to note that the responses of the participants for item 14 were consistent with their views on other statements. As shown in Table 4.1, 49 participants disagree and 16 participants strongly disagree, that is, 52.4 percent of participants indicated that using multiple representations cannot lead to misunderstanding of physics concepts while the other 23 percent were uncertain and only 24 percent agree and strongly agree. Subsequently, this finding indicated that the majority of participants perceived that multiple representation can lead to better understanding of physics concepts. This supports the majority of responses to item seven and item 13 as shown in Table 4.2.

The frequencies of responses to each of the items are worth considering for the purpose of identifying common views or general trends for scale one. For example, for item one in Table 4.2, 92 out of 124 or 74.2 percent of participants agree that they understand how to use demonstrations to explain physics concepts. Additionally, 19 out of 124 or 15 percent of participants strongly agree. This indication can be inferred to represent a general trend. In other words, majority of participants held the view that they understood how to use demonstrations to explain physics concepts. Similarly, for item two, 81 out of 124 and 21 out of 124 agree and strongly agree respectively, that they understand how to use diagrams and graphs to explain physics concepts. That is a total of 82 percent of participants. Similar trends were indicated for items eight and nine as well as for item 11 for use of stories and item 12 for the use of everyday real objects.

In sum, it can be inferred from these descriptive statistics that the majority of science teacher participants for this study responded in a similar way. Their responses indicated that they perceived having some knowledge about how to teach physics concepts. Although item 14 is a negative statement, participants' responses were consistent with other items with similar constructs and concepts. However, responses

to item three is inconsistent with views highlighted in the qualitative findings in subsection 5.3.3. While qualitative findings suggested that understanding technology is significant in science education, the quantitative findings indicated that the majority of participants were not familiar with technology tools like computer simulations in teaching physics concepts.

4.3.2 Knowledge of Learners' Understanding of Physics Concepts

Scale two in the quantitative survey had statements pertaining to the knowledge that science teachers should have of learners' understanding of physics concepts. The statements included the knowledge to identify and understand learners' preconceptions and misconceptions as well as how to facilitate effective learning of physics concepts. There were 12 statements or items in scale two that were designed to have related constructs and concepts on knowledge of learners' understanding. The 12 items and frequencies of responses to their corresponding five points Likert options are presented in Table 4.3.

While some survey participants indicated 'Uncertain' as their response, the majority of participants indicated that they agree and strongly agree with most of the statement concepts except for item 25 and item 27. Generally, the majority of survey participants perceived that they had knowledge on learners' preconceptions and misconceptions of physics concepts. Subsequently, their responses indicated that they had knowledge to plan and effectively teach physics concepts. In fact, from Table 4.1, the Cronbach's Alpha reliability for scale two is 0.66 which is marginally reliable and is acceptable for an exploratory study as this present study (Cohen et al., 2007). Other studies such as Jang (2012) also indicated that the scale on the knowledge of learners' understanding had lower Cronbach's Alpha reliability compared to other scales of science teachers' knowledge components. Jang (2012) found in his study that science teachers could not fully understand learners' difficulties and preconceptions and misconceptions (Jang, 2012). Similarly, the Cronbach's Alpha reliability for scale two indicated that the participants for this study had some inconsistent views and experiences on the knowledge of learners' understanding of physics concepts.

Table 4.3

Frequency of Responses for Scale Two (N = 124)

Item No	Statements on Knowledge of Learners Understanding of Physics Concepts	Frequency				
		SD	D	UN	A	SA
i16	I know how to use learners' preconceptions of a physics concept in planning in my lessons.	1	5	32	74	12
i17	I am able to identify learners' related abilities and skills in learning a physics concept.	0	3	23	78	20
i18	I understand how to use learners' difficulties in planning my lessons to teach a physics concept.	1	5	24	77	17
i19	Physics teaching is effective when the teacher is able to identify concepts that are abstract to learners.	1	6	8	53	56
i20	Determining learners' likely preconception related to a physics concept is important in planning for effective teaching.	1	1	12	55	55
i21	It would be helpful when textbooks or curriculum highlight learners' difficulties related to a physics concept.	0	7	14	58	45
i22	In my teaching, I use knowledge of learners' preconceptions of a physics concept.	2	11	30	64	17
i23	I use the knowledge of related abilities and skills of my learners in learning a physics concept in my teaching.	0	8	25	67	24
i24	I use knowledge of learners' difficulties in solving problems related to a physics concept in my teaching.	4	7	21	65	27
i25	Learners' preconceptions are difficult to overcome.	8	48	28	30	10
i26	Learners' come to the classroom with their naïve knowledge of physics concepts.	3	12	27	59	23
i27	It is easy to teach a physics concept since all learners have the same abilities and skills in learning the physics concept.	31	37	14	25	17

Note. The sample (N) is 124 cases: 64 trainee and 60 practising science teacher participants.

Considering the frequencies of responses to the items in Table 4.3 are crucial in understanding the trends of participants' views and experiences with regards to their knowledge of learners' understanding of physics concepts. For example, the statement for item 25 was – 'Learners' preconceptions are difficult to overcome'. The construct and concept in this statement was negative in comparison to other items in scale two. This statement suggested the view that learners' preconceptions are difficult to

overcome. In response, on the one hand, 48 participants indicated that they disagree and eight participants strongly disagree with this view. On the other hand, 30 participants agree and 10 participants strongly agree. Consequently, it can be inferred here that, a simple majority of 56 participants disagree while 28 participants were uncertain with the view that learners' preconceptions are difficult to overcome. In other words, 40 participants agree and strong agree with the statement while the majority of participants indicated that it is not difficult to overcome learners' preconceptions. Similarly, as indicated from the statements in the other items, the majority of participants agree and strongly agree that they can identify learners' preconceptions as well as use them for effective planning and teaching of physics concepts. This was indicated in the frequency of responses for item 16 and item 20 as shown in Table 4.3. For instance, for item 16, 74 participants indicated that they know how to use learners' preconceptions of a physics concept in planning for their lessons plans. Likewise, responses to other items except for item 27 reinforces the positive perceptions of using learners' preconceptions for planning and effective teaching of physics concepts.

The responses to item 27 in Table 4.3 indicated that the majority of the survey participants in this study inconsistent views with respect to their knowledge of learners' understanding of physics concepts. Basically, item 27 stated that, 'it is easy to teach a physics concept since all learners have the same abilities and skills in learning the physics concept'. As shown in Table 4.3, 31 participants strongly disagree and 37 participants disagree with this statement. Hence, it can be inferred that the majority of participants perceived that it is not easy to teach physics concepts to learners who had the same abilities and skills in learning physics concepts. However, this view is inconsistent with responses to item 23 which stated that, 'I use the knowledge of related abilities and skills of my learners in learning a physics concept in my teaching'. Subsequently, the majority of participants indicated that they agree and strongly agree that they use their knowledge of learners' abilities and skills to teach physics concepts. These two items had inconsistent responses. On the one hand, the majority of participants indicated that it is not easy to teach physics concepts to learners with the same abilities and skills while on the other hand, they indicated that they use knowledge of learners' abilities and skills to teach physics concepts. In other words, these descriptive statistics indicated that the majority of participants' views and

experiences on learners' understanding and learning of physics concepts were not consistent. Hence, as premised in this study, it is imperative to enhance science teachers' knowledge components for PCK.

4.3.3 Knowledge of Content and Purpose of Physics Concepts

Although it was presented as scale three, this scale is important to this study since it provides indications about the participants' responses to statements on knowledge of content and purpose of physics concepts. Hence, scale three had 13 items which provided the construct concepts regarding the knowledge that science teachers should have about the content and purpose of physics concepts in high school. Consequently, the frequencies of responses from the survey participants to items in scale two are present in Table 4.4. In general, the quantitative findings for scale three indicated that the majority of survey participants perceived that they had knowledge of physics content and purpose well enough to effectively teach physics concepts to their learners. Only a minority of participants were uncertain about the items in scale three. As indicated in Table 4.1, the Cronbach's Alpha reliability for scale three is 0.83 which is highly reliable (Cohen et al., 2007). That means, the internal consistency of the items in scale three was high and the items were closely correlated in construct and concepts. Similarly, it can be inferred that the responses for the 13 items were highly consistent. In other words, the 124 participants responded in a similar way.

However, it was shown from calculating the Item – Total Correction statistics that item 29 and item 32 had lower correlation value less than 0.40 (see Table 3H in Appendix H). Hence, it is imperative to further analyse items 29 and item 32 in scale three. From Table 4.4, item 29 stated that – 'I understand physics concepts well enough to teach physics effectively'. Corresponding to this statement, 74 participants agree and 18 participants strongly agree. That means, 74 percent of participants indicated that they understand physics concepts well enough to teach it effectively. Conversely, only one participant strongly disagrees and six participants disagree while 25 participants were uncertain with the statement in item 29. However, although, the value of the corrected item – total correlation for item 29 was lower than 0.40, the general trend of response frequencies was similar to other items in scale three. Hence, this clearly indicated that the majority of participants perceived that they understand physics contents and purpose well enough to teach physics concepts effectively in high school.

Table 4.4

Frequency of Responses on Knowledge of Content and Purpose of Physics (N = 124)

Item No	Statements on Knowledge of Content and Purpose of Physics Concepts	Frequency				
		SD	D	UN	A	SA
i28	I know how physics theories or principles have been developed.	2	9	44	60	9
i29	I understand physics concepts well enough to teach physics effectively.	1	6	25	74	18
i30	I know how to relate physics to everyday science and technology	0	1	17	84	22
i31	I know how to teach the history behind the discoveries of physics concepts.	1	20	45	44	14
i32	Physics learning is enhanced when the teacher has a good grasp of physics contents.	0	0	2	34	88
i33	Physics textbooks should include how physics concepts were discovered.	0	2	4	46	72
i34	Understanding how physics theories or principles are developed will enhance physics learning.	0	2	4	52	66
i35	In my physics teaching, I can use the knowledge of how physics theories or principles have been developed.	0	5	16	69	34
i36	I can tell the history behind the discoveries of physics concepts in my teaching.	3	13	24	62	22
i37	I can relate the physics concept learned to the use of technology and its impact on society in my teaching.	2	0	16	77	29
i38	Knowing how physics is related to science and technology will motivate learners to learn physics.	0	1	1	52	70
i39	An effective physics teacher knows the relationships of central concepts in physics.	0	0	4	52	68
i40	Knowing the historical development of physics helped me understand the content better.	0	3	15	61	45

Note. The sample (N) is 124 cases: 64 trainee and 60 practising science teacher participants.

A similar trend of responses were indicated for item 32 which stated that ‘physics learning is enhanced when the teacher has a good grasp of physics contents’. Unlike item 29, no participant disagree or strongly disagree with item 29. Actually, 88 survey participants strongly agree and 34 agree while only two participants were uncertain. This quantitative finding clearly indicated that the majority of participants held a positive view about the statement in item 32. Hence, although item 29 and item 32 had

lower corrected item – total correlation below 0.40, the frequency distribution of the responses were still similar to all other items in scale three. Subsequently, it can be inferred that scale three had higher indication of psychological homogeneity among the participants. That means, the majority of participants who responded to the survey for this study had a similar point of view to the 13 items in scale three.

However, while the quantitative findings for scale three indicated that the majority of participants had knowledge of content and purpose of physics, it is also important to explore whether these perceptions were consistent with the responses in the quantitative findings on participants' understanding of content knowledge in scale five. Added to that, the inferences from the quantitative finding for scale three will also be triangulated with the qualitative findings in Chapter Five of this thesis.

4.3.4 Pedagogical Content Knowledge of Physics Concepts

Adapted from the transformative model, PCK statements in scale four were constructed as synthesised knowledge statements as described in subsection 2.6.1 and depicted in figure 2.4 (a). As such, the PCK statements in scale four comprised aspects of content knowledge that had been synthesised with knowledge of learners as well as pedagogy, curriculum and assessment processes (Schmidt et al., 2009). For example, item 43 states – ‘I can use strategies in my classroom that combine physics content and teaching approaches that I learned about in my past studies’. Subsequently, the 10 items in scale four were constructed to elicit views and experience of the science teacher participants regarding their knowledge of the SBA of practical work as an avenue to teach and assess physics concepts. As such, although the 10 items were adapted from TPACK, they were rephrased and constructed with related concepts that were synthesised to capture the survey participants' views and experiences on PCK from a standpoint of the transformative model.

This was important since the quantitative findings from scale four were also explored in comparison to the standpoint of the integrated model depicted in figure 2.4 (b) in subsection 2.6.1. That means, the quantitative findings in scale four are compared with the integration model whereby the PCK comprises the responses to the different knowledge components indicated in scale one, two and three as well as the qualitative

findings of this study. Consequently, the frequencies of participants' responses to the 10 items in scale four are presented in Table 4.5.

Table 4.5

Frequency of Responses for Scale Four (N =124)

Item No	Statements on Pedagogical Content Knowledge of physics concepts	Frequency				
		SD	D	UN	A	SA
i41	I can teach lessons that appropriately combine physics contents with teaching approaches.	0	3	12	82	27
i42	I can select multiple representations to use in my classroom that enhance what I teach, how I teach, and what learners learn.	0	6	19	63	36
i43	I can use strategies in my classroom that combine physics content and teaching approaches that I learned about in my past studies.	0	3	19	63	39
i44	I can provide leadership in helping others to coordinate the use of content and teaching approaches at my school.	0	4	25	69	26
i45	I can choose effective teaching approaches to guide learners thinking process of physics contents.	0	2	15	75	32
i46	I can select appropriate assessment activities that will demonstrate learners understanding of physics concepts.	0	0	13	62	49
i47	I use formative assessment to enhance learners understanding of physics concepts.	1	1	13	66	43
i48	I use multiple representations when teaching physics concepts.	0	9	31	64	20
i49	I use school-based assessment for both summative and formative assessment.	0	9	11	68	36
i50	I use school-based assessment for effective teaching and learning in my classroom.	0	9	16	62	37

Note. The sample (N) is 124 cases: 64 trainee and 60 practising science teacher participants.

The quantitative findings for scale four indicated that the majority of survey participants perceived that they had synthesised knowledge on physics content, pedagogy, learners' understanding and the SBA of physics concepts. As indicated in Table 4.1, the Cronbach's Alpha reliability for scale four is 0.89. This was the highest value compared to the other three scales in the survey for this study. According to Cohen et al. (2007), 0.89 is highly reliable and it indicated a very high internal

consistency for the constructs and concepts of the 10 items. Added to that, this was an indication of high consistency between the responses of the 124 participants who responded in a similar way to all the 10 items in scale four. That can be seen as a psychological homogeneity whereby participants had similar views to each of the items. However, the internal consistency for this transformative PCK scale is very high compared to the different internal consistencies for scale one, two and three which comprised the integrated PCK. In other words, the participants' perceptions of the transformative PCK statements were highly correlated than their perceptions on different integrated knowledge components. The inferences from these quantitative findings are imperative for the purpose of this study.

In addition, it was indicated in the Item – Total Correlation statistics (see Table 4H in Appendix H) that all the 10 items in scale four were highly correlated to each other. Consequently, Table 4.5 also indicated that the majority of participants responded in almost the same way. This general trend was indicated in the frequencies of responses to item 46, item 47, item 48, item 49 and item 50 which were highly consistent. Basically, item 46 to item 50 had the similar constructs and concepts on transformative PCK statements that relates to the assessment of physics concepts by using the SBA of practical work for formative and summative purposes. For example, in Table 4.5, item 49 stated – ‘I use school-based assessment for both summative and formative assessment’ and item 50 stated – ‘I use school-based assessment for effective teaching and learning in my classroom’. Subsequently as indicated for item 49, nine participants disagree and none strongly disagree while 68 participants agree and 36 participants strongly agree. Only 11 participants were uncertain on whether they had used the SBA of practical work for both summative and formative assessment. Similarly, for item 50, nine participants disagree and none strongly disagree while 62 participants agree and 37 participants strongly agree and only 16 were uncertain that they had used the SBA of practical work for effective teaching and learning in their classroom.

This quantitative finding indicated that with transformative PCK statements, the majority of the participants perceived that they had the synthesised knowledge to effectively teach and assess physics concepts using the SBA of practical work. However, compared with responses to the perceived integrated PCK in scale one, two and three there were some inconsistencies especially with the knowledge of learners’

understanding of physics concepts in scale two. Added to that, responses to scale four also indicated that nine survey participants consistently perceived that they disagree with statements in item 48, item 49 and item 50. It is imperative to note that seven out of the nine participants were practising science teacher participants. This indicated that only 12 percent of the practising science teacher participants perceived that they did not use multiple representations and formative assessments in teaching and learning of physics concepts in the SBA of practical work. Conversely, it can be inferred that the majority of the survey participants perceived that they had good transformative PCK to teach physics concepts using multiple representation and formative assessment through the SBA of practical work. However, this perception is not consistent with other quantitative findings as outlined earlier for scale one, two, three, as well as for scale five in the next subsection and the qualitative findings in Chapter Five.

4.3.5 Understanding of Newtonian Force Concepts

Scale five of the survey for this study was constructed to capture participants' understanding or content knowledge on Newtonian force concepts. While the other four scales had five points Likert options, scale five comprised four multiple choice questions. The four questions were selected from the FCI that was developed, tested and validated by Hestenes et al. (1992). As outlined in subsection 3.7.3, the four items were selected on the basis that they should be familiar to the participants of this study since the force concepts were usually included in the Solomon Islands high school science syllabus as well as in the SBA of practical work.

The four multiple choice questions or items on Newtonian force concepts are presented in Table 4.6. The four items were used to provide a clear picture of the common trends of misconceptions that were usually indicated in participants' beliefs and perceptions of force concepts. Each of the four items had five multiple choice answers. One of the answers is a Newtonian force concept while the other four are distractors which are commonly known as misconceptions (Persson, 2015). The four misconceptions are common sense beliefs or concepts about forces that individuals had constructed from their everyday experiences and interpretations (Hestenes et al., 1992). Consequently, in general, scale five responses indicated that the majority of both trainee and practising science teacher participants had misconceptions about force concepts compared to the Newtonian force concepts.

Table 4.6

Four FCI Multiple Choice Problems

Item No	Problem	Multiple Choices
i51	Two metal balls are the same size, but one weighs twice as much as the other. The balls are dropped from the top of a two storey building at the same instant of time. The time it takes the balls to reach the ground below will be:	<p>A. About half as long as for the heavier ball.</p> <p>B. About half as long as the lighter ball.</p> <p>C. About the same time for both balls.</p> <p>D. Considerably less for the heavier ball, but not necessarily half as long.</p> <p>E. Considerably less for the lighter ball, but not necessarily half as long.</p>
i52	A large box is being pushed across the floor at a constant speed of 4.0 m/s. What can you conclude about the forces acting on the box?	<p>A. If the force applied to the box is doubled, the constant speed of the box will increase to 8.0 m/s.</p> <p>B. The amount of force applied to move the box at a constant speed must be more than its weight.</p> <p>C. The amount of force applied to move the box at a constant speed must be equal to the amount of the frictional forces that resist its motion.</p> <p>D. The amount of force applied to move the box at a constant speed must be more than the amount of the frictional forces that resist its motion.</p> <p>E. There is a force being applied to the box to make it move but the external forces such as friction are not “real” forces they just resist motion.</p>
i53	If the force being applied to the box in the preceding problem is suddenly discontinued, the box will;	<p>A. Stop immediately.</p> <p>B. Continue at a constant speed for a very short period of time and then slow to a stop.</p> <p>C. Immediately start slowing down to a stop.</p> <p>D. Continue at a constant velocity.</p> <p>E. Increase its speed for a very short period of time, then start slowing to a stop.</p>
i54	Imagine a head-on collision between a large truck and a small compact car. During the collision,	<p>A. The truck exerts a greater amount of force on the car than the car exerts on the truck.</p> <p>B. The car exerts a greater amount of force on the truck than the truck exerts on the car.</p> <p>C. Neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.</p> <p>D. The truck exerts a force on the car but the car doesn't exert a force on the truck.</p> <p>E. The truck exerts the same amount of force on the car as the car exerts on the truck.</p>

Note. All four items in scale five have five multiple choice answers each (Hestenes et al., 1992).

The frequencies of the survey participants' responses for item 51, item 52, item 53, and item 54 are presented in Table 4.7. The correct responses according to the Newtonian force concepts are shaded for each item. Out of the 124 survey participants, 123 of them responded to all of the four items while one participant did not attempt any of the four items. Hence, N for scale five is 123 instead of 124.

Table 4.7

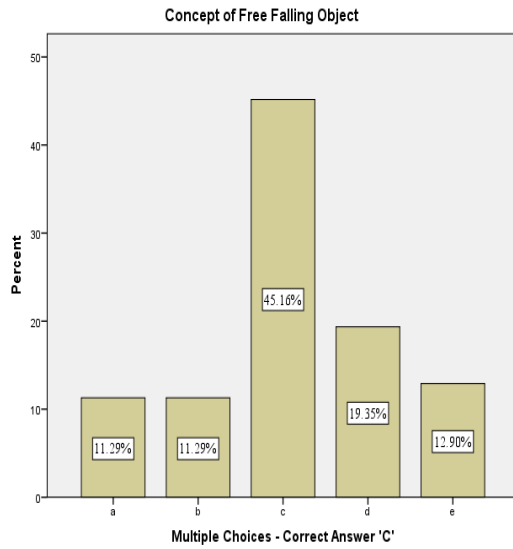
Frequency of Responses for Scale Five (N = 123)

Item		Frequency				
		A	B	C	D	E
No	Newtonian Force Concept					
i51	Free Falling Object	14	14	56	23	16
i52	First Law of Motion	13	21	26	53	10
i53	Force of Friction	62	29	26	3	3
i54	Third Law of Motion	78	7	6	5	27

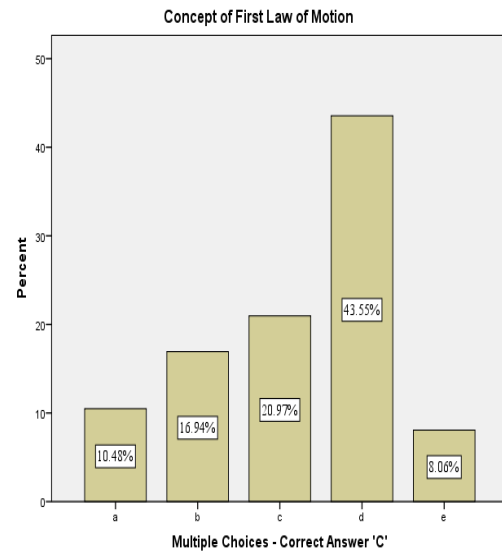
Note. The Sample (N) of 123 cases responding to four multiple choice items. The correct answer for each item is shaded grey.

From Table 4.7, it is evident that the survey participants' responses for each of the items were highly diverse. In other words, the majority of both the trainee and practising science teacher participants did not have similar conceptions about force concepts hence their responses were diverse and different for all the four items. Subsequently, it can be inferred that the majority of participants had misconceptions especially for item 52, item 53 and item 54.

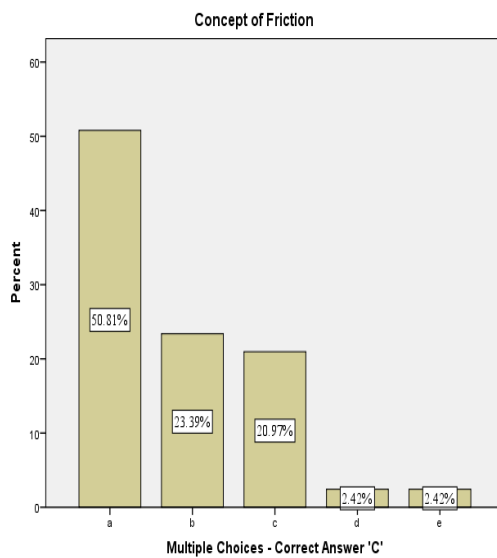
For a clearer visual representation, the frequencies of responses to the four items are also presented on bar charts in figure 4.1. Hence, the bar charts provide a clear graphical indication of the frequencies or percentages of the various participants' responses to the four items in scale five. The bar graphs clearly indicate in their various heights the percentage of the participants who chose one of the multiple choice answers in each item. The correct Newtonian force concept answers are indicated under each item bar graph. Added to that, the specific Newtonian force concept asked in each item is presented as the title of each bar graph. For example, the Newtonian force concept in item 51 related to the concept of a free falling objects. This was also indicated in column two of Table 4.7.



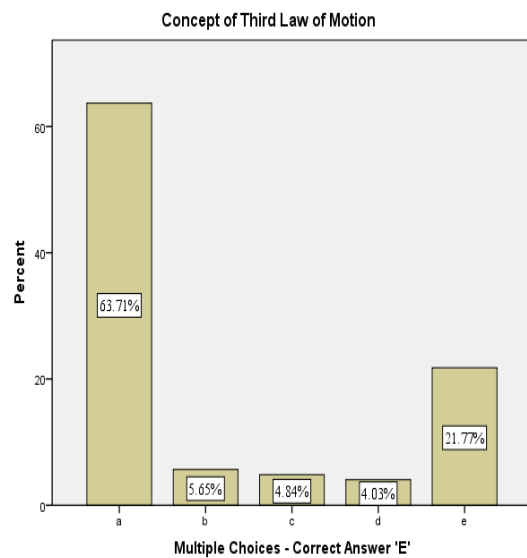
(i) Item 51



(ii) Item 52



(iii) Item 53



(iv) Item 54

Figure 4.1. Bar graphs showing frequency percentage of responses to the four Newtonian Force Concepts.

As depicted in figure 4.1 (i), 45.16 percent of participants chose the Newtonian conception of a free falling object which was presented in answer 'C'. In contrast, 54.84 percent of participants chose other distractors which are common misconceptions. This quantitative finding indicated that more than half of the

respondents had misconceptions compared to the Newtonian force concept of free falling objects.

Likewise, in figure 4.1 (ii), only 20.97 percent of the participants chose the correct conception of Newtonian force concept of first law of motion while the other 79.03 percent chose other distractors. This quantitative findings indicated that the majority of participants had misconceptions regarding the first law of motion. Similarly, the quantitative finding for item 53 as shown in figure 4.1 (iii) indicated that only 20.97 percent of the participants chose the Newtonian force concept of friction. In fact, from other embedded analysis, it was indicated that the same 20.97 percent of survey participants responded correctly for item 52 and item 53. The other 79.03 percent of participants responded by choosing the distractors which are the common misconceptions. Added to that, quantitative findings on item 54 were similar to item 52 and item 53. That is, only 21.77 percent of the survey participants chose the Newtonian concept of third law of motion. The other 78.23 percent of the survey participants had misconceptions on the third law of motion as indicated in figure 4.1 (iv).

These findings were significant to the context of this study. Basically, these quantitative findings are inconsistent to some of the earlier quantitative findings in this Section. For example, the quantitative findings for scale one and scale three indicated that the majority of participants perceived that they had good content knowledge in physics. However, the findings from scale five implied that the majority of participants had misconceptions in comparison to the four Newtonian force concepts. As outlined in subsection 3.7.3, the four force concepts were selected since they were basic force concepts that were usually applied in the SBA of practical work in high school science in Solomon Islands (see Appendix B for sample practical work).

For the purpose of this study, Table 4.8 presented a comparison between trainee and practising science teacher participants' responses to the four Newtonian force concepts. It is indicated that more practising science teacher participants responded correctly than trainee science teacher participants. For example, for item 51, 65 percent of practicing science teacher participants responded correctly compared to 26.6 percent of trainee science teacher participants. Apart from item 51, Table 4.8 also indicated that less than 20.3 percent of trainee science teacher participants and less

than 35.0 percent of practising science teacher participants responded correctly to item 52, item 53 and item 54.

Table 4.8

Comparison between practising and trainee science teacher responses Newtonian Force Concepts

Correct Answer for each Item	Frequency			
	Practising Science Teacher		Trainee Science Teacher	
i51 - C	39	65.0%	17	26.6%
i52 - C	13	21.3%	13	20.3%
i53 - C	18	30.0%	8	12.2%
i54 - E	21	35.0%	6	9.4 %

Note. Comparison between trainee and practising science teacher participants' correct responses.

This quantitative finding indicated that the majority of trainee science teacher participants' lack the content knowledge on Newtonian force concepts in comparison to practising science teacher participants. This is a great concern and it is imperative for the purpose of this study. In essence, this study was premised on the notion that science teachers should have basic content knowledge relating to the four Newtonian force concepts. However, as indicated in scale five, almost 80 percent of the participants had misconceptions.

4.4 Summary of Chapter Four

The quantitative findings for this study had shown that the majority of participants had similar views regarding the knowledge components captured in the first three scales. The majority of participants indicated that they had the knowledge to teach physics concepts by using demonstrations, multiple representations, stories and everyday examples. Likewise, the majority of participants indicated that they had good content knowledge to teach and assess physics concepts. In addition, the quantitative findings for scale four indicated that the majority of participants indicated that they can use the SBA of practical work to teach and assess physics concepts. That said, the transformative PCK in scale four had a high internal consistency compared to that of the integrated PCK as indicated in scale one, two and three.

In addition, the quantitative findings also reveal major inconsistencies in terms of how the science teacher participants perceived their knowledge on learners' learning and understanding of physics concepts. For example, for scale two, on the one hand, the majority of participants indicated that learners have different abilities and preconceptions, hence, it was not easy to effectively teach physics concepts. On the other hand, the majority of participants also indicated that they can recognise learners' different abilities and preconceptions and it was easy to teach physics concepts. Another inconsistency was between what the participants perceived as their content knowledge as compared to their responses to the four Newtonian force concepts in scale five. Although the majority of participants indicated that they had good content knowledge, scale five responses indicated that the majority of participants had misconceptions about Newtonian force concepts. Added to that, it can be inferred that the survey participants' perceptions may not align with what they actually do and experience which warrants a further investigation through the qualitative data. Hence, the qualitative findings for this study is presented next in Chapter Five.

CHAPTER FIVE

Qualitative Findings

5.1 Chapter Overview

While the purpose of the previous chapter was to report the quantitative findings, this chapter specifically reports the qualitative findings for this study. This chapter begins with an introduction in Section 5.2. Then, the qualitative findings for this study are presented under six main themes. The first theme, ‘importance of science education’ is presented in Section 5.3 followed by ‘teaching and learning of physics concepts’ in Section 5.4. Then, ‘school-based assessment (SBA) of physics concepts’ is presented in Section 5.5. This is followed by ‘pedagogical content knowledge (PCK)’ in Section 5.6 and ‘enhancing science teacher training’ in Section 5.7. Subsequently, Section 5.8 reports ‘other perceived improvements’ to the SBA of practical work. Lastly, a summary for this chapter is presented in Section 5.9.

5.2 Chapter Introduction

As described in subsection 3.7.4 and 3.8.2, the qualitative findings for this study were generated from data collected through one-on-one interviews with seven practising science teacher participants and a focus group interview with seven trainee science teacher participants. The conversations were audio recorded then transcribed, verified and later rigorously analysed as direct quotes into pre-guided themes and emerging themes. The pre-guided themes had preassigned words, phrases and concepts within the semi-structured interview questions while the emerging themes emerged from the semantics and concepts that were related to the pre-guided themes as well as the research questions. Consequently, the qualitative findings for this study are presented here with direct quotations from participants as well as the researcher’s third person narratives using qualitative data from the researcher’s written field notes, diary and demographic information. Besides, other relevant references from science education

literature are also cited along with the qualitative findings for comparison and emphasis purposes.

The direct quotations are indicated with the pseudonym and cohort of the participant whom the quotation belongs. For example, ‘Rob TT’ represents: ‘Rob’ – pseudonym for a particular ‘Trainee Teacher’ (TT) participant. Likewise, ‘Hans PT’ represents: ‘Hans’ – pseudonym for a particular ‘Practising Teacher’ (PT) participant.

At the very outset, the participants’ views and experiences on the importance of science education were elicited as a context for making coherent analysis, interpretations and inference to their views and experiences on teaching, learning and assessment of scientific and physics concepts in the SBA of practical work. Hence, it is imperative to present the participants’ views on the importance of science education next.

5.3 Perceptions on Importance of Science Education

The views and experiences of the participants with regards to the importance of science education were divided into five main emerging themes which includes the views to: (i) develop scientific knowledge, understanding and skills for everyday livelihood; (ii) develop ability to solve science problems; (iii) understand new technologies; (iv) develop learners for future careers, and (v) develop learners’ attitude for science and citizenship.

5.3.1 Develop Knowledge, Understanding and Skills in Science for Everyday livelihood

Although participants articulated their views in various ways, general findings indicated that science education is significant for learners’ development of scientific knowledge, understanding and skills for use in everyday livelihood. In fact, most of the participants that were interviewed shared this view. For example, Jen, one of the practising science teachers with fifteen years of science teaching experience, said, “*Science education is important since it is where students obtain science knowledge and skills*” (Jen, PT).

Lin, a trainee science teacher also said “...I want my students to learn the science concepts, knowledge and be able to apply them in their everyday lives” (Lin, TT). Similarly, Rick, one of the trainee science teachers stressed:

...we want our students to develop some basic understanding and knowledge about science... So at the end of the day we want our students to develop their knowledge and skills in science (Rick, TT).

With regards to scientific knowledge, Rick explained that learners should know “...the facts about science and they must be aware of the things that happen to us which relates to science principles” (Rick, TT). Likewise, Rob explained:

I want my students to achieve, first aspect is the knowledge and skills... With knowledge, I want my students when they encounter any phenomenon or use any product, they should be able to give scientific explanations. Even their skills, they should be able to apply them in any activity they come across in life. They should be able to apply their skills in a scientific way which is within their appropriate level of their ability (Rob, TT).

Similar to this view on knowing facts about science Brad, one of the practising science teachers with 13 years of science teaching experience highlighted his view on worthwhile science. He said “*sharing and learning worthwhile science is important about science education. That is science which is worthwhile to students’ daily lives*” (Brad, PT). When asked about what he meant by worthwhile science, Brad said, “*I want my students to learn worthwhile science concepts that will help them better understand the environment they live in*” (Brad, PT). Hence, Brad’s view about worthwhile science relates more to the development of scientific concepts about the environment that learners live in.

Likewise, with regards to the learners’ lived environment and surroundings Kris, one of the female trainee science teachers said:

Science education should educate us and the children about how to live, what surrounds us, how things are happening around us. We need to take note of the things around us in science education (Kris, TT).

More specifically Kris said, *“The first thing is students learn to know who they are, their body parts. They know themselves as well as their surroundings and concern for the future” (Kris, TT).*

Added to that, Pitt, an eleven years experienced practising science teacher said:

Science education provides useful windows of opportunities for both science teachers and students to become familiar with a concept, understand it and apply it... to get rid of wrong and confused everyday explanations (Pitt, PT).

This qualitative finding suggested that science education is important for the development of learners’ scientific knowledge which includes science facts and awareness of the environment and lived surroundings. Additionally, the findings suggested that apart from knowledge, understanding of scientific concepts and development of scientific skills are also vital for learners’ use in their everyday livelihood.

5.3.2 Develop Ability to Solve Problems

More specifically, the qualitative findings suggested that science education is important to develop learners’ ability to solve everyday science related problems and decision making. For example, when asked about what she wanted her learners to learn in science education, Jen said:

Science education is important since it is where students obtain science knowledge and skills. The students will be able to use the science knowledge and skills to solve everyday problems. I mean, problems that involve science and technology (Jen, PT).

Jen further elaborated:

They (students) will also have good analysis because that is what they do in science experiments. I want my students to learn and develop analytical thinking and become good problem solvers (Jen, PT).

The everyday problems that Jen referred to were related to decision making pertaining to socio-scientific issues as well as the kind of science and technology information that is readily available to learners in their everyday civic lives. She explained that:

Our world is full of many information and things that we need to analyse and then make good decisions. So students must have the ability to make good decisions using their analytical skills (Jen, PT).

Jeff, a seven years experienced science teacher, also said:

I want my students to learn and develop investigation and problem solving skills...Understand the links between all the areas of science, to make decisions relating to the appropriate use of science and the environment. (Jeff, PT)

Similarly, relating to solving problems and making decisions based on readily available science and technology information, Pitt said:

Students should develop the understanding and skills to share correct and accurate information...To bridge the gap between understanding of general statements, theories, or law and the successful application of principles to solutions of problems (Pitt, PT).

It can be inferred that Pitt was referring to the view that science education is importance for the development learners' ability to apply their scientific understanding and skills to find solutions to problems.

This emerging view relates to the notion of developing learners' ability to recognise, assess, gather accurate information, analyse, draw conclusions and make appropriate decisions to solve everyday problems as well as issues that are related to science and technology experiences. This finding relates to the aims of the investigative skills project in the SBA of practical work in Solomon Islands (see Appendix A, Section 16.0).

5.3.3 Develop Understanding about Technology

While the terms science and technology are used together, the view that science education develops learners' understanding of technology is worth considering. Basically, some participants view science education as an avenue to understand technology. For example, in emphasizing the importance of science education Hans said *“Oh yes for understanding how to use scientific things like new technologies (Hans PT).*

It is inferred that Hans referred to new technologies as devices and tools that learners would use in their everyday lives. In fact, with some practical examples for understanding new technologies Rick stressed that:

Our lives build on many things through science and technology – like involving the field of health, agriculture. So there are many things that we can benefit from (Rick, TT).

Jeff shared a similar view. He said:

I think science education is fundamental to understanding our world, where live and work. Also to help us keep up with advances in technology and changes that new findings and discoveries bring (Jeff, PT).

Jim a trainee science teacher with some years of teaching experience also said, *“I think most of our living today is based on modern technology” (Jim. TT).*

Sharing the same view but with some analytical assumptions, Andy a trainee science teacher stressed, *“Generally saying, the current level where the world is moving into, science is playing three quarter of the role in what we are using today” (Andy, TT).* Relating to the view of technology he continued to say, *“Technology is introduced, so maybe three quarter of their products, science plays an important role (Andy, TT).*

In line with the view that science is playing an important role in technology Pitt said, *“I want my students to develop and master technical know-how and skills” (Pitt, PT).*

Underpinning these views is the shared notion that science plays an important role in understanding technology. It can be inferred that participants in this study hold the

view that technology is underpinned by the application of scientific concepts and skills. As such, the findings suggested that science education is significant to enhance learner's scientific knowledge, understanding and skills to be able to use new technologies. In addition, participants expressed that new technologies are increasingly becoming part of citizens' everyday livelihood. Hence, science education is significant for learners. However, as reported in subsection 4.3.1, the majority of participants lack the knowledge to use technological tools in their science classes. Hence, this qualitative finding is inconsistent with the quantitative findings. As such, it is imperative for the purpose of this study to premise that science teachers should enhance their knowledge components on science and technology.

5.3.4 Develop for Future Careers and Nation Building

The qualitative findings indicated that high school science education is important for developing learners for possible future careers in science related fields. In turn, learners would participate and contribute to nation building or development. For example, in referring to developing learners for future careers in science related fields and nation building, Rick said:

Basically we want them to develop the knowledge and skills as they grow up and to look forward to use their knowledge in the future as scientists too. For instance, in health, we benefit by sending our students to go and do further study in medicine and even in other areas in science. We want to make science become effective in Solomon Islands. All along we saw that science in Solomon Islands is not like other countries where science is effective (Rick, TT).

One can infer that Rick was referring to the notion that having many science graduates in science related careers would have an impact in developing Solomon Islands. According to Rick, the impact of science in Solomon Islands is less compared to other countries. Rick perceived that this is due to lack of specialists in science fields. Hence, it can be inferred that, according to Rick, science education is significant in developing future scientists who in turn would develop Solomon Islands. In addition to developing learners for future careers in science Pitt also emphasised the view of nation building by saying:

Science education help learners to develop a future career as well as support nation building. Connection to the future career and training of human resources needs of Solomon Islands is vital and must be properly addressed. Students must see themselves within the context of Solomon Islands nation building and how science fits into the entire frame along with the priority areas (Pitt, PT).

In line with the view of nation building Mac said, *“I think science is important for the development of our country (Mac, PT).* He further elaborated, *“I want my students to learn science concepts that are relevant to their lives and to the development of our country” (Mac, PT).*

Similarly, highlighting the development of creativity from science education, Kris a female trainee science teacher said, *“Also they will be creative and one day in the future with their science knowledge they will make something good for the country (Kris, TT).*

In addition to the view of doing something good for nation building, Jim illustrated that:

With regards to science education, in order for the country to develop we need people in such areas (careers in science fields). If we refer to other business, like people who do business, they only deal with money side. Science people are the ones who actually do the work (Jim, TT).

It can be interpreted that Jim illustrated a view and belief that careers in science related fields are vital for the development of a country. He claimed that people working in science related fields are actually the ones that are effectively contributing to nation building. I assume he was referring to careers relating to Science, Technology, Engineering, and Mathematics (STEM). That said, this finding indicated that science education is important for learners' development in science towards choosing a science career path in their lives after high school. Subsequently, with their future careers, they would contribute and participate in the development of their country in one way or the other. In other words, this finding suggested that science education would help develop learners to pursue careers in science fields that are vital for development in Solomon Islands socio-cultural context.

5.3.5 Develop Attitude for Science and Citizenship

The qualitative findings also indicated that science education is important to develop learners' attitude in science as a practice as well as for good citizenship. Some of the participants did mentioned this view as significant in science education. For example, when sharing his view on the importance of science education for developing learners in science Rob said:

This can also affect their attributes and how they behave. For example, they can care for the environment because their scientific knowledge will affect them to behave appropriately (Rob, TT).

According to Rob, the scientific knowledge and understanding that learners develop in science education would also influence their behaviours and attitudes towards their environment as life in general. On the same vein, Jeff pointed out that learners would develop scientific attitudes. He specifically said:

I want my students to learn and develop scientific attitudes of open-mindedness, intellectual honesty, willingness to suspend judgment and a recognition of the tentative nature of theories (Jeff, PT).

It is important to highlight that Jeff referred to scientific attitudes as open-mindedness and willingness to accept that knowledge in science is tentative and subject to change depending on new discoveries.

In addition to the view of developing scientific attitudes in science education Brad also said, "...*That will help student to be better citizens for the country*" (Brad, PT).

This finding suggested that science education in high school is also important for the development of learners' attitude in science as well as to become a better citizens with values and respect for their environment and country as a whole. This affective domain is one of the emphasis in learning about science (Wellington, 1998).

Summary

The findings on the importance of science education provide a context to further interpret and understand the findings on the SBA of physics concepts in practical work.

In this regard, the findings on the importance of science education is crucial for making coherent and cohesive links to the findings on views and experiences about the SBA of physics concepts in practical work. For example, knowing what the participants perceived about the importance of developing learners' ability to solve problems in science and everyday livelihood helps to explain their perceptions about the purpose of the SBA of practical work.

The findings in this section indicated that most participants who were interviewed shared similar views and experiences on the importance of science education. The majority of participants shared the view that science education is significant for the development of learners' scientific knowledge, understanding and skills for everyday use in their livelihoods. In particular, for learners' development of scientific concepts, skills, awareness of science facts and technology as well as attitude for better citizenship. Additionally, to prepare learners for further tertiary studies and future science related careers that in turn would enable them to participate as well as contribute effectively to develop their country. This view corresponds to the notion of science literacy in the Solomon Islands science education curriculum and similar to many other science curricula in many developed economies as well as developing economies. Subsequently, this study was premised on the notion that the views and beliefs on the importance of science education are significant to explain and interpret the participants views about teaching, learning and assessment of physics concepts.

5.4 Perceptions on Teaching and Learning of Physics Concepts

The qualitative findings on teaching and learning of physics concepts are categorised under the following emerging themes: (i) explain with real life examples; (ii) theory and practical work; (iii) theory and demonstration; (iv) theory and multiple representations; (v) theory with exercises, test and short quizzes; (vi) use of stories and analogies; and (vii) group and class discussions.

The term 'theory' in this qualitative findings is used in the sociocultural context of the participants' views on science didactic teaching that mainly involves verbal instructions and writing of notes without conducting practical work and hands-on experiences.

5.4.1 Explain with Real Life Examples

The qualitative findings indicated that one common way of teaching physics concepts is by explaining theory and concepts with relevant examples and practical experiences. For example, Brad said, *“one way of teaching physics concepts is through direct explanation of concepts with examples (Brad, PT).”*

On a similar note Hans emphasised, *“the knowledge of physics in schools can be best understood if real life situation experienced by humans could be used to explain” (Hans, PT).* From his own experience Hans added, *“I use chalk and blackboard to write notes and students copy the notes into their science books” (Hans, PT).*

Jen also shared the same experience as Hans. When talking about how she taught physics concepts Jen said *“mostly theory. That is just using chalk and black board. I give notes to students and also visual diagrams” (Jen, PT).*

One can infer that Hans and Jen were talking about how they taught physics concepts in their respective science classes. That is, they used chalk to write notes on the blackboard and then learners copy the notes into their science exercise books. According to Hans and Jen, that teaching approach is theoretical. In other words, physics concepts are taught by theory in written form.

Furthermore, when talking about introducing physics concepts in teaching theory with examples, Lin a trainee science teacher expressed, *“when I introduce a physics concept, I like to introduce examples before going into calculations” (Lin, TT).*

In a more elaborative form, Rob illustrated:

If you start with surprising students with physics concepts from everyday lives or how items operate, that is very interesting and they (students) will eager to know and be attentive to listen to real life examples like simple machines. Students will be interested and can relate physics concepts to real life (Rob, TT).

Similarly, Kris a trainee science teacher highlighted:

When I teach physics in my class, I just use examples and show pictures so that students can see and connect the ideas about the physics concepts to real things (Kris, TT).

Kris continue to elaborate on her view of providing examples in teaching physics concepts, she said, *“it is good for us to teach physics concepts and relate them to what students can actually see with their own eyes, not just tell them without showing them”* (Kris, TT).

Besides, when responding to the question of effective ways of teaching physics concepts Mano mentioned, *“yes, I relate physics concepts to real things like gravity and falling objects (Mano, PT).*

This view was also expressed by Pitt when he talked about some effective ways he taught physics concepts. He said *“connect and establish relationships. That is using examples from students’ daily experiences, yes contextualise’ (Pitt, PT).*

This qualitative finding suggested that one effective way of teaching physics concepts is through theory and providing appropriate real life and experienced examples that learners can relate to.

While this qualitative finding was highlighted by seven participants, the quantitative data indicated that a large percentage of participants agree as well as strongly agree to this view. For example, Table 4.2 indicated that 63 participants agree and 55 participants strongly agree that they use familiar everyday real objects as examples to help learners understand physics concepts. That means, 95 percent of the participants in the survey shared this view. In other words, it can inferred that this was a general view held by many trainee and practising science teachers. This qualitative finding is consistent with the quantitative findings in item four in Table 4.2.

5.4.2 Theory and Practical Work

The qualitative findings indicated that one effective way of teaching physics concepts is through theory and practical work. As defined in Chapter Two, subsection 2.4.1, practical work is used as an overarching term that covers any form of science activity that learners at some point involve in hands-on experience. That said, participants in

this study used different terms in referring to hands-on experiences. For example, Hans said:

I think just theory alone is not effective. Theories of physics concepts could be understood better when they are supported with hands-on practical for students to actually observe what is explained in theory. What I mean is, teach them knowledge about the concepts and letting them to do hands-on experiments about the concepts. By this students will see theory in real situation in experiments (Hans, PT).

Brad raised the view that practical work can reinforce the understanding of physics concepts that were learnt in theory. He said “*performing lab experiments can reinforce physics concepts and break down common misconceptions of some physical phenomenon*” (Brad, PT). Additionally, Brad stressed the importance of other practical activities like field trips and excursions. He added, “*field trips, excursions which is minimally done but students are given the chance to see or observe applied physics with the environment or in industries*” (Brad, PT).

According to Brad, field trips and excursions were not regularly conducted as practical work from his experience. However, he stressed that such practical work provided the opportunity for learners to see or experience the application of physics concepts in real time. Likewise, Jeff shared the view that learners should experience practical work to make connections to their theoretical knowledge. He stressed “*students relate them to experiences through practical*” (Jeff, PT). Mano also said that “*practical help students to see how the concepts is really happening. They can see, touch – hands-on and construct their ideas from theory*” (Mano, PT).

Talking about effective ways of teaching physics concepts Pitt stated:

Effective ways to teach physics concepts are practical field work and experiments, research projects and oral presentations whether individually or in groups (Pitt, PT).

Mac shared the same view. He said:

I think the effective ways of to teach physics are through field trips, animations, Laboratory, out-door practical, self-design tasks and practical investigations (Mac, PT).

That said, Rick one of the trainee science teachers said:

We teachers just explain concepts through notes, note type of teaching. We do not really put emphasis on practical learning, For example, when we teach about motor mechanics, we do not really go deep where students actually learn and then go and carry out practicals that show motor mechanics (Rick, TT).

According to Rick, one effective way of teaching physics concepts is through practical work. However, from his experience, many times science teachers just explain concepts through written notes.

5.4.3 Theory with Whole Class Demonstration

Some of the participants mentioned the use of class demonstrations when they shared their views on teaching of physics concepts. For example, Brad said, “*one way of teaching physics concepts is teaching the content with a simple demonstration*” (Brad, PT).

From his own experience Hans admitted, “*I do demonstration with whatever material available to appropriately explain the concepts*” (Hans, PT). One can infer that Hans admitted to use class demonstrations to further explain physics concepts only when materials or equipment are available in his school or classroom.

Similarly, when asked about how he taught physics concepts in his science class, Mano said “*I tell the students and demonstrate the concepts*” (Mano, PT).

In referring to demonstrating the physics concepts, Mac who is also a practising science teacher said “*currently I teach theories... as well as demonstrations. I want to try and make the abstract concepts to be more concrete to the students*” (Mac, PT).

According to Mac, using demonstrations to teach physics concepts help learners to construct concrete ideas from abstract concepts learnt in theories. Kris one of the

trainee science teachers shared this same experience. She said *“one other way I teach physics concepts is by demonstrating whatever actions the lead to show the concepts. That is one of the ways to teach the whole class (Kris, TT).*

This qualitative finding indicated some participants had the view that conducting whole class demonstrations is one effective way of teaching physics concepts to learners.

5.4.4 Theory with Multiple Representations

Another view that emerged in the qualitative findings was the use of multiple representation. Many participants did not use the term multiple representation in their responses, but some mentioned the use of different teaching aides. For example, when talking about the effective ways of teaching physics concepts, Pitt said:

With theory classes...teach concepts and principles supported with teaching aide like charts, audio-visual lessons and computer modules...through videos and TV...use prescribed text books with illustrations for students to read (Pitt, PT).

Pitt did not mentioned the term multiple representation. However, he referred to the use of different types of teaching aides such as charts, videos, and text books with illustrations. Having a similar view as in teaching using multiple representation, Jeff stressed that *“effective ways is when a teacher... present them (physics concepts) in a number of ways” (Jeff, PT).* While Jeff did not articulate what he meant by ‘a number of ways’, one can infer that he was referring to the notion of presenting physics concepts using multiple representation. Likewise, while talking about ways of teaching physics concepts Jen said, *“I think through teaching, visual aid like charts and diagrams, documentary videos” (Jen, PT).*

This qualitative finding indicated that some of the participants shared the view on using multiple representation for teaching physics concepts. While the term multiple representation was not directly mentioned by the participants, it can be inferred that their views indirectly suggested the use of different forms of representations. This view is supported by the quantitative findings in Table 4.2. It is also related to the representation framework of concepts and conception presented in subsection 2.3.2.

5.4.5 Theory then Exercises, Tests and Short Quizzes

The qualitative findings indicated that giving exercises or problem solving tasks after theoretically teaching physics concepts is effective. This view was mentioned by some participants. For example, when responding to questions on effective ways to teach physics concepts, Mano said “*theory then give relevant exercises at the end... tests, and short quizzes also help in teaching physics concepts*” (Mano, PT).

According to Mano, to help learners understand physics concepts, it is effective to give learners relevant exercises or tasks as well as tests and short quizzes. In other words, after theoretically teaching physics concepts it is effective to give related written exercises or tests and quizzes to help learners affirm their understanding of the concepts. Likewise, Mac a probationary science teacher said “*I also give class exercises and go through the answers in the class*” (Mac, PT).

With regards to giving tests, Jeff indicated that one way of teaching physics concepts is through testing what learners had learnt. He said, “*one way I teach physics concepts is by testing them (learners) to show what they have learnt*” (Jeff, PT).

Pitt one of the experienced practising science teachers pointed this as one of the ways he taught physics concepts in his class. He said “*one way I teach physics concepts in class is I use probing of questions to learners*” (Pitt, PT).

It can be inferred that Pitt was referring to asking probing questions whereby learners’ response may indicate their level of understanding of physics concepts. Hence, a teacher can identify learners’ level of understanding against what is intended in the learning outcome. Whether the probing questions were given as written or oral tasks, how learners articulated their responses can provide an indication of their understanding of the physics concepts. That inferred, this view of providing exercises, tests, short quizzes and probing questions to learners following the teaching of physics concepts was not fully articulated by the trainee science teachers and other practising science teachers who were interviewed. This may indicate that most participants did not fully associate teaching to giving exercises, tests, quizzes and probing questions.

5.4.6 Use of Analogy and Stories

The qualitative findings indicated that use of analogy and stories can also be used for teaching physics concepts. In fact, only a few of the participants highlighted this view. For example, Hans said that *“sometimes I tell small stories to explain the concepts. Students can imagine the story from their experiences and picture the concepts”* (Hans, PT).

One can infer that Hans had the view that stories help learners to imagine using their own experiences that relates to the story. As such, learners can mentally construct the physics concepts by making connections between the story they heard in class and their own real life experiences. Pitt shared the same view, he said, *“I use analogy like a small story to set the stage for imagery”* (Pitt, PT).

Apart from Hans and Pitt, other participants did not mention this view on telling stories and analogy as one effective way of teaching physics concepts. That said, the view that Pitt and Hans mentioned is associated with idea of further explaining as well as enabling learners to make imagery connections between real life experiences and intended physics concepts. Pitt and Hans did not mention stories with respect to the historical accounts of how the physics concepts were developed. However, they were the only two participants that indicated stories and analogy can be used for teaching physics concepts.

5.4.7 Group and Class Discussion

One view indicated in the qualitative findings with regards to teaching physics concepts was group or class discussions. It was viewed that group and class discussions can help learners to learn from others comments and feedbacks to collectively construct physics concepts. Such a view was shared by Pitt, Mano and Brad. For example Mano said:

I tell students and sometimes discuss with the learners about science concepts. Discuss about what is really happening in real situation where we can apply the concepts (Mano, PT).

Mano stated that he sometimes discuss with learners in his class about concepts. In particular, he mentioned that they discuss the concepts are really happening in real situations where learners can relate to or make imagery connections to. Added to that, Pitt said, *“I teach physics concepts in class... sometimes I use oral discussions like teacher with students and students with peers”* (Pitt, PT).

Pitt referred to two types of discussions. One is between teacher and learners and the other is between learners themselves. In other words, Pitt mentioned that discussions to construct better understanding of physics concepts can take place between teacher and learners as well as learner and learners. Brad also said that *“one way I teach physics concepts is discussion. Questions and answers probing critical thinking”* (Brad, PT).

One can infer that the discussion Brad was referring to encompass the exchange of questions and answers which in turn should probe learners to think critically. It can also be inferred that Brad was referring to the question and answer interaction between, teachers and learners as well as between learners themselves. According to this view, group discussion can help learners to develop critical thinking process as well as construct better understanding of physics concepts.

In sum, these qualitative findings indicated that the majority of participants had knowledge on teaching and learning of physics concepts. The participants perceived that physics concepts can be taught and learnt effectively using theory with: real life examples; practical work; demonstration; multiple representations; exercises, test and short quizzes; stories and analogies; and group and class discussions. Some the participants' views and experiences on the effective teaching and learning of physics concepts are related the findings on the importance of science in Section 5.3. However, the findings in this section suggested that the majority of participants were not able to articulate and use appropriate terms such as multiple representations and scaffolding for conceptual and procedural learning. As such, it is imperative to further enhance science teachers' knowledge on teaching and learning of physics concepts regarding the SBA of practical work.

As outlined in subsection 1.7.4, the science SBA in the context of this study involved the use of practical work to assess learners in science education. Hence, the

participants' views and experiences on SBA in this study were related to the use of practical work as practical assessment activities.

5.5 Perceptions on School-Based Assessment of Physics Concepts

The qualitative findings on participants' perceptions about the SBA of physics concepts are presented under the following emerging themes: (i) assess understanding and application of concepts; (ii) assess problem solving skills in science; (iii) assess knowledge and skills; (iv) assess more topics or concepts; (v) assess relevant topics to daily lives; (vi) use both formative and summative assessments; and (vii) different aspects of formative assessments. The first five emerging themes suggested different aspects of assessment while the last two indicated additional assessment strategies to the SBA of practical work.

5.5.1 Assess Understanding and Application of Specific Concepts

The qualitative findings indicated that the majority of participants had the view and experience that SBA should be used to enhance and assess learners' understanding of physics concepts as well as other science concepts. For example, Pitt said:

The main things students should learn and be assessed for in SBA of physics are: Theory, the concepts and principles. This is the subject content knowledge which is connected with principles (Pitt, PT).

Pitt shared the view that learners can use the SBA to learn as well as assess their understanding of physics theories, concepts and principles. In fact, Pitt stressed that “*aspects of students learning in physics which are important to assess are their theoretical knowledge and understanding*” (Pitt, PT)

Similar to that, when sharing his view about the use of practical work in SBA, Brad said:

SBA should be use for learning and assessing the application of scientific concepts in the experiments... SBA should be used as a medium or tool to emphasize physics concepts. SBA tasks help students connect abstract concepts with the environment around them (Brad, PT).

Brad had the view that SBA can be used for learning as well as for the assessment of learners' understanding and application of scientific concepts. Further to what Pitt and Brad emphasised, Jeff said:

I think SBA practical enhances students understanding of the physics concepts... students are able to prove physics concepts that were presented during theory sessions... It is interesting to see the amazement in their eyes when they were able to discover concepts through their own experiences (Jeff, PT).

It can be inferred that Jeff had the view that using practical work in school-based assessment enhances learners' understanding of physics concepts. In other words, learners can enhance their understanding by discovering the concepts through practical experiences. Further to that, Jeff said:

What is important is the assessment of students' performance in their application of physics concepts, from which their ability can be identified and acted upon (Jeff, PT).

Jeff had the view that assessment of learners' performance in practical work should demonstrate their understanding of concepts. As such, according to Jeff, learners' level of understanding can be identified through their performance and further learning can take place. This view is similar to Mano's view. He said:

Assessment should focus on areas where learners least understand. I mean, we need to assess what learners find hard to understand. I think assessment should help them learn more because they correct their mistakes and they will learn more (Mano, PT).

With a slightly different view, Mac suggested:

The students should be assessed on their understanding of the concepts they learn...I would like to use SBA to determine the level of understanding that students have about physics concepts. (Mac, PT).

According to Mac, SBA should be used to assess learners understanding of concepts that they have already learnt theoretically. Likewise, when talking about the important aspects of SBA for learners Andy said:

We must make sure to assess the application side of it, maybe as a group or individually. So that we actually know whether students are confident to apply the theories they learn in class. That is one thing we should consider when assessing students on (Andy, TT).

It can be inferred that Andy had the view that the SBA of practical work is mainly to assess how learners already understand and able to apply theories and concepts in practical work.

On the whole, these findings indicated that the SBA of practical work should be used to assess learners' understanding and application of scientific concepts. In this regard, two views were highlighted. First view indicated that the SBA of practical work can be used to enhance learners' understanding and application of scientific concepts while the second highlighted the view of proving what was already learnt.

These qualitative findings contradicted the main aims of the SBA curriculum in Year 10 and Year 11 science in Solomon Islands School Certificate (SISC). As highlighted in subsection 1.7.4, the overall aim for the SBA for SISC is to assess skills necessary to science that cannot be assessed in written examinations. The skills include: observations, follow instructions, collect, record and communicate data, interpret and respond to questions related to experimental data as well as draw valid scientific conclusions (see Appendix A, Section 2.0). Contrary to these aims, the participants primarily perceived that assessment of learners' understanding of physics concepts should be assessed. In addition, participants viewed that the learners' problem solving skills in science should also be assessed. This is presented next as another emerging theme.

5.5.2 Assess Problem Solving Skills in Science

The qualitative findings indicated that participants perceived that SBA should be used to assess learners' problem solving skills in science. Although, this view relates to the

significance of science education outlined in subsection 5.3.3, only three practising science teacher participants mentioned this. For example, Pitt stated:

Things student should be assessed for in SBA of physics are practical skills. Application - consider Blooms taxonomy in questioning, like remembering, understanding, applying, analysing and evaluating (Pitt, PT).

Pitt was referring to one of the models of Blooms Taxonomy on different levels of cognitive ability. Hence, Pitt exemplified practical skills as a hierarchy of learners' ability to first remember then understand, apply, analyse and evaluate what they experience in practical work. Pitt further elaborated:

Physics SBA is worthwhile because students have the opportunity to experience and enhance practical skills along with establishing and connecting theory and practical opportunities. That is seeing is believing (Pitt, PT).

It can be inferred that Pitt related practical skills in science to the ability of learners to establish links between what was experienced to theories in science. It can also be inferred that Pitt referred to Blooms Taxonomy of cognitive levels of ability as procedural skills that learners should develop and demonstrate in the SBA. Similar to the view that Pitt had, Brad also mentioned:

I think problem solving skills and applied knowledge of content are important aspects of physics learning that should be assessed. That is critical thinking (Brad, PT).

Brad articulated problem solving skills and applied knowledge of content as important aspects of physics learning that should be assessed in the SBA. This encompassed the ability of learners to understand, apply, analyse and evaluate data as well as information related to scientific theories and issues. Similar to this view on assessing skills to solve problems, Jen commented:

Students should do extended investigation research and construction of models in physics for SBA. More of coming up with a question or problem

they experience and planning how to look for solutions. This kind of process is important for students learning in physics (Jen, PT).

It can be inferred that Jen also shared the view that learners' problem solving skills are important to assess in the SBA. That is, learners should demonstrate their ability to identify a science related problem then plan and design an investigation to find solutions. According to Jen, such process is important for learners to learn and be assessed for when doing practical work in the SBA. Subsequently, it can be inferred that, the assessment of problem solving also involves the assessment of both the knowledge and skills in science.

5.5.3 Assess General Knowledge and Practical Skills

The qualitative findings indicated that participants had the view that SBA should be used to assess learners' knowledge and skills in science. This finding is similar to the view on assessing learners' understanding and application of science concepts. However, it is imperative to present this finding as an emerging theme since it relates more to general knowledge of facts in science and basic skills in doing practical work. This view was evident in the responses of the participants. For example, Rob said:

I think knowledge and skills aspect of physics learning should be assessed. For example, they could look at if you can plan and make a small motor that can generate electricity. You can plan and talk about it or elaborate or write about it then ok they can say that they can assess you on that. So knowledge is there and the skills that you can demonstrate is there to assess (Rob, TT).

Rob had provided the example of making a small electric motor to illustrate what he meant by assessing learners' knowledge and skills. It can be inferred that according to Rob, learners could demonstrate their knowledge by how they plan and write about the physics behind the generation of electricity in the electric motor. As well, skills can be demonstrated by assembling the motor in order to generate electricity. On the same vein, Rick suggested:

The other part we can assess is the assessment of their application of the theories, the practical aspect. So it is good to assess both the knowledge

and skills. Knowledge basically is about the theories we gave them and skills basically the application of the knowledge or practical part (Rick, TT).

According to Rick, knowledge is basically theories in science and skills are the application of the knowledge. One can infer that Rick's view about theories in science encompasses the knowledge of facts as well as systems of concepts that can be practically demonstrated and logically explained. Subsequently, according to Rick, the demonstration of applying the knowledge in practical work involves skills. It can be inferred Ricks was referring to procedural as well as skills in handling practical work.

In regards to handling skills, Jen said "*assess understanding of concepts and handling skills as well as skill to follow lab procedures and come with conclusions (Jen, PT)*". It can be inferred that, according to Jen, understanding of concepts and handling skills are inseparable. Similar to Jen, Mano also stressed that SBA should be used to "*assess the concepts they already learn and skills too. Skills for observation and drawing conclusion from practicals*" (Mano, PT).

It can be inferred that Jen and Mano emphasised the view that the SBA of practical work should assess learners' knowledge of concepts that they had already learnt as well as other different skills such as: handling skills; skills to follow procedures, skills to observe; and skills to draw conclusions. One can infer that, according to Jen and Mano, drawing conclusion may be seen as the ability to make connections between what was experienced, observed and collected during practical work to the domain of scientific theories and concepts. In fact, when talking about making connections Hans said:

It is important to assess students' explanation of concepts to make sure it is correct as well as the correct use of formulas. The formulas are proved so it is important for students to learn and be assessed. Because many problem in physics can be solved with using correct formulas. Apart from correct formulas, explanation of concepts must be correct as well, yes so we need to assess them on that (Hans, PT).

Basically, Hans shared the view that explanation of concepts with respect to relationships as depicted in formulas are significant to assess. In other words, one can

infer that Hans' view is associated with the practice of verifying relationships of different entities in practical work. Hence, drawing conclusions may involve explaining relationships demonstrated in practical work. This should include explanations that theoretically connects information from practical work data, graphs and tables to formulas of scientific concepts.

On the whole this qualitative finding continues to suggest that assessment of understanding concepts in relation to different skills in doing science cannot be separated. This also contradicts the overall aim of the Solomon Islands science SBA for Year 10 and 11.

5.5.4 Assess More Topics (Scientific Concepts)

The qualitative findings indicated that participants perceived that the SBA of practical work should include many topics in physics since the SBA comprised only three practical assessments for each science subject. This view was shared by both trainee and practising science teacher participants. For example, Mano said:

My view is to have more practicals because there are many physics topics covered but only one or two applied in the SBA... I think all the topics in physics are vital thus SBA should give fairly on each topic. I mean SBA should assess each topic or concepts. Maybe there is no time but it is good to make a fair assessment on all the topics because all are vital (Mano, PT).

This view is consistent with the views shared on the significance of science. That is, most participants perceived that practical work in science education is important for the development of learners' understanding of scientific concepts. Hence, practical work should include many topics or concepts. Similar view was expressed by Rick. He said:

Using my experience concern the SBA of physics. I think I also realise that they have been putting the same content over the years in our SBA. I said this because, in physics we have many areas or topics that we talk about in form 4 and form 5. From my experience I have seen that they repeat the same content yearly. Even they took a long period of time to revise the

SBA. I think it is good to shorten the time for reviewing the SBA information so that students can cover different contents at short period of time and be assessed rather than keeping a long period of time and repeating the same assessment (Rick, TT).

According to Rick, although many topics or physics concepts were covered in the science syllabus for Year 10 and 11, only the same concepts were included in the SBA of practical work over a long period of time. Hence, it can be inferred that Rick perceived the SBA of practical work should include more topic and concepts. A similar experience was echoed by Andy. He exemplified:

So that is the truth about having one SBA for a long period of time. Like the SBA of pressure had been done since 2010, I think the last year (for the topic of pressure) is this year (Andy, TT).

Hans elaborate further on this view as well. He said:

All concepts in physics topics should be used in the SBA. Thus, one different concept for each year. It is not good to repeat the same concept every year in the SBA. There are many concepts so assess all the concepts. So different concept this year and next year another different one. This will also avoid copying by students coming after the next year (Hans, PT).

According to Hans, the school-based assessment of practical work should assess different scientific concepts every year. This would also avoid current learners from copying practical work reports from previous years. Hence, more scientific concepts should be assessed in the SBA. In the same vein, Hans continued to stress:

I think there needs to be equal number of physics assessment as chemistry and biology. For the designed practicals are ok. It is the investigations and library research topics that I see are not equal. Many are chemistry and biology topics. Because many are about the environment. Physics topic is less, only research topics like hydro power generation (Hans, PT).

Hans, perceived that the number of practical work relating to physics concepts should be the same as for chemistry and biology. This view indicates that, assessments relating to physics topics and concepts are not equal to other science disciplines.

On the whole, this qualitative finding suggested that the SBA of practical work should include more physics topics and scientific concepts. This finding supports the view that practical work is significant for the development and assessment of learners' understanding of scientific concepts. This is again inconsistent with the overall aim of the Solomon Islands science SBA curriculum of the assessing skills that are not possible to assess through written examinations as outlined in subsection 1.7.4.

5.5.5 Assess Topics Relevant to the Country and for Use in Daily Livelihood

The qualitative findings also indicated that participants perceived that the SBA should be used to assess science topics or concepts that are relevant to the country as well as for learners' to use in their everyday livelihood. For example, Mac commented:

For me I think students should be assessed on the concepts in science which are relevant to use in our country. Something concrete and not abstract or rather a concept used often in our daily lives but not realised (Mac, PT).

According to Mac's view, the SBA of practical work should focus on assessing scientific concepts that are relevant to the context of Solomon Islands. Mac also stressed that, the scientific concepts should be useful to learners' everyday livelihood. He referred to concepts that learners experience daily yet did not realise they are scientific concepts. With the same view, Jeff said:

Main things that students should learn and be assessed for in SBA of physics are the concepts that, through their experiences from the assessments, will help them acquire knowledge and skills that they can benefit from as they progress through formal education or life in general. Example, the science skills and knowledge that they can use every day or during their lives (Jeff, PT).

One can infer that Jeff's view is related to the notion that the SBA of practical work should include knowledge and skills in science that are relevant to learners' everyday livelihood. While Jeff and Mac did not articulate or name the kind of knowledge and skills in science that should be assessed, their point of view is related to the perceptions

reported in subsection 5.3.1, that is, to develop learners' understanding and skills in science for use in their everyday livelihood. It can be inferred that this view is linked to the views expressed in the importance of science education, especially in the context of Solomon Islands. Added to that, this view resonates with the majority of participants who indicated that they were confident in using familiar everyday examples to explain physics concepts, as presented in subsection 4.3.1.

5.5.6 Completing the Curriculum

The qualitative findings indicated that science teachers facilitated the SBA of practical work in science specifically to complete the curriculum requirements. While sharing his view on meaningful SBA in science education Rick said:

We should make sure that our SBA is meaningful to all Solomon Islands schools not only to schools in Honiara that have access to labs. If that is the case, then some of our schools like in Tikopia (an Island in eastern Solomon Islands), we will not be able to fulfil the SBA requirements. We do not have any hydrochloric acids or things like that. I think this affects all SBAs in science (Rick, TT).

One can infer that Rick was referring to the designs of the SBA tasks that should be fair to schools in all parts of Solomon Islands, not only in Towns or urban centres. He voiced that requirements of the SBA curriculum may not be fulfilled if the designs do not consider schools in the rural contexts. This view suggests that it is significant to complete the requirements of the curriculum. On that note, Brad stressed “*well SBA is only done barely as an assessment task to meet the MEHRD (ministry of education) requirements given to schools*” (Brad, PT).

The way Brad stressed his view suggests that the SBA tasks were designed basically to fulfil the requirements by the Ministry of Education and Human Resources Development (MEHRD) in Solomon Islands. It can be inferred that, Brad perceived that the SBA should go beyond this notion of completing MEHRD requirements. Added to that, when commenting on completing the SBA curriculum requirements, Andy explained:

Some information in our science curriculum are out of date. Especially if we look at the information in the science content and compare them with our current world today. There are some information that we teach which I usually tell my students that they are out of date. But for the sake of curriculum if someone ask you a question on this, just tell them what you know...So I want the curriculum to have some changes. (Andy, TT).

It can be inferred that Rick saw a need to design assessments tasks such that schools can fulfil the requirements of the SBA in science. However, one can also infer that Brad's and Andy's comments suggest that the SBA of practical work should not be done only to complete the curriculum. This finding suggests that the SBA of practical work can be utilised further than just completing the curriculum.

5.5.7 Use both Formative and Summative Assessments

The qualitative findings indicated that majority of participants expressed the importance of using both formative and summative assessments in the SBA of practical work. For example, Brad explained:

All forms of assessments can be a tool in helping the students learn physics concepts if done in the right way to enhance learning. I think summative and formative assessment should be done not only for just assessment purposes but should be aligned with students learning of physics concepts (Brad, PT).

Brad emphasized the notion that one of the purposes of assessment is to support learning. Hence, both formative and summative assessments are important for learners' learning of physics concepts. Jeff also commented:

Well, if the primary purpose of assessment is to support high quality leaning, then formative assessment is the most effective assessment practice... By contrast, summative assessment is the attempt to summarize student leaning at some point in time, say at the end of a course (Jeff, PT).

Subsequently, Jeff concluded "we need both formative and summative SBA. Formative SBA used as guidance to improve their summative SBA for assessments" (Jeff, PT).

Hence, according to Jeff, both formative and summative assessments should be used in the SBA of practical work. Similarly, Pitt emphasized:

My views about formative and summative assessment in student learning. Well both are equally important and must be given equal opportunity. The actual application, implementation and mentoring must be considered by teachers (Pitt, PT).

When talking about formative and summative assessments, Rick also stressed:

Both are important and we should have balance. All along summative assessment should reflect from your formative assessment because formative gave you feedback. Because if you do not keep track on your students work and your own teaching then you will end with your summative assessment which either will very poor or something like that (Rick, TT).

However, although this view of using both formative and summative assessment were seen as equally important, from his own experience with the SBA of practical work Hans reported:

So far we always use summative assessment but it is usually at the end of each topic. Formative assessment should be practiced and applicable in all lessons (Hans, PT).

Basically, Hans reported that summative assessments had been predominantly used. This was also raised by Rick. He said:

I think common practice in our schools is always summative. At the end of the semester we give exams to our students. Formative, I think is one very important area that many of us teachers over looked every time (Rick, TT).

It can be inferred that although majority of participants agree on the use of both formative and summative assessments in the SBA of practical work, summative assessment was predominantly used and experienced. According to purpose of this study, it is imperative to highlight the notion of using both formative and summative assessment in the science SBA of practical work. Retrospectively, the purpose of this

study is to enhance science teachers' PCK for use in implementing both formative and summative assessments in the SBA of practical work.

5.5.8 Different Aspects of Formative Assessment

While the majority of participants perceived that both formative and summative assessments are equally important, the qualitative findings also indicated that some participants emphasised different aspects of formative assessment. Some participants perceived formative assessment as a feedback interactive process during learning while others perceived it comprises feedback from continuous summative assessments. For example, Hans explained that *'formative is questions and answers during lessons. Right, giving feedback to students is formative (Hans, PT)*. According to Hans, formative assessment involves questioning and answering during class time. In the similar vein, Mac emphasised:

Formative assessment is very effective for learning science. It is a better way to assess understanding of science since it is more interactive during the process of learning (Mac, PT).

Having a similar view, Jeff said:

... Formative assessment occurs when teachers feed information back to students in ways that enable the students to learn better, or when students engage in a similar, self-reflective process. It has been proven through research that formative assessment is a powerful means to improve students' learning (Jeff, PT).

Mano also explained:

Yes, when teacher discuss with students that is formative assessment. So teacher asking and students answering questions when discussing... Formative assessments really help and assist students learning more effectively (Mano, PT).

With the same view of interaction by asking and answering, Rob further pointed out:

Maybe formative assessment can be used when you start at the beginning of a class, without teaching or going into the main content or concept. You ask the students from the start, then they respond, then you can see, oh this is their level of understanding. Then you can also come in during teaching, like in the middle of the lesson you can come in and ask questions or when you go past during experiment and ask to cross check their understanding. So the interaction during the lesson is formative (Rob, TT).

According to Rob, formative assessment can also take place during practical work. He suggested that teachers can interact with learners by asking questions during practical work in order to identify learners' level of understanding. With a similar view, Rick said:

I think formative is basically to give feedback to students, mainly verbal. Right feedback on what are the learning level of students in physics for example. If we do not give formative assessment to our students we would not have the knowledge about the learning levels of our students. So I see formative assessment is a continuous thing. (Rick, TT).

It can be inferred that Hans, Mac, Jeff, Mano, Rob and Rick shared the view that formative assessment is interactive and involves asking questions and answering during the process of learning. Their views suggest that formative assessment is mainly a verbal interaction between teachers as experts and learners as novices. However, Jen and Andy shared a different view about formative assessment. For example, commenting on formative assessment Jen said:

It is an important and effective strategy to improve students' performances. Provided that teachers provide a mile checkpoint schedule to give guidance for students' progress. I mean formative SBA is important for students' progress to finally do their summative SBA. Mile checkpoint schedule is a plan to do formative SBA with students. Do small practicals and tests to check students' performance and provide feedback (Jen, PT).

Jen was referring to formative assessment as a small practical work and test. Jen did not describe what she meant by small practical work. However, it can be inferred that small practical work may mean practical activities that are not used for the SBA. This

may suggest that Jen's view of small practical work was influenced by the context of the SBA outlined in subsection 1.7.4 that regarded the SBA as a major component of science assessment for learners' in Solomon Islands. Thus, Jen may have perceived small practical work as class activities that can be used as check points to assess and monitor learners' progress towards the main summative assessment in the SBA. Besides, she also mentioned tests as a form of formative assessments. On the same note, Andy also commented:

I can say that formative assessments are continuous assessments which are done according to courses. Like as long as one unit is complete then you give whether an assignment, unit test or a quiz or homework. Those are counted to go towards the final grading of students (Andy, TT).

Andy continued to express:

Right formative assessment also help us to produce progressive reports for students' academic progress. Like maybe after a quarter or three months then we can have something like the teacher student interview. Call the student in and tell him or her. Oh for the first three months you have this graph, then you draw a graph for the student's performance, this would help student to progress academically. Then at the end of the semester we can give one big final examination which covers every unit from the beginning of the semester, yes that is summative assessment (Andy, TT).

Andy suggested that continuous summative assessment can be regarded as formative assessments that would help inform the progress of learners as well as for teachers to prepare for the final or main summative assessment. Andy further justified his view by explaining:

...if we do not have proper formative and then just give summative at the end then it will not reflect well the students' performance in schooling. This is because summative in some sense, I see it as though we are trying to test how much the students remember. Because if one does not think of some concepts then they would just forget about it at that time. Otherwise, one understands the concepts but needs some time and ability to recall the concepts (Andy, TT).

Andy's explanation suggests that having formative assessment as continuous summative assessment would avoid learners from trying to recall many science concepts right at the end of a school term or year. While this view relates to the use of summative assessment results to inform both teachers and learners for further progress, Bell (2007) argues that this is a weak form of formative assessment.

In sum, these qualitative findings suggested that the science SBA of practical work should be utilised to assess learners' understanding of concepts, problem solving and manual skills. The qualitative findings inferred that knowledge of concepts and necessary skills in science are inseparable. This contradicts the overall aim of the Solomon Islands science SBA aim of assessing the skills only. In regards to assessing concepts, the qualitative findings suggested an increase to the number of topics or concepts to be assessed as well as their relevance to daily lives. In addition, the use of both formative and summative assessments in the science SBA was indicated by the participants. This qualitative finding corresponds with the quantitative findings in subsection 4.3.4 which indicated that the majority of participants had used the SBA for both formative and summative assessments. However, the qualitative findings indicated a need to enhance science teachers' understanding of the nature of formative assessment. This is an important point to consider in regards to the guideline for enhancing science teachers' PCK for use in the SBA of practical work.

5.6 Perceptions on Pedagogical Content Knowledge of Physics Concepts

The qualitative findings suggested that some participants had diverse views on the definition as well as what comprises PCK. The diverse views are presented in the following emerging themes: (i) knowledge of content and application; (ii) ability to teach and teaching methods; (iii) knowledge of learners learning; (iv) ability to conduct effective learning; and (v) a set of procedures to teach.

5.6.1 Knowledge of Content and Application

The qualitative findings suggest that some of the participants viewed PCK as a knowledge of content or an understanding of content and its application. For instance, when referring to PCK, Rick commented:

I think it is like the process of understanding the content or things like that in a specific area. So yes, it is more our knowledge and understanding of contents in a specific area (Rick, TT).

Similarly, when talking about PCK, Nan said:

To me PCK is something to do with understanding what you are going to teach. So science teachers should have understanding about what to teach in science education. I think it is about how or our knowledge about the content. Their subjects in science (Nan, TT).

Kris also shared the same as Nan and Rick. She added:

What I think about the term PCK. Yes, I myself must have the content knowledge about whatever I am going to teach. When I teach it, I must relate whatever I have, apply the various knowledge I have towards whatever subject or content knowledge (Kris, TT).

One can infer that Kris's view about PCK encompasses the knowledge of content as well as how to apply that knowledge in the classroom. Although Kris did not articulate what she meant by applying the content knowledge, she suggested that PCK includes the application of content knowledge. In other words, Kris perceived that science teachers should have the ability to demonstrate their content knowledge when they teach. It is evident here that these three trainee science teacher participants - Rick, Nan and Kris shared this view. Besides, Mac, one of the practising science teacher participants had the same view. When commenting on PCK, Mac said:

I think this is important for teachers. Teachers must have good content knowledge about their subject. To teach abstract concepts and make them concrete for students to understand is vital for teachers (Mac, PT).

According to Mac, PCK comprises content knowledge as well as the knowledge to transform abstract concepts into concrete forms that learners can comprehend. Andy also shared this view of having content knowledge as well as the knowledge of applying the content. He stressed:

Pedagogical Content knowledge in my personal understanding, is the application of the knowledge. Like how you apply the knowledge you have in terms of teaching. Like in the text books, concepts are there, only the applications and understanding the content (Andy, TT).

Andy did not articulate what he meant by application of knowledge. However, one can interpret that Andy shared a similar view as Mac. That is, science teachers should have the knowledge to transform abstract concepts to be more comprehensible to learners. This may mean, the knowledge and ability of science teachers to deconstruct concepts into its smaller constituents that learners can be able to conceptualise into their existing schema. This qualitative finding indicated that some of the participants had a partial perception about the nature of PCK. Hence, it is significant for the purpose of this study to enhance science teachers' understanding about PCK.

5.6.2 Ability to teach and knowing teaching methods

The qualitative findings indicated that some of the participants perceived PCK as science teacher's ability to teach and knowing the teaching methods. Hence, unlike the view on application of knowledge, participants indicated teachers' skills and teaching methods as PCK. For instance, Jim said "*I think PCK is basically your ability to teach what you are trying to bring across in terms of knowledge. So what I think is, it is all about our ability*" (Jim, TT).

Having the same view as Jim, Nan also commented on the term pedagogical. She said:

About how we can teach a particular curriculum or subject content. That is pedagogical, your knowledge about teaching, skills that you may apply, how you can put across what you want to teach, how you can teach concepts (Nan, TT).

It can be inferred here that Nan had a view that relates to the integrated model of PCK that was depicted in figure 2.4 (b) in subsection 2.6.1. That is, Nan had emphasised the term pedagogical which she explained as the knowledge about teaching. Besides, she also had the view that knowledge of content is PCK. In this regard, one can infer that Nan's views were associated with the basic meaning and interpretation of the terms pedagogical and content. However, according to Gess-Newsome (1999), PCK

is more complex than just the general view on combining knowledge of content and pedagogy.

5.6.3 Knowledge of learners' learning

When sharing his view on PCK, Pitt, one of the practising science teacher participants mentioned that teachers should have knowledge about learners' learning. He stressed:

It is better to target different learning abilities in students. Students have different learning abilities and teachers should know that (Pitt, PT).

Pitt highlighted that learners have different learning abilities and science teachers should have a knowledge about learning as well as their learners' learning styles. One can interpret that, according to Pitt, science teachers' PCK encompasses the knowledge about different learning abilities as well as the knowledge on how to address these differences. While Pitt did not articulate other knowledge components, his view indicated that science teachers' knowledge of learners' learning can be regarded as a component of PCK.

Although, only one participant mentioned this view, this qualitative finding is significant to the purpose of this study since it relates to one of the quantitative findings on knowledge of learners' preconceptions and misconceptions reported in subsection 4.3.2. Since only one participant mentioned this view, it can be assumed that not many participants thought of this knowledge as part of PCK. Correspondingly, quantitative findings indicated low internal consistency for survey participants' responses on the scale on knowledge of learners' understanding of physics concepts in subsection 4.3.2. As reported in subsection 4.3.2, other studies such as Jang (2012) also found that many science teachers could not fully understand learners' learning as well as learners' preconceptions and misconceptions. This is imperative for the purpose of this study to enhance science teachers' knowledge components of PCK.

5.6.4 Ability to Conduct Effective Learning

Some participants in the qualitative findings pointed out that PCK is the means to carry out effective learning for learners. Jeff one of the practising science teacher participants, said "*PCK are the means through which the teacher organises his work*

and monitors the students to maximise their learning” (Jeff, PT). One can interpret that Jeff regarded PCK as an ability for science teachers to organise and carry out effective teaching, learning and assessment. Jeff further illustrated his view by saying:

Yes, I always try my best to equip myself with necessary knowledge and skills to teach and assess physics concepts with confidence to attain the ultimate goal of effective learning in students. (Jeff, PT).

Jeff’s view suggests that PCK comprises the necessary knowledge and ability to effectively conduct the process of teaching, learning and assessment. He emphasised that, science teachers should be equipped with appropriate content knowledge, skills as well as knowledge to teach and assess physics concepts with confidence in order to facilitate effective learning for learners.

Brad shared a similar view about PCK. He explained that PCK is teachers, “*knowledge of the environment around, knowledge of the physics concepts and how to impart science concepts and science knowledge to the students” (Brad, PT).* This suggests that, Brad regarded PCK as a combination of different components of knowledge that science teachers should have. He specifically, mentioned, knowledge of the environment, knowledge of physics concepts and knowledge of pedagogy. Although Brad’s and Jeff’s views about PCK seemed different, one can infer that they emphasised a similar notion. That is, both participants pointed out the need for science teachers to have a combination of different knowledge components to effectively teach and assess learners learning process.

5.6.5 A Set of Procedures to Teach

Rob one of the trainee science teacher participants had the view that PCK is a set of procedure to teach. When commenting on his view about PCK, he said:

When I heard about PCK. It is about, may be they say a way or format to achieve the level or knowledge that they want to disseminate. It is a sort of format (Rob, TT).

This response indicated that Rob had heard about PCK. However, it can be inferred that Rob was not sure about the nature of PCK or what it comprises. As such, he said,

‘maybe they say a way or format to teach’. One can infer that Rob used the word ‘they’ to refer to teacher educators or lecturers or education providers. According to Rob’s view, PCK is a set of procedures that teachers can use for teaching. This view suggested that the nature and definition of PCK was not clear to Rob. Although only Rob shared this view, it is significant to the purpose of this study since it also indicates a lack of knowledge about PCK.

On the whole, these qualitative findings indicated that the majority of participants had partial knowledge of PCK. In fact, the majority of participants mentioned one or two components of the knowledge combination that comprises PCK. This suggests that although the majority of participants had some knowledge about PCK, most could not articulate what it comprises or describe its nature. In saying that, some participants pointed out components of PCK that science teachers should develop in order to effectively facilitate the process of teaching, learning and assessment of physics concepts. Some of the knowledge components mentioned by the participants are related to the ones outlined in subsection 2.6.1. That said, these qualitative findings are inconsistent with the high Cronbach’s Alpha reliability for scale four in the quantitative findings in subsection 4.3.4. In other words, although the quantitative findings indicated that the majority of participants had views and experiences about PCK, the qualitative findings suggest that some participants find it difficult to articulate the definition and nature of PCK.

These qualitative findings are necessary for the purpose of this study. Retrospectively, this study was sought to develop a set of guidelines to enhance science teachers’ PCK for use in the SBA of practical work in science education. Subsequently, participants were also asked to share their views and experiences on science teacher training and ongoing professional learning.

5.7 Perceptions on Science Teacher Enhancement

The qualitative findings indicated a need to enhance both science teacher pre-service training as well as on-going professional learning. As such, the qualitative findings in this section are presented with views and experiences regarding science teacher pre-service training first, followed by views and experiences about on-going professional learning. Finally, findings on other aspects pertaining to the SBA of practical work

that require improvement are presented. These qualitative findings are related to research question four and five.

5.7.1 Views from Trainee Science Teacher Participants

The qualitative findings for this study indicated that the majority of trainee science teacher participants shared several views and experiences with regards to their science teacher training. Their views and experiences are presented according to the following emerging themes: (i) enhance explicit content and theoretical knowledge; (ii) more training on practical work; (iii) develop confidence in teaching senior levels of physics; (iv) teacher specialization and subject streaming; and (v) complement knowledge in physics with knowledge in mathematics.

Enhance Explicit Content and Theoretical Knowledge

Majority of trainee science teacher participants expressed that they need to enhance their content and theoretical knowledge in physics. For example, Nan highlighted:

I think there is lack of depth in learning the content. Training here is for teacher to go out, but if teacher go out with limitations in content knowledge, that is a problem (Nan, TT).

Nan was referring to the science teacher training program she did when this study was conducted. She admitted that there was a lack of deeper learning of the content knowledge. She did not describe or quantify what she meant by deeper learning. However, she stressed that lack of deeper learning of content is a problem for trainee science teachers who are trained to go out and teach. Subsequently, she further said:

For myself, since I will have to go out to the field, I will need more of my own discovery and read more about the contents. Because here there is lack of content knowledge. In the past, they covered the contents well but now our days we experience that content is what is lacking in the courses. So for myself when I go out I will try my best to learn more content from more reading. I think that is one trend of teacher training (Nan, TT).

Due to a lack of deeper learning of the content knowledge, Nan suggested that she has to enhance her own content knowledge by doing her own reading. She assumed that content knowledge was well covered in the past teacher training programs. Nan assumed that maybe the teacher training program had changed. Hence, she perceived that lack of deeper learning of content knowledge is a new trend of teacher training program. A similar view was raised by Lin. She said:

I came... straight from high school to do my Bachelor in teaching programme. I did physics, chemistry and biology in my first and second year but not in my third year, we do not cover the contents fully. Not like others before in the previous programmes, they covered the contents but not us now (Lin, TT).

Same as Nan, Lin perceived that science teacher training program may have changed from past years. She was concerned with the level of content knowledge that they covered in their third year. Jim, another trainee science teacher participant claimed:

There is a problem with the programs.... Before when we came here we learn the contents in physics, Biology, Chemistry and even Earth Science but today that has changed. We come and just learn theory, like what we have just experienced with the Bachelor program we are doing now. It is all about theory. When you go out into the schools you will find it a bit hard. We really need to know the concepts, like what is the real concept in that topic (Jim, TT).

While Jim echoed the same view that Nan and Lin mentioned, he went further to emphasise the need to know the concepts as compared to only theories. Jim admitted that they learn more theories in science. However, there was a lack of learning the real concepts. Talking about real concepts in physics, Andy explained:

When it comes to higher forms physics, there are concepts that even teachers need to look deeper into them. That he should have more knowledge about the concepts. So that when he transferred that knowledge to the students, it should be clear to the students. But when teacher have very limited knowledge in physics concepts then teaching and learning is not effective. Then what the teacher present to the students are limited. So

when the students ask more questions it is quite difficult for the teacher because of his limited knowledge (Andy, TT).

One can infer that according to Jim and Andy, the learning of scientific concepts is important. Hence, both Jim and Andy suggested that trainee science teachers should develop a deeper knowledge about physics concepts. According to Andy, the knowledge should be deeper enough for them to transfer that knowledge to learners. This view is relevant to the notion of scientific concepts mentioned in subsection 2.3.1. The notion that scientific concepts comprises systems of abstract ideas put together to specifically describe and categorise an entity or a phenomenon. These scientific concepts were rigorously scrutinised as well as verified and sanctioned by the scientific community of practice. Consequently, this qualitative finding suggests the importance of enhancing trainee science teachers' deeper learning of scientific concepts.

More Training on Practical Work

Two trainee science teacher participants viewed and experienced the lack of training on practical work for teaching, learning and assessment. Hence, the participants suggested that teacher training should involve more teaching of practical work. For example, Rick was one participant who directly mentioned this view. He said:

Especially in practical aspects, I really lack the skills. In theory I am good because I can read and learn from. It is when I go to do own practicals that I lack the skills to apply the knowledge that I suppose to do the practicals on. Unless, might be if you are here, I might be clearer with the skills to do practicals, experiments (Rick, TT).

Kris mentioned the same view and experience as Rick, she said, “*the knowledge is there but the lack of some practical skills are also there*” (Kris, TT). Kris indicated that although she had content knowledge there was a lack of practical skills. Similarly, Rick claimed that even though he can enhance his theoretical knowledge from reading, the knowledge and skills to carry out practical work was what he lacked the most. Subsequently, he said:

I think it is one area of its own. We should have it here. Like experiments or laboratories should be a unit of its own. We the students should learn

how to do the labs and have the knowledge to do practicals. I think this is one thing that is lacking with us the new teachers. So I think there should be a research to find out that laboratory should be a unit for training science teachers (Rick, TT).

According to Rick, practical work should be an area or a subject of its own in science teacher training. It can be inferred that Rick emphasised the importance of enhancing trainee science teachers' knowledge and skills in conducting and facilitating practical work. Rick suggested that research should be conducted to investigate the potential of practical work as a unit of itself in pre-service science teacher training. This view resonates with the goals of this study to enhance science teachers' PCK for use in teaching, learning and assessment of scientific concepts in the SBA of practical work.

Develop Confidence in Teaching Senior Levels of Physics

The qualitative findings suggested that the majority of trainee science teacher participants were confident to teach junior high school level of physics. However, they were not confident to teach senior high school level of physics. For instance, Jim commented:

In terms of teaching science and physics, I think teachers do not have any problems. They are confident. Even if you finish form 5 you can teach forms 1, 2 and 3. With a diploma from SICHE (Solomon Islands College of Higher Education) a teacher can teach lower forms but it is when you come to form 6 that you need to do more readings. So confidence to teach the curriculum at that level is quite low. I think teachers need to do a bit more training in order to teach form 6 science (Jim, TT).

According to Jim, teaching Year 12 physics may require more knowledge and reading about physics concepts and theories. Hence, Jim perceived that science teachers may have low confidence to teach Year 12 physics. In this regard, Jim thought that science teachers need to enhance their knowledge to teach Year 12 physics with confidence.

Similar to Jim, Kris also said, “*now what I want to put across is that with physics in lower forms, I have the confidence to teach*” (Kris, TT). While she did not directly

mentioned her lack of confidence in teaching senior high school physics, one can infer that she indirectly indicated that she has confidence in teaching physics at lower forms.

Besides, Rob also said, “*I see teachers took physics as teaching subject but when they come to teach the higher forms then they are not confident*” (Rob, TT). Rob indicated that even teachers who took physics as their teaching subject during their teacher training program were not confident to teach senior high school physics.

Talking about confidence, Lin said “*so now for physics I would say that I am not confident to teach it in high school. I am only confident to teach chemistry and biology*” (Lin, TT). Likewise Nan also admitted:

I for one I am not so confident in teaching physics. I feel more confident to teach chemistry. I see that the trend of learning in our programme here with respect to teaching (Nan, TT).

Both, Lin and Nan indicated they were not confident to teach physics. Nevertheless, Lin claimed she was confident to teach chemistry and biology while Nan claimed she was confident to teach chemistry. These claims suggested that the same trainee science teacher participants who were not confident to teach physics were confident to teach other science subjects.

This qualitative finding has a significant implication to the purpose of this study since it indicated a greater need to enhance trainee science teachers’ PCK to teach and conduct practical work for the SBA of physics concepts at senior high school level.

Teacher Specialization and Subject Streaming

While contributing to the view on teaching physics at senior high school level, Andy stressed that it is significant for teachers to be specialise in one subject area in science. He said:

Physics, Biology and Chemistry one teacher can teach them from form one to form five. After that and onwards there is a barrier, when we come to teach form 6 we need one teacher to teach each stream. I think that is one thing that we need to improve on (Andy, TT).

Andy pointed out that science teachers should be specialised in one subject area in science such as Physics or Chemistry or Biology. According to Andy, one science teacher can teach all the three science subject areas at Year seven through to Year 11. However, he argued that at Year 12 one teacher should only teach one subject area. Relating to the same view he suggested:

Just like a funnel, at the junior level, physics content is too general and small. But as you go up to senior forms it is all of a sudden wider. Form 6 is needed to be streamed as well to cater for the context of the Solomon Islands (Andy, TT).

One can infer that Andy had the view that contents of subject areas at senior high school or Year 12 is broader than the content at junior high school level. Hence, corresponding to streaming of subject areas at Year 12, science teachers should also be specialised in the subject areas. Besides, on the view of streaming Kris also explained:

When we come up to form 4 and 5, I think science need to be streamed into separate disciplines. So that if students choose to they can continue with each stream further into higher education. In that way they will continue to learn and be curious to learn more in that particular stream. They should be able to see how that stream is related to the development in our country (Kris, TT).

This qualitative finding indicated that trainee science teacher participants perceived that science teachers should be specialised in one subject area in order to effectively teach and assess that streamed subject area at the senior high school level as well. Despite this view on specialization, some participants perceived the knowledge in mathematics should complement knowledge in physics.

Complement Knowledge in Physics with Knowledge in Mathematics

The qualitative findings suggested that trainee science teacher participants perceived that physics is difficult since it involves a lot of mathematics. As such, some participants perceived that knowledge of physics should be complemented by knowledge in mathematics. For example, Andy explained:

Because physics is very much related to mathematics as well. Teachers who do not have good knowledge in maths will also have problems in physics. Such teachers sometimes just skip the topics that are quite difficult for them to teach. That makes teaching physics not effective (Andy, TT).

According to Andy, teachers with good knowledge in mathematics should have less difficulty in teaching physics. Similarly, Rick also mentioned:

One thing is physics involve a lot of calculation than other subjects. So students recognize that physics is one subject like mathematics. I think that made me as a general science teacher in chemistry, biology and physics to really focus more on physics. So that I can teach the basics in physics clearer to the students. It is not like biology and chemistry where they can just read and understand. With Physics we have to show them the calculations. If do not do it properly then students will have difficulties because physics involves a lot of formulas (Rick, TT).

It can be inferred that, according to Rick, physics teachers with a good knowledge in mathematics can teach physics more effectively since physics involves a lot of formulas as well as calculations. Having this same view and experience Lin admitted, “*I am one of the students who love physics but found it tough as well because I am also an average student in mathematics*” (Lin, TT).

This minor qualitative finding indicated that Andy, Rick and Lin associated the difficulty in teaching and learning physics to the difficulty in understanding mathematics. Hence, this finding suggests that trainee science teachers should complement their knowledge in physics with deeper knowledge in mathematics as well.

5.7.2 Views from Practising Science Teacher Participants

While trainee science teacher participants shared their views and experiences regarding science teacher training, the practising science teacher participants shared views on practising science teacher improvements. These views are presented as part of the qualitative findings under the following emerging themes: (i) have confidence;

(ii) enhance content knowledge; (iii) enhance knowledge of assessment; and (iv) enhance PCK.

Have Confidence

The qualitative findings indicated that practising science teacher participants perceived that they were confident to carry out the teaching, learning and assessment of process of physics concepts using the SBA of practical work. For example, Pitt said, “*well, I can say that I am confident because I have been teaching for 11 years now and conducting SBA too*” (Pitt, PT). Pitt was confident to teach physics and conduct the SBA of practical work because of his 11 years of experience.

Similarly, Brad with 13 years of experience in science teaching said, “*yes, I am confident to teach and assess physics concepts in high school*” (Brad, PT).

Apart from 15 years of teaching experience Jen also said, “*I am trained to teach general science which includes physics, so I think I am confident to teach and assess high school physics subject*” (Jen, PT). It can be assumed that Jen perceived she was confident to teach and assess physics concepts because she was trained to teach general science.

Added to being confident, with five years of teaching experience, Mano admitted:

Surely I am confident for as long as the prescribed books are available. That is the materials and resources. The text books help us to teach and give notes to learners (Mano, PT).

Mano raised an important point regarding his confidence to teach in relation to the availability of teaching resources. One can infer that Mano’s confidence is subjective to the availability of teaching and learning resources. However, although confident, Hans added:

I have been teaching, this year is my seventh year in teaching science and also physics. I am confident enough. But as I have said though teacher are capable they need improvement (Hans, PT).

This qualitative finding suggests that while the majority of trainee science teacher participants perceived they had low confidence in teaching high school physics, the majority of practising science teacher participants were confident.

However, this view on having confidence is inconsistent with the responses to scale five of the survey as presented in subsection 4.3.5. The quantitative findings indicated that the majority of practising science teacher participants had misconceptions on three of the four items on Newtonian force concepts. That being said, according to Hans, although practising science teacher participants were confident, they still need improvements.

Enhance Content Knowledge

The qualitative findings for this study indicated that one of the practising science teacher participants perceived that science teachers need to enhance their content knowledge. For example, Mano explained:

I think if we misunderstood the concepts then this may be difficult to the learners. High school science is alright, many topic covered. But if teacher misunderstood the concepts and explain wrongly then the learners will find more difficulty to understand the concepts properly. So it is good that teachers must have good understanding of topic concepts before explaining (Mano, PT).

Mano voiced the need for science teachers to develop a good content knowledge in physics. He specifically emphasised that the understanding of concepts is imperative for teaching. He stressed that if science teachers have misconceptions then they would also transfer the misconceptions to learners. Hence, Mano suggested the need for science teachers to enhance their understanding of the science concepts in order for them to effectively transfer or facilitate learners' learning in the classroom.

Enhance Knowledge of Assessment

The qualitative findings indicated that two practising science teacher participants perceived that science teachers' knowledge of assessment should also be enhanced. For example, Jeff said "*the real attention is needed to be paid to strengthening*

teachers' classroom assessment capabilities (Jeff, PT). Jeff used the adjective 'real' to emphasise his view. This suggests that, according to Jeff, the need to strengthen science teachers' capabilities to carry out assessment actually exists. One can infer that Jeff's view was based on his experience in the teaching, learning and assessment process. Add on to this view, Pitt also commented on using SBA to evaluate and enhance science teachers' capability. Pitt expressed, "use SBA to evaluate then improve teaching and learning approaches. The actual application, implementation and mentoring must be considered by teachers" (Pitt, PT).

It can be interpreted that Pitt pointed out the notion that science teachers should evaluate and enhance their actual implementation of the SBA of physics concepts. In other words, science teachers can enhance their knowledge of teaching and assessment in science learning by evaluating their own experiences.

Enhance Pedagogical Content Knowledge

The qualitative findings indicated that some practising science teacher participants shared the view on the need to improve science teachers' PCK. For example, Hans highlighted:

Science teachers still need improvement though they have learnt and are capable of teaching. I think content knowledge is vital to teach and yes the methods to teach as well. Teacher improvement is important in teaching science so PCK is vital for them. By the way not all teachers are qualified in science. Some are not qualified teachers so PCK is for every teachers (Hans, PT).

Likewise, referring to this view on enhancing science teachers' PCK, Mano added:

So teachers will know the methods of teaching and also their subject content. Sometimes teacher know how to teach but not the subject. Good for unqualified teachers to know too (Mano, PT).

According to Hans and Mano, a lot of science teachers still need to improve their PCK. They stressed that, although practising science teachers were already trained, they still need to improve their content and pedagogy knowledge. It can also be inferred that,

according to Hans and Mano, not all practising science teachers were qualified to teach science. As such, they suggested that PCK is important for most science teachers. On the same note, Brad emphasised “*all science teachers should have a sound PCK*” (Brad, PT). With a stronger emphasis, Pitt also commented, “*I strongly think that science teachers’ PCK needs to be broader and deeper. We need more qualified and committed science/physics teachers*” (Pitt, PT).

It can be assumed that Pitt used the adverb ‘strongly’ because of his view on the importance of PCK for science teachers. One can infer that Pitt also used the adjectives ‘deeper’ and ‘broader’ to emphasise his view on the scope of enhancing science teachers’ PCK. This finding not only emphasised the importance of enhancing science teachers’ PCK but also to provide them with deeper and broader understanding of content and pedagogy.

This qualitative finding corresponds with the quantitative findings in subsection 4.3.2 and 4.3.5 which indicated that science teachers need to enhance their knowledge on learners’ understanding, formative assessment as well as content knowledge.

5.8 Perceptions about Other Improvements

Both the trainee and practising science teacher participants shared some concerns on other requirements related to the SBA of practical work that need improvements. The concerns are grouped under the following emerging themes: (i) lack of resources for teaching and practical work; (ii) crowded classroom; (iii) manipulate assessment and false marking; (iv) teacher uniformity and collaboration: (v) incompetent science teachers; and (vi) encourage learners to do physics and speak English.

5.8.1 Lack of Resources for Teaching and Practical Work

The qualitative findings for this study indicated that the majority of participants perceived that the lack of resources is one requirement that also needs improvement. For instance, Hans said:

Another improvement is to have available resources for students to carry out their research. Also improve the number of equipment for all students

to have hands-on experience not only few while others just watch (Hans, PT).

Similar to Hans, Jeff also mentioned that:

Learning physics is effective when curricular material, theory and practical embodying physics concepts are available. I mean, practical equipment should be available to use when explaining theories in physics (Jeff, PT).

For Jeff, the effective learning of physics in the SBA curriculum is subjective to the availability of resources and laboratory equipment. On the same note on curriculum, Rick commented:

Sometimes the curriculum required students do experiments but we lack the resources, we lack the materials, we lack the facilities. I think that is the big thing on our curriculum (Rick, TT).

According to Rick, the lack of resources, materials and appropriate facilities was a big problem. In addition, Rob also pointed out that:

There is a new outcome based year 7 book. But the delay of its availability and the lack of supplementary books on the side, lack of equipment and other resources. I see that with science we will just go back to the dominance of the theoretical part and not the practical part (Rob, TT).

Rob indicated that the delay of providing text books or lack of resources had forced science teachers not to carry out practical work. Likewise, talking about the lack of resources, Jim exemplified:

The amount of text book we received in our school was only enough to lend to one class, the form ones. So to teach form twos with same text book is very difficult, so it is important to look at that and improve on it (Jim, TT).

In reference to the difficulty due to the lack of available resources, Jen remarked:

The main difficulty is teachers methods of teaching depend entirely on the resources available. So even if teacher have the knowledge about concepts

*and methods for teaching it is hard to apply when resources are not there.
But it is important that teachers develop their PCK (Jen, PT).*

In this regard, Jen also reiterated the importance of developing science teachers' PCK. This suggests that despite the lack of resources, science teachers should develop their PCK. Hence, it can be inferred that, according to Jen, PCK should help science teachers to address the challenges in teaching despite the lack of available resources.

5.8.2 Crowded Classrooms

The qualitative findings indicated that one of the trainee science teacher participants perceived that the number of learners in a classroom should be reasonable in order for science teachers to provide effective feedback during formative assessments. For instance, Rob described:

I mean for formative assessment in a crowded classroom, for formative, you can give questions but those verbal questions only. So that you can just check to know whether they understand the concepts that you relay to them. But when you do that maybe some students just relax and do not respond. So you have no way to find whether the students understand or not, what is going on in their brains and things like that. I mean maybe formative is true for schools in Honiara. But when we go back to the most classes in the province, the classes are generally big and crowded. Only places like the centres maybe have small classes (Rob, TT).

It can be inferred from Rob's view that crowded classroom is one hindrance to providing effective formative assessment. As mentioned earlier, formative assessment is significant for use in the SBA of practical work. However, as suggested here, one way to effectively facilitate formative assessment for learners is to reduce the number learners in one classroom. This finding is significant to consider in relation to the notion of enhancing the science teachers' PCK for use in the SBA of practical work.

5.8.3 Manipulate Assessment and False Marking

The qualitative findings indicated that due to the lack of resources coupled with crowded classrooms, chances of science teachers to manipulate assessment marks as well as learners cheating is high. For example, Rick said:

Where they lack resources, then teachers will definitely lie about the assessments. They might not do the practicals. For example, for circuits, they might not have a circuit board, no laboratory materials, but this is included in the SBA. So I think teachers will just provide a false information (Rick, TT).

Similar view was echoed by Andy when he talked about the SBA of practical work in year 11. He stressed:

I am not sure whether form 5s are doing a proper SBA. Whether they actually carry out a proper practical on pressure and do proper assessment. Or teacher use previous copies and submit samples and give free marks to students (Andy, TT).

Andy also alluded to another form of making up marks for learners. He said:

For example, in a class I might give the first assessment then mark it. Tom got 10/20, Ben got 8/20 and so as the rest of the students. I have understanding about their assessment abilities. Then I give a second assessment, Tom got 9/20, Ben got 9/10 and so on for the rest of other students. Later on I would not mark the third, fourth, fifth and sixth assessments. I would just give assessment marks to students according to my knowledge with respect to their marks from the first two assessments. That is when teachers can manipulate such system (Andy, TT).

According to Rick and Andy, manipulation of learners assessment mark is an important concern that requires attention. They suggested that such practice by science teachers may compromise the credibility of the SBA of practical work as well as the learning achievements of learners. As such, it is within the scope of this study to suggest ways to enhance science teachers' PCK in order to minimise false marking.

5.8.4 Teacher Uniformity and Collaboration

The qualitative findings suggested that some participants perceived that science teacher uniformity and collaboration is required for improving the SBA of practical work. Mano shared this view when he commented on the need to provide relevant and adequate resources like text books. He said:

In my opinion relevant resources like text books must be available in schools for teachers. This is for us teachers to use in-order to have standard notes for students. Not like a teacher from one school gives a different note from a teacher in another school. So for uniformity in assessment as well (Mano, PT).

Additionally, Pitt emphasised that “uniformity is required across all levels of teaching and learning of science and physics” (Pitt, PT). Pitt went on to say “I think more collaboration is needed between teachers to improve the implementation of the curriculum and syllabus” (Pitt, PT). According to Pitt, greater collaboration is required between science teachers in order to improve the implementation of the science curriculum and syllabus. This finding resonates with the notion of creating communities of practice (Duschl 2008).

5.8.5 Incompetent Science Teachers

Andy shared a concern about science teacher’s attitudes and competency in facilitating the school-based assessment of practical work. When he commented on the use of continuous summative assessments for formative purposes, he said:

In our case today especially when teachers become lazy and cannot cope with their work, they just lazy around, not long it is already the end of the year. However, without having any formative assessment done. So they try to push many kinds of questions for assessment, some try to collect students’ exercise books. They call this book assessment. Those are what teachers try to make up because they did not do formative assessments throughout the semester or year (Andy, TT).

This view suggests that science teachers cannot cope with what they supposed to do in terms facilitating school-based assessment of practical work. According to Andy, some science teachers maybe lazy or they might not have consistent continuous summative assessment activities as well as formative assessments. This finding is also significant for the purpose of this study which aims to enhance science teachers' pedagogical content knowledge. Subsequently, to improve science teachers competency to facilitate school-based assessment of practical work for both summative and formative assessments of physics concepts.

5.8.6 Encourage Learners to do Physics and Speak English

One of the minor emerging themes in the qualitative findings was pointed out by Pitt. He mentioned that there is a "*conservative view that science or physics is very difficult to pursue further as a career by students*" (Pitt, PT). As a result, Pitt said "*attitude towards value of education in some students is discouraging due to low self-esteem and lack of support at home*" (Pitt, PT). Pitt perceived that the lack of support and the conservative view that physics is difficult has negatively influenced learners' attitude towards doing better in high school physics. With this view, Pitt suggested that, "*every student is capable of doing physics and pursuing it to become a future career*" (Pitt, PT).

One can infer that, according to Pitt, while it is important to improve science teachers as well as the resources, learners should also be encouraged and motivated to do physics in high school. In saying that, Pitt added that "*the English language must also be properly and thoroughly taught to enable students to be confident both in writing and verbal communication*" (Pitt, PT). Pitt also perceived that developing learners to confidently and fluently speak as well as write English in high school is significant to the SBA of practical work.

On the whole, while these qualitative findings can be regarded as minor themes to the purpose of this study, they have indicated what both the trainee and practising science teacher participants perceived as other requirements that needed to be improved as well. Consequently, the majority of participants shared the views and experiences on improving the resources and facilities for effective teaching, learning and assessments in the SBA of practical work.

5.9 Summary of Chapter Five

Initially, the qualitative findings regarding the importance of science education were elicited as a context for making coherent analysis, interpretations and inferences to the findings on teaching, learning and assessment of physics concepts in the SBA of practical work. Consequently, the views on the importance of science education resonated with the aims for scientific literacy. In this regard, the qualitative findings suggested that teaching, learning and assessment of physics concepts should involve both the theoretical and practical approaches. The qualitative findings also indicated the significance of using both the formative and summative assessment in the SBA of practical work. However, the qualitative findings suggested the participants had different understanding of formative assessment. There were inconsistent views between continuous summative assessment for formative purpose and formative assessment.

The qualitative findings indicated that the majority of practising science teacher participants perceived that they were confident to teach and assess physics concepts at high school level. However, the majority of trainee science teacher participants perceived that they were not confident to teach and assess physics concepts at senior high school level. Additionally, the majority of participants indicated a lack of knowledge about learners' understanding, preconceptions and misconceptions in physics. The qualitative findings also indicated some hindrances that required improvements for the better implementation of the SBA of practical work. This included the lack of resources, crowded classrooms, false marking and cheating, incompetent teachers, and lack of uniformity and collaborations. Subsequently, the qualitative findings suggested that science teachers need to enhance their knowledge of content, pedagogy, learning environment, learners' learning and curriculum in order to provide effective teaching, learning and assessment of physics concepts in SBA of practical work.

Next, Chapter Six contains the discussion of the key findings. The discussion will triangulate and combine the quantitative and qualitative findings in synthesis with the relevant key research areas presented in the literature review in Chapter Two of this study.

CHAPTER SIX

Discussion of Key Findings

6.1 Chapter Overview

Previously, Chapter four and Chapter five had reported the quantitative and qualitative findings for this study respectively. Subsequently, this chapter provides the discussion of key findings in synthesis with the key research areas in the literature review as well as the researcher's own reflections and sociocultural experiences relating to the phenomenon investigated. This chapter starts with an introduction in Section 6.2. Then, a discussion of the key findings is divided into four main sections that addresses the five research questions underpinning this present study. Section 6.3 addresses the first research question with respect to guidelines for improvements. Section 6.4 addresses the second and fourth research questions pertaining to the trainee science teachers. Section 6.5 addresses the third and fifth research questions pertaining to the practising science teachers. Finally Section 6.6 provides a summary for this discussion of key findings.

6.2 Introduction for this Chapter

This study sought to explore and document both trainee and practising science teacher participants' views and experiences on teaching, learning and assessment of physics concepts in the school-based assessment (SBA) of practical work in Solomon Islands. At the outset, the findings for this study indicate that the majority of participants had relevant views and experiences about the importance of science education and the aim for learners to develop the understanding of scientific concepts, skills and attitude for everyday livelihood. However, the findings indicated some inconsistencies in the views and experiences about content knowledge and knowledge of learners' preconceptions and misconceptions. Besides, while the findings indicate a strong support for utilising both formative and summative assessments in the SBA of practical work, there are inconsistent perceptions about formative assessment and understanding of pedagogical content knowledge (PCK). Further, apart from the view

to improve science education resources and facilities, the findings indicate a need to enhance science teachers' confidence to teach and assess physics concepts at senior high school level.

Guided by a case study design, the findings for this study were generated from data collected and collated through a triangulation mixed methods approach within a bounded phenomenon (Creswell, 2008). Hence, both the qualitative data and quantitative data were collected concurrently without a predetermined sequence. The two sets of data are seen as complimentary to each other. As described in chapter three, both the qualitative and quantitative data were generated, analysed and triangulated to answer the following five research questions:

1. What do trainee and practising science teachers know and understand about scientific and physics concepts in science SBA?
2. How do trainee science teachers view and experience their learning and assessments of physics concepts?
3. How do practising science teachers view and experience their teaching and assessing of physics concepts?
4. What do trainee science teachers suggest as ways to improve their learning, understanding and assessment of physics concepts in the SBA?
5. What do practising science teachers suggest as ways to improve their understanding, teaching and assessment of physics concepts in the SBA?

The findings from chapter four and five indicate that the understanding of scientific concepts is one of the main and important goals for high school science education. These findings resonate with the notion that the understanding of scientific concepts is paramount in the nexus depicted in the underlying conceptual framework for this study which was presented in figure 2.1 in Section 2.2. As such, it is imperative for this discussion to begin with the key findings on the understanding of scientific and physics concepts as well as the importance of science education. Subsequently, this discussion of key findings will develop a coherent connection between the importance of science education, the understanding of scientific concepts, and the purposes of practical work, SBA and PCK.

6.3 Understanding Scientific Concepts and Importance of Science Education (Response to Research Question One)

The first research question for this study sought to explore both trainee and practising science teacher participants' views and experiences about what they know and understand about scientific and physics concepts. To answer this research question according to the conceptual framework for this study, the findings on the importance of science education were also elicited mainly from the qualitative data. These findings provide the overarching understanding to further interpret the views and experiences of participants on the SBA of physics concepts in practical work. Subsequently, this section also discusses the key findings in synthesis with the suggested improvements premised in the conceptual framework for this study.

The qualitative findings indicate that the science teacher participants perceived science education is important for learners' to: (i) understand scientific concepts for use in everyday livelihood; (ii) understand relationships and laws in a real world context; (iii) develop inquiry skills to solve science problems and socio-scientific issues; and (iv) motivate and develop interest for future career and economic development.

6.3.1 Understand Scientific Concepts for Use in Everyday Livelihood

The qualitative findings indicate that the majority of participants perceived that high school science education is important for science learners to develop a basic understanding of scientific concepts for use in everyday civic livelihoods. Particularly, in subsection 5.3.1, 5.3.3 and 5.4.1, the participants perceived that the understanding of physics concepts is significant since they relate to many physical phenomena and technology that learners may encounter in their everyday livelihood. They perceived that learners should be able to make scientific explanations of any phenomenon they come across as well as be aware of the benefits and dangers of using different types of technologies in their everyday livelihood. These findings resonate with the overarching aim for science education in other developing and developed economies as well. For instance, science curricula from other sociocultural and geopolitical contexts such as Australia and New Zealand also emphasises the importance of

developing learners' understanding of scientific concepts and skills in school science (Gluckman, 2011; QSA, 2015). Similarly, the Solomon Islands high school science curriculum also aims to develop learners' understanding of scientific concepts (MEHRD, 2011). In fact, one of the primary goals in science education is to develop learners' understanding of scientific concepts and skills (Fleer, 2009; Khishfe & BouJaoude, 2016). Consequently, this finding reinforces the significance of developing learners' as well as science teachers' understanding of scientific concepts as highlighted in the conceptual framework of this study.

This finding corresponds to the notion of scientific literacy since it is associated with the goal to develop learners' understanding of scientific concepts for everyday use in societies that are increasingly influenced by science and technology (Allchin, 2011; Gluckman, 2011). As discussed in subsection 2.4.2, science education in many sociocultural and geopolitical contexts has developed multiple aims to address scientific literacy. The multiple goals can be summarised under two main categories. One is to help science learners understand the established body of scientific knowledge and the other, to develop learners' understanding on the nature of science (NoS) (Millar, 2004). While these two aims have overlapping elements, the aim to develop the understanding of the NoS is closely related to the purposes of practical work since most aspects of teaching, learning and assessment in practical work for the NoS are experienced and not taught (Nott & Wellington, 1999; SCORE, 2011). Besides, over a century, practical work had been purported to enhance learners' to understand scientific concepts, develop practical skills and problem solving abilities as well as to understand the NoS (Hofstein & Lunetta, 2003). Hence, in-line with the conceptual framework for this study, this study concludes that science teachers should enhance their understanding, knowledge and skills for teaching, learning and assessment of scientific concepts in the context of using the SBA of practical work in high school science.

The qualitative findings indicate that the majority of participants perceived that using both theoretical teaching and practical work for learners in school science is imperative for teaching, learning and assessment of scientific concepts. The participants had views about using sociocultural artefacts, multiple representations as well as analogies and real life examples to teach and assess scientific concepts for everyday use. In fact,

some participants perceived that physics concepts are difficult to understand since they are abstract. Hence, using examples that are familiar to learners is helpful for making connections to the new scientific concept. Actually, the majority of participants perceived that they understand and know how to use demonstrations, multiple representations and everyday familiar examples to introduce and teach new scientific and physics concepts to learners. These qualitative findings are consistent with the quantitative findings on knowledge of teaching physics concepts reported in subsection 4.3.1.

The quantitative findings indicate that the majority of participants perceived that they knew how to use their learners' preconceptions and prior knowledge to help them design their next remedial activities as well as lesson plans. This is indicated in Table 4.3 in subsection 4.3.2. Similarly, the qualitative findings reveal that some participants perceived that they have used pre-tests to assess and identify the initial level of their learners' understanding of a particular concept before they introduce it in their science classes. Basically, science teachers' understanding of learners' preconceptions or prior knowledge is imperative in tailoring the teaching, learning and assessment of new scientific concepts (De Jong, 2007; Vosnaidou, 2002). However, the quantitative findings also indicate inconsistent responses as reported in subsection 4.3.2. On the one hand, the majority of participants indicated that identifying learners' preconceptions is simple and this had helped them to introduce new scientific and physics concepts. On the other hand, they also indicated that they had difficulty in teaching physics concepts because it is difficult to identify learners' different abilities and preconceptions. These conflicting views indicated that there is a need for science teachers to have a better knowledge and understanding about their learners' preconceptions and misconceptions. Therefore science teachers need to enhance their knowledge of learners' understanding of scientific concepts as well as preconception and misconceptions when introducing new scientific concepts.

The findings indicate that the majority of participants perceived that they can use formative assessment during the teaching and learning of scientific concepts in the SBA of practical work as reported in subsection 4.3.4. Actually, science teachers can use planned and interactive formative assessments in their teaching as described in subsection 2.5.2. Planned formative assessment requires prior planning while

interactive formative assessment evolves during the process of teaching and learning (Bell & Cowie, 2001; Bell, 2005). The formative assessment process can be regarded as a means of scaffolding in practical work whereby science teachers can make contextual and conceptual links between learners' everyday preconceptions to what is practically experienced and the intended learning outcomes (Kwalkar & Vijapurkar, 2013; Millar, 2004). In saying that, although, not directly asked about scaffolding, science teachers should have the knowledge that formative assessment for learning scientific concepts involves scaffolding. However, the term and notion of scaffolding was not articulated by them in this study. In fact, other studies found that one of the challenges science teachers face when using practical work for teaching, learning and assessment of scientific concepts is that there is lack of knowledge on scaffolding strategies from science education research (Kwalkar & Vijapurkar, 2013). Other studies also found that using practical work to facilitate and communicate scientific concepts, relationships and theories demands appropriate scaffolding from science teachers (Abrahams, 2011; Hodson, 2014). On that note, there is a need to enhance science teachers' understanding, knowledge and skills on formative assessment and scaffolding strategies to teach and assess scientific concepts in the SBA of practical work.

In sum, the findings for this study indicate that science education is important for developing learners' understanding of scientific concepts for use in everyday livelihood. However, there is a need to enhance science teachers' PCK to effectively utilise the SBA of practical work for teaching, learning and assessment of scientific concepts. Scientific concepts are well researched, scrutinized and historically established hence they cannot be easily and simply reconstructed as well as discovered through classroom experimentation and observation (Wells, 2008). As such, this study recommends that science teachers should develop the knowledge, understanding and skills to deconstruct and then reconstruct scientific concepts using everyday examples in the SBA of practical work. In addition, science teachers need to enhance their knowledge of learners' understanding, preconceptions and misconceptions as well as develop the ability to scaffold using formative assessment for teaching and learning of scientific concepts.

6.3.2 Understand Relationships and Laws in Real World Context

The findings for this study indicate that the scientific concepts in school science are significant for learners' understanding of the real world that they live in. When learners understand and are aware of how they are related to their natural world, they can appreciate and take care of it. In other words, the more the learners understand and relate to their lived world the more they will appreciate and respect the relationship they have with it. For this purpose, the participants perceived that the teaching, learning and assessment of scientific concepts in school science should include diverse practical work that provides the opportunity for learners to actually experience science in their real life context. As reported in subsection 5.4.1, scientific concepts can be taught, demonstrated and experienced in real life through a teaching, learning and assessment process that is conducted in real life environments or contexts.

However, the actual teaching, learning and assessment process in real life and in situ can be complex (Wellington, 1998). In fact, excursions and field trips are exciting opportunities for learners to go out and learn through experience in the real world. Learners can have the first-hand experience with the phenomenon investigated and other physical entities that are actually present in real time and context. Nevertheless, the actual intended learning that should take place in real time and space is questionable and may not be simple to the learners as well as science teachers. Some learners may enjoy the scenery without concentrating or being made aware of the kinds of teaching, learning and assessment that are supposed to take place. Other learners can concentrate on the actual practical work but they may not be able to make connections between the real life phenomena and intended scientific concepts to be learnt. As such, in order to make practical work in real life environments useful and effective for learners, science teachers need to develop a deeper understanding of the scientific concepts as well as develop skills on how to relate and demonstrate scientific concepts in real contexts.

Most of the ideal scientific concepts in nature were developed over many years of experimentations with many failures and retrials, thorough scrutiny and approval. Therefore, as part of enhancing their PCK, science teachers should develop a knowledge about history, socio-political and epistemic practices of the scientific community as well as the NoS (Kind, 2009; Berg, 2015). Generally, the records and

knowledge of scientific epistemic practices and development of scientific communities as well as scientific concepts can be researched from science history. Having a knowledge of science history is significant because most of the ideal scientific concepts that are taught and learnt in high school science do not occur in real life as they are usually depicted and formulated in school science curriculum. There were many other influential factors that were intentionally ignored or suppressed in order to investigate and understand specific scientific concepts. For example, to understand the ideal concept of free falling objects, other factors such as shape of an object and air resistance are ignored. Thus, according to the premise of this study, such a knowledge is significant for science teachers' PCK for teaching and assessing scientific concepts in the natural environment.

The finding for this study indicate that science teacher participants may lack some knowledge and confidence to explain as well as illustrate how different physics entities are connected and related in a scientific concept in the natural world. Some participants mentioned physics concepts such as naming the different kinds of energy and forces when they expressed their views about understanding physics concepts. Added to that, some participants briefly gave examples associated to some natural relationships and laws pertaining to physics concepts. Nevertheless, apart from mentioning gravity and motor mechanics, the findings indicate that science teacher participants did not articulate or emphasize some of the natural relationships and laws in nature that correspond to understanding of physics concepts. This finding is important in regards to enhancing science teachers' content knowledge and understanding about the relationships and laws in nature.

This study premised that science teachers should develop an explicit understanding of the relationships and laws depicted in scientific concepts, especially in physics. While physical relationships in nature are experienced in everyday physical encounters, recognising them and being aware of their relationships in a scientific way is not so simple (Vygotsky, 1987; Fler, 2009). For example, learners may not be able to experience and recognise the concept of the first law of motion since it is difficult to detect and be aware of it in real time. Hence, the relationships connecting the entities that comprised the concepts of forces may not be easily observed and learnt in everyday life. That said, learners may have constructed their own interpretations on

relationships that they may have observed and experienced in their everyday lives. In fact, Vygotsky (1987) argued that the everyday concepts or ideas that learners formed about the physical entities and phenomena are grounded in their daily life experiences and interactions in real time. In this regard, learners' everyday concepts are well situated in their mind. However, these conceptions may turn out to be misconceptions.

Hence, as explained in subsection 2.3.2, science teachers should develop the skill, understanding and knowledge to deconstruct and represent the relationships depicted within a scientific concept. For example, in regards to the concept of force, science teachers should be able to develop the connections and relationships that Newtonian concepts of force have with other entities and concepts in the physical world. Additionally, science teachers should be able to deconstruct scientific concepts into intelligible human actions and practices with appropriate language and inscriptions (Tang, 2011). By deconstructing scientific concepts into multiple representations and actions coupled with scaffolding from science teachers, learners should be able to identify, learn and appreciate the relationships of ideas combined with language, symbols and inscriptions. Subsequently, learners should be able to understand and appreciate that scientific concepts are systems of relationships and laws in the physical world.

In sum, as premised in the conceptual framework of this study, science teachers need to develop the understanding and knowledge that scientific concepts are systems of ideas which comprised many other relationships and entities as well as other scientific concepts and ideas. In other words, the system of ideas can also show the connections that represent relationships of the physical entities and laws in the natural world. Added to that, along with the combination of scientific ideas, scientific concepts are systems of ideas that are connected with languages, semiotics and inscriptions (Roth & Tobin, 1997; Tang, 2011). Hence, science teachers should develop explicit content knowledge and understanding about the composition of entities, ideas, language, symbols and inscriptions within a scientific concept. On that note, this study proposed that science teachers need to develop explicit understanding of scientific concepts in order to show the ideal relationships and laws in nature that are associated to physics concepts and the physical world.

6.3.3 Develop Inquiry Skills to Solve Science Problems and Socio-Scientific Issues

The qualitative findings indicate that the science teacher participants perceived that science education is important for learners to develop inquiry skills to solve and make informed decisions pertaining to science and socio-scientific issues. In this regards, some participants raised the view that science learners should develop their science inquiry skills which they can employ when they are encountered with real life science as well as socio-scientific problems and issues. In addition, the findings suggest that individuals are continuously faced with everyday challenges that are associated with science and technology, for example, the challenges related to climate change impacts and responses. As such, the majority of participants perceived that science education is significant to develop learners' inquiry skills in order for them to identify then plan and carry out ways to make informed and responsible decisions pertaining to such scientific challenges or issues that they may face in their everyday lives.

The findings reveal that practical work or investigations in the SBA should be used to develop learners' ability to identify problems then plan and carry out science inquiry. Some participants perceived that practical skills in science are associated with the ability of learners to establish links between what they experience during practical work to the theories they have learnt in class. In addition, some participants perceived that learners' problem solving skills coupled with their knowledge of content are important elements of physics learning that should be assessed in the science SBA curriculum. Inquiry skills to solve science problems encompass the ability of learners to identify and understand issues, plan and implement a process, analyse and evaluate data and draw conclusion that are related to scientific theories and issues. Hence, learners should be given open investigations in order for them to demonstrate their ability to identify a science related problem or topic of interest then plan and design an investigation to find solutions and draw conclusions. The findings indicate that this process of inquiry learning and assessment is important for learners when doing the SBA of practical work.

However, the qualitative findings indicate that the participants did not articulate how they should teach and assess inquiry skills. In fact, other studies have shown that there are several challenges for science teachers in facilitating open inquiry teaching,

learning and assessment strategies in practical work (Shedletzky & Zion, 2005; Zion & Mendelovici, 2012). Studies have also found that the effectiveness of open inquiry can be a challenge since the learning outcomes may not be precise as well as difficult to identify and measure (Miller, 2004). The procedural skills and understanding are not merely handling or manual skills but they include cognitive processes and conceptual understandings. On top of that, other studies indicate that science teachers had a lot of challenges in managing and facilitating open inquiry or investigations for learners in high schools. Hence, many science teachers perceived that teaching, learning and assessment for inquiry skills may only be possible for above average learners (Windschitl, 2002). In other words, learners should have the ability to take the central role in carrying out open inquiry with little assistance from their science teachers.

Although learners should take the central role in open inquiry or investigation, its effectiveness depends on the ability of science teachers to facilitate as well as scaffold through the stages of decision making. Investigations are not theory free. As such, to actively conduct open inquiry, learners should have some content knowledge and procedural skills to do science inquiry (Wellington, 1998). In fact, a study conducted by Zion and Mendelovici (2012) found that science teachers' experiences as well as their content and procedural knowledge in science complemented with the cognitive ability of learners are significant elements for the teaching, learning and assessment for inquiry skills. They found that science teachers should have the ability to recognise and be familiar with their learners' prior cognitive, skills and affective capabilities as well. Having the knowledge and understanding of their learners, science teachers can provide appropriate scaffolding at the initial stages in formulating questions for investigation and progressively at other stages that learners need to make decisions to proceed (Zion & Mendelovici, 2012).

The effectiveness of this process depends mainly on science teachers' understanding of the content and process coupled with the skills to scaffold. Added to that, the more complex and challenging the practical work is with regards to teaching and learning, the more difficult it is to be assessed, especially with regards to the notions of effectiveness and manageability (Osborne, 1998; Osborne, 2014). As such, it is important for science teachers to develop some understanding and ability to employ a

coherent approach in teaching, learning and assessment of inquiry skills through the SBA of practical work. In this regard, open inquiry types of practical work are pivotal for the development of learners' inquiry skills and procedural knowledge (Branchi & Bell, 2008; Tamir, 1991). Open inquiry may simulate and reflect the type of research and practical work that scientists usually perform in real contexts. Hence, learners require high-order cognitive and processing capabilities in doing open inquiry (Zion & Mendelovici, 2012). While learners can work individually as well as have the onus to determine the purpose and the questions to be investigated in open inquiry, science teachers should have the ability to provide scaffolding as discussed earlier in subsection 6.3.1.

The findings show that some participants for this study perceived that group work in practical work can also help learners to socially critique and construct their inquiry skills. They claimed that with group discussions, learners are able to demonstrate and strengthen their confidence to share their views and understanding. In fact, with the sociocultural views of learning, learners are encouraged to collaborate with their peers to construct as well as evaluate their decision-making and procedural processes (Haigh, France & Forret, 2005). Basically, social collaboration in the science classroom provides an environment whereby learners can evaluate and modify their decision-making and designs using the evidences and ideas they progressively contribute together (Glaesser, et al., 2009). With open inquiry learners should be able to experience and develop some basic understanding of the epistemic processes in science as well. Nevertheless, science teachers do play an important role in teaching, learning and assessment for developing learners' open inquiry skills to address science problems and socio-scientific issues.

Science teachers should have the content knowledge and procedural understanding and skills to facilitate the complex process of developing learners' inquiry skills in open inquiry. The teaching, learning and assessment of conceptual and procedural understanding in science is complex. However, science learning is embedded in learning activities in school science that promotes the NoS which encompasses the understanding and practice that: knowledge in science is tentative; there is no one method to construct it; scientists who developed the concepts have their own personal and sociocultural milieus; epistemology of science knowledge is rigorous and has gone

through a lot of integrated processes of scrutiny. In addition, procedural understanding in science practice encompasses the knowledge and skills to make decisions about why, what, how, when, and how to proceed (Shedletzky & Zion, 2005). These conceptual and procedural understanding and skills are complex. Hence, this study argues that science teachers should develop the understanding and skills to facilitate learners' open inquiry learning and assessment.

In fact, some studies had indicated that science teachers who lack pre-service and ongoing professional experiences in conducting open inquiry activities in school science also lack procedural understanding and skills to facilitate open inquiry teaching, learning and assessment strategies (Shedletzky & Zion, 2005). Studies have shown that science teachers may have some difficulty in identifying and evaluating the sequence and how to proceed. Added to that, with no experience in conducting open inquiry, science teachers may also lack the knowledge, understanding and skills to facilitate and scaffold their learners in open inquiry (Windschitl, 2002). As such, while open inquiry is important as well as challenging, science teachers should develop their understanding, knowledge and skills regarding the strategies that can be employed to achieve what is intended in open inquiry practical work (Shedletzky & Zion, 2005). This finding is imperative to the purpose of this study to enhance science teachers' PCK.

6.3.4 Motivate and Develop Interest for Future Career and Economic Development

The findings indicate that the participants perceived that learners' understanding of scientific concepts in high school is significant for future tertiary studies and careers in science-related fields as well as for economic development of the country. Some participants perceived that with good content knowledge and skills in science, learners can be motivated as well as develop stronger interest to continue on to do further education that leads to future career paths within specialised fields in science. Learners would venture into science fields that would be beneficial to their own future lives as well as for the economic development of the country. For example, a scientific literate citizen would be willing to work in industries and organisations that require special skills in science. This finding indicate that learners' understanding of scientific concepts in high school science can strengthen their interest and motivation for future

careers in science fields and, subsequently, contribute to the economic development of the country.

The findings indicate that some participants perceived that high school science should provide a kind of science education that would produce scientifically capable citizens who should also have the interest and motivation to continue on to do further research and innovations in science related areas. In addition, developing economies like Solomon Islands should educate future scientists who would also be able to invent new products in technology, medicine, fisheries and agriculture. In fact, one participant exemplified this view by saying that learners who are good at motor mechanics in physics can go on to develop small automotive tools for growing cash crops or build windmills in their villages for generating electricity. Consequently, the participants perceived that learners' deep understanding of scientific concepts and skills would have a trickle-down effect in their contribution to socio-economic developments.

The findings reveal that some participants perceived that teaching, learning and assessment strategies that encompass the use of familiar and everyday meaningful connections should motivate learners to be more curious as well as to develop their interests. In fact, studies in other sociocultural and geopolitical contexts found the one of the purposes of employing practical work in school science is for learners' affective development (Abrahams, 2011; Hodson, 1998). This involves the development of learners' feelings and attitudes towards science, their keenness, self-esteem to do science and self-belief that they can actually learn and do some science in school science as well as in real life contexts (Wellington, 2005). This notion of learners' affective development is associated with the category of learning about science which is aimed at developing learners' awareness about the sociocultural, historical and epistemic processes of science and scientific practice.

This study argues that science teachers should develop the knowledge and skills to motivate learners when using practical work experiences as an avenue to enculture them into scientific culture. With practical work experiences learners are gradually encultured into the scientific practice of using scientific language, semiotics and artefacts, as well as ways of making claims and arguments (Hodson, 2014). Besides, learning about science promotes the awareness and the understanding of how and why science has value in socio-scientific societies and for pressing global issues. In this

regard, science teachers should enhance their knowledge on learning about science and the processes of doing practical work such that they can help learners to appreciate as well as be motivated to do science in their future careers.

In sum, the findings for this study indicate that there is a need to develop learners' interest and motivation in doing science as well as to contribute to future career and development. Hence, it is necessary to develop science teachers' knowledge, understanding and skills to utilise the SBA of practical work to motivate learners and to instil in them the interest and aspiration to do further studies in science-related fields. Subsequently, learners would maintain the motivation and interest to pursue careers in science fields that contribute to the economic development of the country. As such, this study recommends that science teachers need to develop the scientific knowledge and skills to gradually enculture learners into learning about science and the practice of doing science through practical work.

6.4 Findings from Trainee Science Teachers' Perceptions (Response to Research Questions Two and Four)

The second and fourth research question of this study sought to explore trainee science teacher participants' perceptions of their learning and assessment as well as their suggested changes to the SBA of physics concepts in practical work. This discussion is presented under the following key findings: (i) not enough physics content knowledge and confidence to teach senior high school physics; (ii) not enough training for conducting practical work; and (iii) not enough experience in assessing science concepts and skills for formative purposes.

6.4.1 Not Enough Physics Content Knowledge and Confidence to Teach Senior High School Physics

The qualitative findings for this study indicate that the trainee science teacher participants perceived that the content of science subjects in their training courses, especially physics was not broad or deep enough. The participants indicated that physics as a teaching subject was not fully offered as part of their teacher training course when the data for this study were generated in May 2015. Furthermore, most of the trainee science teacher participants indicate that they tended to choose chemistry

and biology more than physics as their preferred teaching subjects in science. As such, the trainee science teacher participants perceived that they need to strengthen their content knowledge in physics as one of their teaching subjects. These qualitative findings indicate that the science teacher training program for science teaching did not offer enough physics content knowledge. Besides, the qualitative findings indicated that, while trainee science teachers can choose any two of the three science teaching subjects or strands in science, many of them preferred to choose chemistry and biology as their major rather than physics.

The qualitative findings suggest that the majority of trainee science teacher participants had some level of doubt in their ability to teach senior high school physics. Some participants who already taught science in high school before training to further their teacher qualification were only confident to teach and assess physics concepts at the junior high school classes. They were not confident enough to teach and assess physics concepts at senior high school science classes. In other words, their physics content knowledge was not good enough. In fact, some trainee science teacher participants in this study indicated that physics concepts in senior high school level are abstract and comprised a lot of complex systems of ideas. Hence, it was not easy to fully understand high school physics concepts. This finding is imperative to the premise of this study since it provides the evidence to enhance trainee science teachers' content knowledge to teach and assess physics concepts at the senior level of high school science.

The quantitative findings also indicate that trainee science teacher participants' perceptions regarding their level of physics content knowledge were inconsistent with their conceptual understanding of Newtonian Force concepts. As indicated in Table 4.2 in subsection 4.3.1, the majority of trainee science teacher participants perceived they had good content knowledge in physics to teach and assess physics concepts at high school level. They perceived that they can teach and assess physics concepts using everyday examples and stories as well as illustrations. However, the quantitative findings in Table 4.7 and Table 4.8 showed that, the majority of trainee science teacher participants had misconceptions about the Newtonian force concepts. In fact, Table 4.8 show that less than 26.6 percent of trainee science teacher participants had the correct conceptual understanding of the four Newtonian force concepts in the survey

for this study. This finding on the inconsistencies between participants' perceptions and their actual content knowledge is concerning for trainee teachers who will be future teachers. Hence, as premised in this study, it is important to enhance trainee science teachers' content knowledge to teach and assess physics concepts at senior high school level of education.

This concern of developing trainee science teachers' content knowledge in physics as well as other science subjects is evidently important in other sociocultural and geopolitical contexts as well. As mentioned in the background of this study in Section 1.4, a study conducted in Malaysia indicated that even beginning physics teachers had the same level of understanding of the Newtonian Force Concepts as their Year 10 learners (Saleh, 2011). As fully trained science teachers, their physics content knowledge should be greater than their high school learners. It is also evident in other studies that science teachers who graduated from teacher training institutions that focused more on pedagogy may lack deeper content knowledge (Halim & Meerah, 2002; Isak & Zulkifli, 2008). Likewise, the findings for this study indicated that the Bachelor of Teaching program at the Solomon Islands National University (SINU) placed more of a focus on science classroom pedagogy than content knowledge. In fact, science content knowledge in the Bachelor of Teaching program at the SINU is "pitched at senior secondary school curriculum level" (SINU, 2017, p. 149). In this regard, this study recommends that training programs for trainee science teachers should develop a deeper and broader content knowledge than what is required at senior high school level.

This study premise that having good content knowledge and confidence to teach physics in school science is vital for science teachers. For instance, when carrying out scaffolding during practical work that has learning outcomes for understanding of concepts, science teachers must be confident. They should be confident to facilitate the scaffolding by providing feedback and feedforward. Correspondingly, learners should trust their teachers as experts to provide feedback and feedforward. To ensure learners develop a trust for their teachers for scaffolding, science teachers have to demonstrate their confidence when providing appropriate feedback and feedforward. However, the confidence to effectively carry out the teaching, learning and assessment processes is subjective to the teachers' level of PCK (Etkina, 2010). In this regard,

while PCK is a personal construct that improves with time and experience, it can be established through science teacher training programs by way of microteaching experiences and action research (Etkina, 2010).

In sum, this study premise that the components of PCK posited in the conceptual framework for this study can be integrated into science teacher training courses. The training courses should focus on developing deep conceptual and procedural understanding in science. In addition, trainee science teachers should engage in microteaching or clinical practise during their training courses to develop their knowledge of: curriculum; learners' preconceptions and misconceptions and effective teaching, learning and assessment strategies. Such training should help trainee science teachers to develop their foundational knowledge to enhance their PCK. Subsequently, when they become practising science teachers they may continue to develop their PCK through action research and establishing communities of practice as well as the use of external information and facilitators on an ongoing basis (Etkina, 2010).

6.4.2 Not Enough Training on Conducting Practical Work

The qualitative findings for this study indicate that trainee science teacher participants perceived that they did not do enough practical work in their teacher training courses. Some of the participants pointed out that, while science is a practical subject, it was not fully reflected in the amount of practical work they do in their teacher training. As such, the trainee science teacher participants perceived that they need to do more practical work in all the science subjects that they would teach in high school after they completed their training programs. The findings indicate that there was not enough training in understanding and conducting different types as well as levels of practical work. Hence, it can be inferred that the majority of trainee science teacher participants had little knowledge about different types, levels and learning outcomes, as well as the effectiveness of practical work. The majority of trainee science teacher participants shared the view that practical work is mainly for learners to affirm their understanding of scientific concepts that they had learnt in theory. In addition, they perceived that practical work is conducted to develop learners' manual skills to handle and manipulate science equipment as well as to follow procedures. These findings indicate that the trainee science teachers need to develop their understanding,

knowledge and skills in facilitating practical work for teaching, learning and assessment of scientific concepts at different levels.

These findings are significant to the premise of this study since they emphasise the need to develop trainee science teachers' content knowledge and skills in facilitating different types and levels of practical work along with their specific learning outcomes. As outlined in subsection 2.4.2, the learning outcomes influence as well as determine the level and type of practical work (Millar & Abrahams, 2009; Tamir, 1991). As such, trainee science teachers should develop the knowledge that any practical work that has pre-prepared experimental questions, aims, procedures and post experimental questions are level 0 (Zero) or a recipe type of practical work. This type of practical work has learning outcomes that intend to develop learners' skills to observe, handle practical work equipment, record data and use the data to verify scientific concepts learnt in class. This type of practical work does not require deep and complex thinking since it only requires manual skills and more of memory recall from theory knowledge (Llewellyn, 2005). Nevertheless, this of level practical work still requires a development of knowledge to recognise the right equipment as well as how to use it correctly. This involves the knowledge to measure and read the data registered on the equipment. In this regard, it is argued that trainee science teachers need to develop their knowledge, understanding and skills to facilitate teaching and learning of level zero practical work.

The qualitative findings indicate that some trainee science teacher participants perceived that it is easier to teach other science subjects than physics when doing practical work. For example, they stressed that biology concepts are related to living things; hence, learners can easily observe and experience these whereas physics concepts are abstract and difficult to observe. In other words, it is not easy to provide a simple explanation or illustration in practical work to teach and assess the understanding of physics concepts to learners. However, as stated earlier, the relationships of the physical entities and semiotics that comprised a physics concept must be clearly identified, deconstructed and understood. This finding indicate that trainee science teachers should not only develop their content knowledge from theory but they should also develop their understanding, knowledge and skills in conducting more practical work. They should practise to demonstrate as well as verify their own

understanding by identifying the necessary physical entities, semiotics and relationships in physics concepts by conducting more practical work while on training.

The qualitative findings indicate that while some trainee science teacher participants mentioned the use of open inquiry, they did not articulate their need to understand as well as to do more practice on open inquiry. However, they perceived that open inquiry is important for teaching and assessing learners' ability to solve problems. Basically, science teachers' understanding, knowledge and skills for open inquiry are crucial for teaching, learning and assessment of learner's conceptual and procedural understanding and skills as outlined in subsection 2.4.3. Hence, apart from enhancing their content knowledge, trainee science teachers also need to develop their understanding and skills to facilitate open inquiry teaching, learning and assessment in school science (Branchi & Bell, 2008; Osborne, 2014).

Consequently, this study argues that teacher training programs for science teachers need to develop and include a number of different types and levels of practical work pertaining to scientific concepts. They should learn by theory as well as by conducting more practical work to identify, demonstrate as well as affirm and verify the complex composition of scientific and physics concepts.

6.4.3 Less Understanding and Skills for Formative Assessment

The qualitative findings indicate that while trainee science teacher participants perceived that they had some knowledge and skills to facilitate formative assessment, their views and experiences about the definition and nature of formative assessment in practical work was not well articulated. As reported in subsection 5.5.8, some of the trainee science teacher participants perceived that formative assessment comprised of the assessment activities that are conducted on a regular basis over one semester for a particular course, program or topic. By providing formative assessments on a regular basis, science teachers would be able to add up the marks at the end of a program or course to determine their learners' grades. These findings indicate that formative assessment was perceived as small assessment activities that are carried out purposely to assess learners' learning after they complete specific parts of the course, program or topic. It can be inferred that some of the trainee science teacher participants perceived formative assessments as similar to continuous summative assessments

whereby assessment results such as grades and marks are generated and accumulated over time at the end of a course, program or topic.

Generally, assessment information from summative assessment tasks can be used to provide feedback or feedforward as well as remedial actions to improve the learners' performance or achievement of learning outcomes. However, this is a weak formative assessment purpose (Bell, 2005). Basically, formative assessment is regarded as an assessment for learning, and as such formative assessment is employed during the teaching and learning process since it is used to improve the teaching and learning process (Bell & Cowie, 2001; Bell, 2005). Hence, it is misleading to view continuous summative assessments as a strong form of formative assessment. Consequently, it can be inferred that, although the findings indicate that some trainee science teacher participants had some knowledge about formative assessment, there is a need for them to develop the appropriate understanding and skills to facilitate formative assessment in the SBA of practical work. This finding supports the findings by Walani (2009) and Sade (2009) which indicated that teachers need to improve their knowledge and understanding beyond the traditional summative assessment foci.

This present study is premised on the notion that the SBA of practical work should be used for both continuous summative assessments and formative assessments. As such, trainee science teachers should be provided with the appropriate training to facilitate both assessment purposes, the assessment of learning – a summative purpose; and the assessment for learning – a formative purpose. They should be trained to provide quality and trustworthy assessments that would add value to learners' achievement (O'Farrell, 2002). As outlined in subsection 2.5.3, a valid formative assessment is associated with the level of feedback and feedforward that science teachers can provide during the teaching and learning process that evidently and subsequently improves learners' learning to achieve the learning outcomes (Green & Johnson, 2008). Subsequently, the validity of formative assessment for learning new concepts is embedded in the kind of scaffolding that teachers provide for learners to make a conceptual change from prior misconceptions to construct, assimilate and accommodate new scientific concepts in school science (Kawalkar & Vijapurkar, 2013; Cheung, 2016). Consequently, this study concludes that trainee science teachers should be trained to provide effective scaffolding that would assist learners to close

the gap between what is intended and what is achieved during the teaching and learning process in the SBA of practical work.

On the whole this section provides a discussion of key findings on how trainee science teacher participants in this study view and experience their learning and assessment of scientific and physics concepts with respect to the use of SBA of practical work during their teacher training. The findings indicate that science teacher training programs should include more content knowledge and practice in conducting practical work for formative assessment purposes and scaffolding. The next section will go on to discuss how practising science teacher participants view and experience their teaching and assessing of scientific and physics concepts in the SBA of practical work.

6.5 Findings from Practising Science Teachers' Perceptions (Response to Research Question Three and Five)

The third and fifth research question for this study sought to explore practising science teacher participants' perceptions of their teaching and assessment as well as their suggested changes to the SBA of physics concepts in practical work. This discussion is divided into the following key findings: (i) mismatch between curriculum design and availability of resources and logistics; (ii) not enough teaching and assessment for conceptual and procedural understanding in science; (iii) not enough formative assessment; and (iv) enhance PCK in physics.

6.5.1 Mismatch between Curriculum Design and Availability of Resources and Logistics

The qualitative findings indicate that the majority of practising science teacher participants perceived that there is a mismatch between what is expected in the curriculum and the availability of resources and logistics. They shared the view that their science classroom environments were not supported logistically to implement and effectively fulfil what is expected in the heavily prescribed science curriculum. The findings indicate that, not only was there a lack of science classroom resources but the number of learners per classroom was also an inhibiting factor from teaching and assessing for conceptual and procedural understanding in the SBA of practical work. As reported in subsection 5.8.1 and 5.8.2, science classrooms were usually

crowded with learners, beyond the preferred number per classroom. Such crowded science classrooms have restricted the movement of science teachers in the class and this has impacted the effectiveness of implementing the SBA of practical work and formative assessment.

According to the findings in Section 5.8, logistics referred to in this study include: the number of science laboratories, equipment and consumables; number of text books for learners to use throughout the academic year; number of classrooms and desks; teaching aid for individual and whole class approaches; resources for learners to do literature reviews of topics in science as well as access to remote and isolated schools. The findings indicate that learners who study at the high schools in the urban centres have better access to academic resources like libraries and internet to do literature reviews than learners in the rural and remote areas. The majority of the practising science teacher participants also shared the view that they prefer to use whole class teacher demonstrations for practical work experiences instead of allowing learners to do practical work individually. Given this finding, it is imperative to propose alternative ways to enhance the teaching, learning and assessment of physics concepts in the SBA of practical work despite the lack of resources and logistics.

The qualitative findings of this study indicated that some practising science teacher participants had suggestions to address the concern about the lack of resources and logistics. As reported in subsection 5.8, on the one hand, practical work in the SBA curriculum should be designed according to the resources available in and logistic capacity of individual high schools. In this regard, the kind of topics or physics concepts that can be included in the SBA are subjective to the availability of resources and logistics in each individual high schools. On the other hand, the high schools should be provided with the necessary resources and logistics according to the predesigned practical work. In other words, appropriate resources and logistics should also be provided with the SBA handbook to the high schools. While these suggestions provide logical views and reasoning, administering and managing such an approach in the long run may be costly for the Ministry of Education and the curriculum designers.

Alternatively, this study suggests that practising science teachers should enhance their PCK in order to effectively carry out the SBA of practical work despite the lack of resources and logistics. In fact, studies have shown that even when logistics is

addressed to a substantial level, the other concern is whether science teachers can effectively conduct different types and levels of practical work (Osborne, 2014). Retrospectively, the findings for this study indicate that the lack of resources and logistics support was a concern. Given such a concern, it can be inferred that it is imperative to enhance practising science teachers' PCK, skills and confidence to effectively conduct the SBA of practical work even when there is a lack of resources and logistics support. In fact, other studies have indicate that science teachers' PCK is essential when it comes to making critical decisions about effective teaching, learning and assessment processes in science classrooms (Kind 2009). In this regard, practising science teachers should continue to enhance their PCK in order to make informed decisions and to find alternative ways to improvise in SBA of practical work.

Having an explicit PCK is a bonus for practising science teachers who may face difficulties with the lack of resources and logistics to implement the SBA of practical work. In essence, this study premised that practising science teachers should have the ability to improvise and provide effective teaching, learning and assessment of physics concepts in the SBA of practical. For example, instead of using common laboratory equipment to verify the concept of force, other sociocultural and readily available artefacts can be used to improvise. As such, practising science teachers need to develop their content knowledge, procedural understanding and skills in order for them to have the ability to make informed decisions on how to contextually facilitate teaching, learning and assessments in the SBA of practical work (Kind, 2009; Berg, 2015). Besides this, practising science teachers need to enhance their understanding and skills to scaffold and facilitate formative assessment for learners to make links between the domains of observables to the domain of ideas, especially when practical work is improvised and artefacts used are contextualised (Osborne, 2014). Hence, given these findings, there should be more ongoing professional learning programs for science teachers to enhance their professional capacity to teach and assess physics concepts despite the lack of resources and logistics.

6.5.2 Not Enough Teaching and Assessment for Conceptual and Procedural Understanding in Science

The findings indicate that the majority of practising science teacher participants perceived that one important aspect of science and physics education is to develop

learners' understanding of scientific concepts as well as the ability to solve problems in science. According to Tamir (1991) and Osborne (2014), developing learners' ability to solve problems in science involves the teaching, learning and assessment of procedural understanding and skills in practical work. As explained in subsection 2.4.2 and 2.4.3, this can be addressed by using open inquiry or level three practical work (Tamir, 1991). Generally, Table 4.2 indicates that the majority of study participants perceived that they know and can use multiple representations to teach as well as assess physics concepts and procedural skills in school science. However, qualitative findings also indicate that it was not possible to conduct pragmatic teaching, learning and assessment methods during normal class times due to crowded classrooms and the lack of resources as discussed earlier in subsection 6.5.1. As such, the majority of participants perceived that they conducted the SBA of practical work mainly to complete the curriculum as reported in subsection 5.5.6. In this regard, the findings indicate that there was not enough teaching and assessment activities to develop learners' conceptual and procedural understanding as well as skills in the SBA of practical work.

The findings indicate that practising science teacher participants perceived that it is more effective to teach and assess scientific concepts as well as procedural skills with individual learners or a small group of learners. However, subsection 5.4.7 showed that some practising science teacher participants tend to use the whole class approach to teach and assess their learners' understanding of scientific and physics concepts. While some participants perceived that they can interact with their learners by asking questions and getting responses from them, it may not be possible to clearly identify different learners' level of understanding within a whole class approach. Hence, it may not be easy to identify learners who understand the concepts from those who are struggling or do not understand at all. Consequently, it can be inferred from this finding that even though science teachers perceived that they knew how to effectively teach and assess conceptual and procedural understanding in physics, it may not be effective within a whole class approach. Therefore, practising science teachers need to enhance their knowledge, understanding and skills to effectively teach and assess given the situation implied in these findings.

The findings also indicate that the majority of practising science teacher participants perceived that they used practical demonstrations in the whole class approach. In this regard, many scientific concepts and procedural understanding were taught predominantly by theory and observation. While practical work includes demonstrations by a science teacher in front of a science class or using videos, the learning experience that learners should develop from observation in the class is significant (Miller, 2004). The process of making conceptual and procedural links between what is observed to scientific ideas requires appropriate scaffolding from science teachers (Abrahams, 2011; Hodson, 2014). Although the quantitative findings indicate that the majority of practising science teacher participants perceived that they had knowledge of teaching and assessing physics concepts, the qualitative findings indicate that it was not easy to provide scaffolding within a whole class approach. Hence, given such a classroom environment, it is recommended that science teachers should develop better understanding, knowledge and skills to provide scaffolding for conceptual as well as procedural understanding and skills in the SBA of practical work.

This study suggests that science teachers should enhance their knowledge and skills to teach and assess physics conceptual and procedural understanding within a whole class approach. Basically, facilitating, scaffolding or providing progressive feedback and feedforward during practical work in a whole class approach is complex and highly demanding for both learners and teachers (Cheung, 2016; Kawalkar & Vijapurkar, 2013). Even though science teachers may have the knowledge and skills to understand and identify individual learner's preconceptions and misconceptions, it may not be possible in a whole class approach. As such, providing quality feedback and feedforward to a whole class is a professional skill that science teachers need to develop over time in their teaching careers as well as by enhancing their PCK (Bell, 2005; Cheung, 2016; Hodson, 2014). As expressed in subsection 2.6.2, practising science teachers can form communities of practice that can provide the sociocultural and constructivist environment whereby scaffolding experiences for a whole class approach can be shared and developed over time as professionals.

6.5.3 Not Enough Formative Assessment Practice

The findings for this study indicate that the practising science teacher participants perceived that their practice on conducting effective formative assessment process was

lacking. While some participants understood the importance and nature of formative assessment, its use in the classroom was not common in comparison with summative assessments. This finding is similar to findings by Sade (2009), F. Rodie (2014) and Walani (2008) in Solomon Islands. All these three studies found that summative assessment was common and there was a lack of formative assessment. In fact, some of the participants for this study perceived that they rarely employed formative assessment during the SBA of practical work since it was basically for summative assessment purposes. It can be inferred that the notion of high stake examinations and the obligation to complete the curriculum within a certain time frame had influenced the majority of practising science teacher participants to rarely use formative assessment. The findings indicate that summative assessment is important because learners need to be tested on what they have learnt at the end of each topic, course or program. Subsequently, the participants perceived that summative assessment is also a practice for learners in preparation for their final external high stakes examinations at the end of their high school education.

The findings for this study indicate that some of the practising science teacher participants perceived that, while formative assessment was crucial for learning during teaching and learning process, the use of summative assessment for the SBA of practical work was more appropriate. As outlined in subsection 1.7.4, the SBA of practical work curriculum is purposely designed to assess learners' manual skills as well as their ability to follow instructions. However, as reported in subsection 5.5.1, the understanding and application of scientific concepts were perceived to be assessed more than that of the skills to follow instructions. Hence, there was a mismatch between what was intended for the SBA and what was perceived by the practising science teacher participants. In this regard, validity of summative assessment in practical work should be maximised to assess what it is supposed to assess (Cheung, 2016; Harlen, 2005).

Consequently, on the one hand, since the majority of participants for this study perceived that learners' understanding of scientific concepts should be assessed, the SBA of practical work should be designed to assess learners understanding of scientific concepts that should have been learnt in class. In other words, both science teachers and learners must be familiar with the learning outcomes and learners should have

been given the opportunity to develop the understanding of the concepts prior to the summative assessment. If this was the case, then the process of formative assessment or assessment for learning is still crucial in the prior process of teaching and learning of scientific concepts in normal class and practical work. However, while formative assessment is significant for conceptual learning, the findings indicated that it was not a common practice used for the purpose of the SBA of practical work.

This study argues that practising science teachers should enhance their knowledge and increase their practice in carrying out formative assessment in class as well as during practical work. With more practice in doing formative assessment science teachers can develop better knowledge and skills to identify what level of learning the learners have reached, and what learning still needs to be done in order to reach the intended learning outcome (Bell, 2007). Science teachers can identify the level of learning through the words, inscriptions, and artefacts learners may have used to demonstrate their reconstruction of their conceptions during the formative assessment process. That means that, through scaffolding with appropriate feedback and feedforward science teachers should be able to identify the learners' preconceptions and zone of proximal development (Vygotsky 1987). As well, learners would also ensure that they have progressively improved their construction of the physics concepts. So for the teaching, learning and assessment of scientific and physics concepts, formative assessment can be an effective strategy to use in class teaching and practical work prior to as well as during the SBA.

These findings reveal trends of inconsistencies in the use of formative assessment in the SBA of practical work. On the one hand, the quantitative findings indicate that the majority of participants can use formative assessment in the SBA of practical work. This is indicated in Table 4.5 in subsection 4.3.4. On the other hand, the qualitative findings indicate that participants had inconsistent views and experiences on the definition and nature of formative assessment as reported in subsection 5.5.8. Although participants indicated that formative assessment is important in the SBA of practical work for the learners' conceptual and procedural understanding, some participants also perceived that summative assessment was predominantly utilised. As such, it can be inferred that, assessment for summative purposes was imperative and dominant in this sense. However, the literature indicated that formative assessment is a powerful tool

for scaffolding for the development of conceptual and procedural understanding (Cowie, 2005) as highlighted earlier in subsection 6.5.2. Hence, it is recommended that science teachers should develop the knowledge and skills to conduct formative assessment when teaching and assessing for learners' conceptual and procedural understanding. In addition, formative assessments should be frequently employed during the teaching and learning processes in normal science practical work in class as well as for the SBA of practical work.

6.5.4 Enhance Pedagogical Content Knowledge in Physics

The findings for this study indicates that the majority of practising science teacher participants shared the view that PCK is significant for improving science teachers' knowledge and understanding in teaching. As reported in subsection 5.7.2, science teachers need to broaden and deepen their PCK. It was also stressed that having a better PCK will help science teachers teach as well as assess scientific concepts and skills in high school science. Some participant perceived that many science teachers still need improvement even though they had already completed their teacher training and are capable of teaching. As discussed in subsection 2.6.2, PCK is a personal construct that teachers themselves could develop over time through practice, self-assessment and enactment to do better (Etkina, 2010). Hence, science teachers should do more practice as well as develop the ability and skill to improve themselves. However, Wongsopawiro et al. (2017) suggested that action research could be used as an avenue to stimulate as well as enhance science teachers to carry out their own progressive journey to develop their PCK over time. In saying that, this study recommends that schools as well as education authorities should promote and advocate for the professional learning of science teachers by employing action research within a community of practice.

The findings of this has inferred that the enhancement of science teachers' PCK for use in the SBA of practical work can be complex. As discussed earlier in this section 6.5, the majority of practising science teacher perceived that there are challenges to effectively carry out the SBA of practical work. The challenges involve the lack of resources as discussed in subsection 6.5.1 and the lack of practice and skills in applying what they know in SBA of practical work as discussed in subsection 6.5.2 and 6.5.3. However, as discussed by Wongsopawiro et al. (2017), this can be addressed through

teacher training courses and an ongoing practising science teachers' professional practice and learning. Science teachers can improve their PCK from external sources, such as planned workshops and from their own peers as in a community of practice (Wongsopawiro et al., 2017). Accordingly, Yung (2012) suggested that science teachers should play a proactive role in developing their PCK with their peers within their community of practice. Consequently, while science teachers focus and reflect on their own individual practices they should also take time to consult, share as well as review the practices of their peers within their community of practice.

This study posited that in having a community of practice, science teachers can establish collaborative professional learning environments that integrate sociocultural and constructivist practices as well as professional development. As outlined in subsection 2.6.2, such a community of practice could provide an environment wherein science teachers can interact with each other to develop their conceptual, procedural and epistemic understanding in science. Such a collaborative approach would also promote the epistemological and sociological processes in learning and doing science, as well as developing teachers' PCK in relation to the features of the NoS (Duschl, 2008).

Retrospect to the purpose of this study, the enhancement of science teachers' PCK is significant for use in the SBA of practical work. In fact, other studies had found and argued that as a personal ability science teachers can strengthen their capacity to improve their PCK through their many years of teaching experiences and professional learning (Etkina, 2010; Wongsopawiro et al., 2017). Besides, specific and targeted professional training for practising science teachers is also highly recommended (Etkina, 2010). As outlined in subsection 2.6.2, there are different pathways that practising science teachers' can undertake to progressively enhance their PCK over time during their teaching career. For example, one pathway is a result of a reciprocal relationship of reflection and enactment between four factors: personal domain - teacher's knowledge, beliefs and attitudes; external domain - external information and support; domain of practice - trying out new activities; and domain of consequence - new conclusions from effective outcomes in classroom practice (Clarke & Hollingsworth, 2002; Wongsopawiro et al., 2017). Given this four factors, this study recommends that awareness and professional learning environments should be

developed for science teachers to progressively undertake and subsequently enhance their PCK on ongoing basis.

In sum, the findings for this study indicates that the purpose to enhance both trainee and practising science teachers' PCK for the teaching, learning and assessment of scientific and physics concepts in the SBA of practical work is necessary.

6.6 Similarities and Differences between Trainee and Practising Science Teacher Participants' Views and Experiences

The findings for this study indicates some similarities and differences between the trainee and practising science teacher participants' perceptions on teaching, learning and assessment of scientific and physics concepts in the SBA of practical work. Hence, for the purpose of understanding, and subsequently addressing, the need to enhance the PCK of these two cohorts it is imperative to specifically highlight the key similarities and differences between the two cohorts.

6.6.1 Key Similarities

The quantitative and qualitative findings for this study indicate that the trainee and practising science teacher participants perceived that an understanding of scientific concepts for use in everyday livelihood is significant in science education. However, while the quantitative findings in subsection 4.3.1 and 4.3.3 suggested that participants perceived that they have the physics content knowledge to teach and assess, the quantitative findings in subsection 4.3.5 indicated that the majority of participants in both cohorts had misconceptions in relation to the four Newtonian force concepts. Added to that, the qualitative findings indicates that while trainee science teacher participants perceived that they were confident to teach and assess physics concepts at junior high school level, they were not confident at senior high school level. Similarly, even though the majority of practising science teacher participants perceived that they were confident to teach and assess physics in high school, they perceived that they still need to enhance their physics content knowledge to teach and assess physics concepts at senior high school level.

These similarities are imperative for this study since they provide the basis to enhance the PCK of the trainee and practising science teachers. These findings support as well as correspond to the Solomon Islands National Education Action Plan 2016 – 2020, which states:

It is also identified that many teachers do not have the required subject knowledge needed, and while there has been a rapid increase since 2007 in the proportion of teachers who are qualified many teachers with subject qualifications are not trained to be teachers. There are very limited in-service opportunities for current teachers and teachers wishing to access in-service training resulting in a qualification, have to enrol and attend a tertiary institution, mainly the Solomon Islands National University (SINU). Even then a question remains as to whether the subject knowledge gained as part of the teacher training is sufficient to teach at the senior secondary level. There is an emerging consensus that teachers should be degree holders in their specialty subject area, but concerns are expressed by Education Authorities about the quality of many pre-service teacher graduates (MEHRD, 2017, p. 15).

The findings indicate that the majority of participants from both cohorts had inconsistent views and experiences about the nature and definition of formative assessment and PCK as well as learners' preconceptions and misconceptions. The majority of participants from both cohorts defined formative assessment as a continuous summative assessment. Further, they also perceived PCK as a model of knowledge components that combines content knowledge and pedagogy knowledge. The similarities between the two cohorts in this study indicates that it is imperative to improve and develop better training programs for trainee science teachers as well as ongoing professional learning for practising science teachers. Consequently, both cohorts should enhance their PCK, which comprises the key research areas premised in the conceptual framework for this study.

6.6.2 Key Differences

The findings for this study indicate that there are key differences between the views and experiences of the trainee and practising science teacher participants. The key

differences lie in the fact that one cohort was in training while the other was practising. Hence, the trainee science teacher participants shared their views on their teacher training experiences as well as their perceptions for the future while practising science teacher participants shared their views about their ongoing teaching experiences.

On the one hand, the findings indicate that the trainee science teacher participants perceived that there was lack of training to conduct practical work in teacher training programs. In particular, the participants perceived that there was not enough training and practice in utilising practical work to teach and assess scientific concepts and skills during their teacher training. Added to that, there was a lack of training on developing their understanding and skills to scaffold as well as to facilitate formative assessments in the SBA of practical work. As such, trainee science teacher participants indicated their concern to have more theoretical and practical training in order to develop their understanding and skills to utilise practical work to teach and assess scientific and physics concepts. Besides this, trainee science teacher participants suggested a need for teacher specialization training and subject streaming. In other words, trainee science teachers should be trained to specialise on a specific teaching subject instead of training to teach multiple science subjects in high school science.

On the other hand, the findings indicate that the majority of practising science teacher participants highlighted the challenges they face in implementing practical work due to insufficient school science resources and crowded classrooms. The majority of practising science teacher participants perceived they had used practical work for whole class demonstrations to further explain and verify scientific concepts to learners. However, they perceived that there was a lack of interaction in terms of scaffolding and formative assessment. They perceived that while practical work is significant to develop learners' understanding of scientific concepts and skills, it was not possible to teach and assess effectively. Hence, they were inclined to use a whole class approach to teach and assess more theoretically than practically. In fact, some of the practising science teacher participants perceived that there is a mismatch between what the SBA of practical work intended to achieve and the availability of resources in high schools. Further, although practising science teacher participants perceived that they were confident to teach and assess physics concepts, they still expressed the need to enhance their PCK to teach and assess scientific concepts in the SBA of practical work.

6.7 Summary of Chapter Six

The purpose of this study was to explore alternative ways to enhance both trainee and practising science teachers' PCK to carry out the teaching, learning and assessment of scientific and physics concepts in the SBA of practical work curriculum in science education. Although the findings were generated from both quantitative and qualitative data, this chapter has brought them together into a cohesive and relevant discussion of the key findings. In essence, this chapter provides a discussion that synthesises the findings, the literature review and the researcher's sociocultural and contextual reflections to answer the research questions for this study. The discussion of key findings for this study indicates that the majority of participants had relevant views and experiences about the importance of science education and the purpose for learners to develop an understanding of the scientific concepts, skills and attitude for everyday livelihood. Subsequently, the findings suggest that both the trainee and practising science teacher participants perceived that this purpose can be achieved through utilising both the theory and practice teaching, learning and assessment approaches.

However, the findings indicate that the participants had inconsistent views and experiences about their level of content knowledge and knowledge of learners' preconceptions and misconceptions. In addition, although the majority of participants strongly supported utilising both formative and summative assessments in the SBA of practical work, their perceptions were inconsistent with their practices about formative assessment and scaffolding. Subsequently, this study found that the participants had inconsistent definitions and understanding about formative assessment and PCK. Hence, while there is a need to improve the design of the SBA of practical work and science education resources and facilities, this study had focused on enhancing science teachers' PCK. This study suggests that the trainee and practising science teachers' should enhance their PCK to facilitate the teaching, learning and assessment of scientific and physics concepts in the SBA of practical work curriculum. As shown in this discussion of key findings, science teachers need to enhance their confidence to teach and assess physics concepts at senior high school level as well. As such, this study suggests that there should be further improvements in the training courses for trainee science teachers as well as on ongoing professional learning strategies for practising science teachers.

This chapter has provided a set of guidelines that can be used as a framework to enhance science teachers' PCK to facilitate the teaching, learning and assessment of scientific and physics concepts in the SBA of practical work. Next, Chapter Seven will present a comprehensive conclusion to this study, which includes the summary, implications and limitations for this study as well as suggestions for future research and the researcher's concluding remarks.

CHAPTER SEVEN

Conclusion of this Study

7.1 Chapter Overview

Leading to this conclusion chapter, Chapter One presented the introduction, motivation, background, theoretical framework, significance, context and purpose for this study. Chapter Two established the conceptual framework by reviewing the key research areas in the literature. Chapter Three described the research design which includes the research perspectives, case study design, mixed-methods approach as well as the generation and analysis of data. Chapter Four reported the quantitative findings followed by the report on qualitative findings in Chapter Five. Then Chapter Six presented a synthesised discussion of key findings in relation to the literature review and researcher's sociocultural and contextual reflections. Finally, this chapter presents the conclusion by outlining a summation of the outcome of this study in Section 7.2. Then Section 7.3 highlights the implications followed by the limitations for this study in Section 7.4. Subsequently, Section 7.5 provides the considerations for future studies. Finally, Section 7.6 presents the researcher's concluding remarks for this study.

7.2 Summation of the Outcome of this Study

This section presents the summation of the theoretical basis for this study and highlights the key findings pertaining to the research questions and conceptual framework of this study.

7.2.1 Summation of the Theoretical Basis for this Study

The motivation for this study arose from a review of key research areas in the science education literature as well as the researcher's personal experiences and reflections pertaining to the quest to improve the nexus between what is intended for and what is

attained by learners in the school-based assessment (SBA) of practical work. Thus, this study was underpinned by a theoretical framework that postulates a gap between intended curriculum and attained curriculum as outlined in Section 1.5 (Goodlad, 1979; Rosier & Keeves, 1991; Van den Akker, 1998). According to the theoretical framework, teachers play a crucial role since their perceptions about the curriculum, subject matter, pedagogy, assessment along with their practices in the classroom are significant in minimising the gap (Van den Akker, 1998). Hence, this study specifically focused on the role of science teachers in minimising the gap between intended and attained curriculum for the SBA of practical work in high school science education.

Based on the theoretical framework and the literature from related key research areas, a conceptual framework was developed and outlined in Section 2.2 and depicted in figure 2.1. The conceptual framework posited that science teachers' pedagogical content knowledge (PCK) is central to minimising the gap between what is intended in the SBA of practical work and what is attained by learners. This study argued that science teachers' PCK should include the integration of: the understanding of scientific concepts as one of the important aims of science education; the knowledge of teaching, learning and assessment of scientific concepts and skills in relation to the nature of SBA and practical work. In this regard, this study specifically explored and documented both the trainee and practising science teacher participants' views and experiences on teaching, learning and assessment of physics concepts in the SBA of practical work curriculum by addressing five research questions presented in subsection 1.6.1.

Guided by a case study design, this study employed a triangulation mixed methods approach. Hence, bounded by the phenomenon investigated and the geographical convenience of the participants, both quantitative and qualitative data were concurrently collected and generated from participants' views and experiences. The quantitative findings provided a deductive perspective while the qualitative findings provided an inductive perspective. The findings from both data were complementary to each other and their inferences were triangulated and presented as a synthesised discussion with literature review as well as the researcher's sociocultural reflections. Subsequently, the findings and discussions from this study can be used as a context

and guideline to improve science teachers' PCK for teaching, learning and assessment of scientific concepts in the SBA of practical work in science education.

As depicted in figure 7.1 below, the theoretical basis for this present study is manifested in the relationship between the theoretical framework and integration of key research areas into a coherent conceptual framework. In essence, this study premised that the conceptual framework is imperative in enhancing science teachers' capacity to address the perceived and operational curriculum in order to minimise the gap outlined in the theoretical framework underpinning this study.

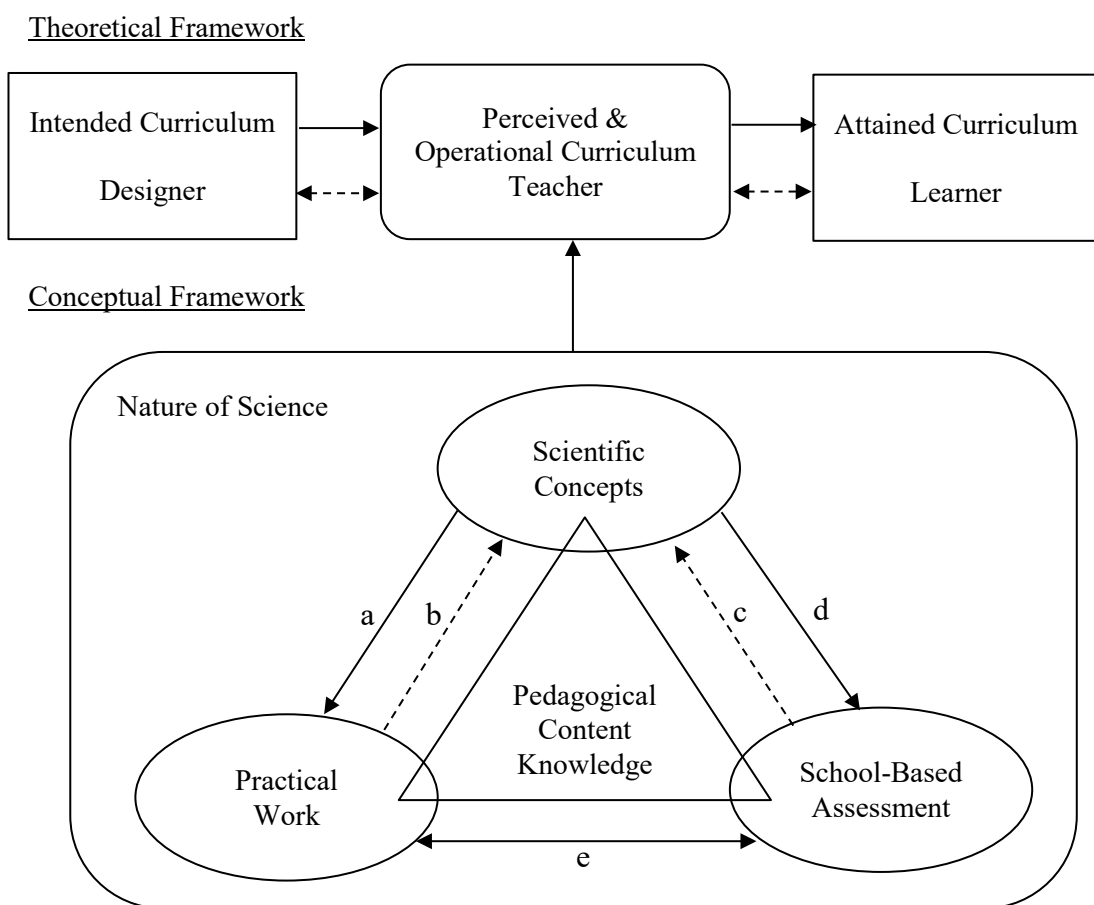


Figure 7.1. The relationship between the theoretical framework and conceptual framework for this study

Consequently, this study had demonstrated that to minimise the gap, the key areas of the conceptual framework must be coherently and cohesively addressed through science teacher training as well as on ongoing professional learning programs.

7.2.2 Key Findings in Relation to the Research Questions and Conceptual Framework

This study found that the majority of participants perceived science education as an important avenue for developing learners' understanding of scientific concepts, skills and attitude for use in their everyday livelihood. In addition, the findings indicated that science education is also imperative for learners to develop their understanding on how scientific and physics concepts are useful to explain physical relationships and laws in real life contexts as well as appreciate and care for their natural environment. Besides, the findings suggested that developing learners' understanding of scientific concepts and skills would also benefit them in their future careers as well as for nation building and economic development. Subsequently, the majority of the participants perceived that the SBA of practical work is important for the development of learners' skills and understanding of scientific and physics concepts.

Understanding of scientific concepts is one of the key research areas in the conceptual framework for this study. In this regard, the findings indicated that the majority of participants had some knowledge about teaching, learning and assessment of scientific concepts in the SBA of practical work. The majority of participants perceived that scientific concepts can be taught and learnt in multiple ways. For example, the findings suggested that scientific concepts can be effectively taught and learnt through theory, demonstrations, practical work, charts, diagrams and videos. The findings claimed that making connections between abstract concepts and observable materials and objects are effective ways to enhance learners' understanding of scientific concepts. Added to that, the majority of participants indicated the importance of using everyday examples to make connections between scientific concepts and learners' prior familiar experiences as well as preconceptions.

However, the findings revealed some inconsistencies with the majority of participants' perceptions on content knowledge and how to teach and assess physics concepts. On the one hand, the quantitative findings indicated that the majority of participants perceived that they had good content knowledge to teach and assess scientific and physics concepts. This finding was also evident in the qualitative findings. On the other hand, the quantitative findings indicated that the majority of participants had misconceptions about the four Newtonian force concepts presented in the survey for

this study. In addition, the qualitative findings showed that the majority of trainee science teacher participants were not confident to teach and assess physics concepts at senior high school level. Besides, the quantitative findings indicated the participants had inconsistent responses on knowledge of learners' understanding, preconceptions and misconceptions. The majority of participants indicated that it is not easy to teach physics concepts since it is difficult to overcome learners' preconceptions. Conversely, the majority of participants also perceived that they can teach physics concepts since they can easily recognise learners' abilities and preconceptions. Consequently, according to the conceptual framework of this study, science teachers should develop deeper understandings of scientific concepts as well as enhance their knowledge of learners' understanding, preconceptions and misconceptions.

The findings indicated a mismatch in the participants' views and interpretations of what is intended in the SBA of practical work. As outlined in subsection 1.7.4, the main purpose of the SBA of practical work for the Solomon Islands School Certificate (SISC) is to assess learners' skills in science that are difficult to assess in written examinations. However, the findings indicated that while science skills are significant to teach and assess in the SBA of practical work, it is the understanding of scientific concepts that should be paramount. In fact, the findings suggested that the SBA of practical work should include more scientific and physics concepts or topics. Added to that, the findings indicated that the SBA of practical work should include more open investigations such that learners' are assessed on their understanding and knowledge of problem solving and science inquiry. The mismatch between the findings and the aim of the SBA of practical work is an obstacle to closing the gap between what is intended and what is attained in the SBA of practical work curriculum. Therefore, with respect to the conceptual framework of this study, science teachers need to enhance their understanding and knowledge on the nature and purpose of the SBA of practical work.

The findings also indicated that there was a mismatch between the participants' perceived knowledge about PCK and articulation of its definition and nature. On the one hand, as shown in the quantitative findings, the majority of participants had comprehensive PCK to teach and assess scientific and physics concepts in the SBA of practical work. However, on the other hand, the qualitative findings indicated that the

participants were not able to articulate the definition and nature of PCK. A similar mismatch was indicated in the findings on the importance of formative assessment in the SBA of practical work. Although the majority of participants perceived that the formative assessment or assessment for learning is significant and they had used it for teaching, learning and assessment of scientific concepts in the SBA of practical work, its definition and nature was not well articulated in the qualitative findings. The majority of participants had different perceptions, in particular, they perceived formative assessment as continuous summative assessments. Consequently, with respect to the conceptual framework of this study, science teachers should enhance their understanding on the definition and nature of PCK and formative assessment in the context of the SBA of practical work.

The findings also indicated considerable obstacles for the effective implementation of the SBA of practical work in Solomon Islands science education. The findings indicated that many schools in the rural and urban areas in Solomon Islands may not have the appropriate or necessary science equipment to effectively implement the SBA of practical work as intended. In addition, the findings revealed that many schools have crowded science classes. As such, it was not simple to carry out practical work with very few and inappropriate science equipment. The participants perceived that they had to resort to conducting practical work with large groups of learners while others mainly used whole class demonstrations and didactic teaching using blackboard and chalk. The findings indicated that such obstacles had caused even the experienced science teachers to make up marks for learners or allowed learners to copy from past practical work reports that were written by learners from previous years. Such a practice was related to the ability of science teachers to implement their responsibilities professionally and ethically. In this regard, these findings reinforce the need for science teachers to enhance their knowledge, understanding and skills for use in the SBA of practical work

These findings are worthwhile for the purpose of enhancing both trainee and practising science teachers' role in minimising the gap between what is intended and what is attained in the SBA of practical work. Consequently, as underpinned by the theoretical framework and premised in the conceptual framework of this study, the findings had indicated that it is necessary to enhance both trainee and practising science teachers'

PCK in relation to the understanding of scientific concepts, the purpose and nature of the SBA of practical work.

7.3 Implications of this Study

The findings for this study have four key implications, namely: (i) improving SBA of practical work; (ii) enhance science teachers' PCK; (iii) influence on science education policies in Pacific Island nations; and (iv) contribution to science education literature.

7.3.1 Improving School-Based Assessment of Practical Work

The findings for this study implied that there is a mismatch between the aim of the SBA of practical work in the SISC curriculum and the participants' perceptions and interpretations. While the SBA curriculum for SISC is intended to assess learners' skills in science that are difficult to assess in written examinations, the findings indicated that it should assess learners' understanding of scientific concepts as well as problem solving skills and knowledge for use in everyday livelihood. The majority of participants perceived that the SBA of practical work enable learners to verify and further develop their understanding of scientific concepts and procedural skills. This implication indicated a need to revisit and improve the intended purpose and design of the SBA of practical work curriculum, especially, in the context of the Outcome-Based Education (OBE) in Solomon Islands.

According to the notion of 'fitness for purpose' there are different levels of practical work that can be designed for different purposes (Hodson, 2014; Tamir, 1991). If the purpose was to assess learners' manual or handling skills then practical work in the SBA should be designed to assess learners' skills as they perform the activity and not afterward from a written report. Likewise, practical work that is intended to assess learners' understanding of scientific concepts should be designed to assess learners' understanding from written or oral explanations (Millar, 2004, Osborne, 2014). In addition, open inquiry activities can be designed to assess learners' procedural understanding, knowledge and skills in science inquiry (Tamir 1991; Osborne, 2014). However, science teachers should develop the appropriate knowledge, understanding and skills to facilitate teaching, learning and assessment in open inquiry.

These implications are significant for both the science curriculum designers who design the intended curriculum and the science teachers who played the crucial role in implementing the curriculum in the science classroom. Hence, science SBA curriculum designers need to have the knowledge and understanding to design practical work with clear purposes and learning outcomes for teaching, learning and assessment of scientific concepts and skills that intend to address the aims of science education. This is essential to the aims of OBE as well. That said, other studies had found that while the SBA of practical work can be designed and used effectively to teach and assess scientific concepts and skills, the process is value-laden and the outcome depends very much on science teachers' competence to implement as well (Bell, 2005; Cheung, 2016). Consequently, while it is important to improve the design, both trainee and practising science teachers should also enhance their knowledge and understanding of scientific concepts as well as the purpose and nature of the SBA of practical work.

7.3.2 Enhance Science Teachers Pedagogical Content Knowledge

The findings for this study implied that science teachers need to enhance their content knowledge in order to conduct formative assessment and scaffolding for teaching and assessing of scientific concepts and skills. In particular, science teachers need to develop the ability to deconstruct scientific concepts during practical work and make connections between abstract ideas and observable objects. As described in section 2.3, a scientific concept comprises a combination of several ideas, symbols and inscriptions that were well investigated, scrutinized, established and sanctioned by the scientific community. Hence, science teachers need to develop deeper and broader level of content knowledge in order to deconstruct abstract scientific concepts into comprehensible components that learners can identify and subsequently reconstruct for deeper conceptual understanding. With deeper content knowledge science teachers can also use formative assessment to improve teaching, learning and assessment of scientific concepts which involves intentional scaffolding and enculturation (Hodson, 2014; Vosniadou, 2002). This implication of assessment for learning is also significant for the teaching and assessment of procedural and inquiry skills as well as for the NoS.

The findings implied that trainee science teachers need to enhance their PCK during their teacher training programmes. The findings indicated that trainee science teachers

had less training on developing their content knowledge as well as less practice on conducting practical work. As such, the findings implied that trainee science teachers should further enhance their understanding and skills to use practical work for teaching and assessment of scientific concepts and skills. Accordingly, there is an implication to include more pragmatic microteaching for trainee science teachers to develop their understanding and skills to conduct scaffolding in the SBA of practical work for formative purposes.

The findings implied that practising science teachers need frequent ongoing professional learning to enhance their perceptions and practise for conducting formative assessments in the SBA of practical work. Apart from giving practising science teachers further formal training in an institution, there is an implication to address the notion of having a community of practice involving science teachers from a cluster of high schools. This involves establishing a community of science teachers who would share and progressively learn as well as evaluate their practice and experience within their community. This resonates with establishing science communities that integrated aspects of cognitive, epistemic and sociocultural processes for professional learning (Duschl & Grandy, 2013). As such, apart from further training in an organised institution or in professional development workshops science teachers can also enhance their professional capacity within their community of practice. This notion of developing school science communities of practice can also influence the science teachers' classroom practices as well as for them to reflect and strengthen their PCK development (Etkina, 2010; Osborne, 2014).

Besides more professional learning modules and activities, science education research also has a role in this. Research on scientific concepts, conceptual and procedural learning, conceptual change and other related researches as well as studies in the assessment for learning need to translate into work that can be used by science teachers in their science classrooms. Science teachers can participate in intervention studies that aims to improve their knowledge and understanding in learning science, doing science and learning about science (Hodson, 2014). Added to that, science teachers can be part of an action research study that aims to enhance change in classroom teaching, learning and assessment. As such, science teachers can also involve in improving themselves as well as be part of the data for the research. Other studies have

shown that external information and support are also significant in influencing change (Clarke & Hollingsworth, 2002). In this regard, research outcomes can be translated into workable modules and strategies that science teachers can use for ongoing professional learning as well as to implement in the teaching, learning and assessment process. The research outcomes can be further developed into working framework and educational policies as well.

7.3.3 Influence on Science Education Policies in Pacific Island Nations

The findings and implications from this pioneer study can be utilised to provide sociocultural and geopolitical context and informed framework for science education in Solomon Islands as well as the other Pacific Island nations. This was the first study in Solomon Islands to explore and document both trainee and practising science teachers' views and experiences on teaching, learning and assessment of scientific concepts in the SBA of practical work curriculum. As such, this study provided valuable and validated information for improving the design and purpose for the SBA of practical work curriculum for both primary and high school science education. Added to that, this study can also be used to inform science education curriculum in other sociocultural and geopolitical contexts in both the developing and developed economies globally.

This study provides evidence based data and guideline for policy designers, educators as well as science teachers to recognise the connections between the aims of science education, SBA of practical work and science teachers' PCK. In recognising the connections and the need for coherency, stakeholders can develop and design a curriculum that effectively addresses the aims of science education and SBA of practical work. For example, the aim for scientific literacy in the Solomon Islands science education can be addressed by utilising the connections implicated in the outcome of this study. That is, the aim for scientific literacy should be reflected in the purpose and design of the SBA of practical work and science teachers should have the appropriate PCK to implement the curriculum as intended. This implication is imperative to the implementation of the OBE in Solomon Islands as well.

This study is in-line with one of the main facets in improving the quality of science education and education as a whole in the Pacific Islands nations. As highlighted in Section 1.3, one of the facets in improving the quality of education in the Pacific Islands nations is to refocus on assessment strategies such the SBA (Fasi, 2005; Lingam & Lingam, 2016). The South Pacific Board for Educational Assessment (SPBEA) has promoted that SBA can be used for multiple assessment purposes. On that note, this study provided informative guidelines to support the notion of improving the implementation of SBA. This notion of utilising the SBA of practical work for both summative and formative assessment of scientific concepts is significant for improving the quality of science education. Added to that, this study also provides guidelines for policy makers to develop programmes for science teacher training courses and ongoing professional learning models.

7.3.4 Contribution to Science Literature

In essence, this study has contributed a conceptual framework that can help researchers examine the capacity of science teachers in facilitating the teaching, learning and assessment of physics concepts using practical work in the SBA curriculum. The conceptual framework was developed based on a holistic study that linked: (a) the aims of science education; (b) understandings of scientific concepts; (c) purposes of practical work; (d) the dual purpose of SBA; and (e) science teachers' PCK. Previous studies have explored one or two aspects on SBA, such as the use of SBA in both developed and developing economies (Bell & Cowie, 2001; Cheung, 2016; Chong, 2009; Malakolunthu & Hoon, 2010; Maxwell, 2004), understanding scientific concepts (Fleer, 2009; Khishfe & BouJaoude, 2016) and various facets of practical work and its significance, effectiveness and challenges (Abrahams & Reiss, 2012; Harrison, 2016). By contrast, this study integrated the different aspects of these key research areas into a coherent conceptual framework.

Other studies provided literatures from research relating a combination of two key research areas. For example, Halim and Meerah (2010) examined science teachers' PCK of selected physics concepts in Malaysia. Chun (2006) conducted a case study in Hong Kong to examine the practice and challenges of School-based Formative Assessment. Kapambwe (2010) examined the implementation of school-based continuous assessment in Zambia. Thimmappa and Sharma (2003) examined the

implication of SBA within the Pacific Island nations. In the Solomon Islands, Walani (2008) reported a study on the perceptions of teachers about the use of formative assessment while F. Rodie (2014) presented a study relating to summative assessment practices in Year nine. While these other studies had provided findings on one or two key research areas, this present study had provided a set of guidelines which combines the key research areas into a more coherent platform to effect the process of teaching, learning and assessment of scientific concepts in the SBA of practical work in school science.

In sum, this study had argued that science teachers' PCK should comprise an integrated knowledge and understanding of: the importance of science education; scientific concepts and procedural skills; purpose and nature of practical work; and nature of SBA as well as the NoS. In other words, PCK is associated with the ability of science and physics teachers to carry out teaching, learning and assessment using the SBA to achieve the aims of practical work and science education. That encompasses the capacity of science and physics teachers to effectively facilitate the teaching, learning and assessment of scientific and physics concepts, procedural skills as well as to motivate learners to learn about science, learn in science and do science. In this regard, this study provides a conceptual framework that can be used as a platform to inform other researchers who have the interests related to the scope of this study.

7.4 Limitations of this Study

This present study had involved a number of limitations that need to be clarified before its findings can be generalised to other sociocultural and geopolitical contexts. Firstly, the sample population that responded to both the quantitative survey and qualitative interviews were small compared to the general population of science teachers in Solomon Islands. This study involved a sample size of 8.4 percent of the total number of high schools and 21.8 percent of the total population of science teachers in Solomon Islands in 2015. While the sample population was small, to ensure external validity, sample schools and participants were purposely selected and invited to represent different range of school organisations in Solomon Islands (Creswell, 2003). In addition, by employing a case study design, the selected sample of schools and participants were bounded by their geographical locations as well as their experiences

and knowledge in science education and the SBA of practical work (Yin, 2002). In this regard, the attributes of the sample population for this study can reflect and provide a representation of the views of science teachers in Solomon Islands.

Secondly, two issues emerged during the piloting of the original survey instrument that was approved in the candidacy proposal for this study. The survey was too long and most of the 29 items in the FCI were difficult to answer. As detailed in subsection 3.7.3, it was indicated that not all science teachers graduated with a good content knowledge in science, particularly in physics. There were concerns of getting the answers to FCI items wrong, despite the fact that instructions indicated that items were constructed to elicit perceptions. To combat these two issues, a number of refinements were made to the survey instrument before the actual study was undertaken. It was decided that only four out of the 29 items from the FCI were included in the main survey as the fifth scale. The four items were selected since they are included in the Solomon Islands high school science syllabus and were frequently used for the SBA of physics concepts. However, the use of only four items had contributed to the limitation of measuring the validity of content knowledge. Besides, while there are several other methods and techniques to examine PCK, this study was limited only to use survey and a set of semi-structured interviews. Subsequently, factor analysis for the survey scales was a limitation of this study as well.

Thirdly, there were logistical challenges in terms of prior communication with potential agents and travelling within the study sites in Solomon Islands. In fact, prior to the actual data collection, attempts were made using emails and telephone to engage local agents and advocates at the convenient selected sample sites. However, communication using email and telephone were not reliable and efficient in the sociocultural context of Solomon Islands. As such, it was not possible to engage research agents or local advocates to administer the survey prior to the actual field trip so it was not possible to send copies of the surveys. Hence, the printed surveys were physically transported from Curtin University in Western Australia to Honiara, Solomon Islands when the researcher actually went for the data collection. Subsequently, there was limited time to conduct one-on-one interviews with the seven trainee science teacher participants. Consequently a focus group interview was

conducted instead. Added to that, travelling in Solomon Islands was inconvenient due to the form of transportations used and geographical locations of the study sites.

Finally, the scope of this study was limited to science teachers' views and experiences only. It did not explore the views and experiences of learners regarding the SBA of practical work as well as teaching, learning and assessment of scientific concepts and skills. As well, it was not within the scope of this study to explore learners' perceptions and experiences about their science teachers' level of PCK. Basically, perceptions from learner's point of view would have enhanced the verification for science teachers' views and experiences. In addition, there were other demographic and socioeconomic factors that could have been analysed and critiqued to further explain and interpret the findings for this study. That said, these limitations should be taken in consideration for future research.

7.5 Considerations for Future Research

The limitations for this study indicated that there are several suggestions that are worth considering for future research. It is suggested that future research in this same interest area should involve a larger sample size of schools and science teacher participants. A larger sample population is important to generate better representative findings that can be generalised from large quantitative data. To have a larger sample population, it is suggested that future research should take into consideration a larger range of schools and participants. Added to that, the selection of schools and participants should be based on "simple random sampling" (Creswell, 2012, p. 145) or stratified random sampling (Crossman, 2018). That means, every science teacher has an equal probability to be selected and invited to take part in the future study. Registry for all trainee and practising science teachers in Solomon Islands can be utilised for simple random sampling by allocating random numbers to their names. Equally significant for future research, the sample size for interview should also be increased.

More time and funding is suggested for future research in the same interest area as this present study. Time and finances are crucial to carry out research that would involve a wider range of schools and participants that reside in diverse and remote geographical locations in Solomon Islands. Since email and telephone communications are not reliable and efficient, physical transportation of hard copies

of data collection instruments is necessary since the only frequent and reliable transportation in context of Solomon Islands is shipping. However, to travel from one place to another takes time and require finances. As such, it is recommended that future research should allocate more time and finances in order to have a larger sample population size as well as a wider range of schools and participants.

It is suggested that future research should further explore and document science teachers' physics content knowledge by using more appropriate items to elicit science teachers' perceptions and understanding of physics concepts. In addition, future research should be designed to elicit science teachers' ability to define and explain physics concepts. This could include eliciting science teachers' perceptions and ability to deconstruct as well as reconstruct physics concepts during the teaching, learning and assessment process. Added to that, learners' perceptions of their science teachers' ability and PCK to teach and assess physics concepts and skills through the SBA of practical work could also be investigated for comparative purposes.

Finally, an intervention study is suggested for the future. The outcome of this study can be used to construct a professional development intervention model. In particular, professional development model to enhance practising science teachers' PCK for use in the SBA of practical work. The intervention model can be used to further verify the argument premised in the conceptual framework for this study. That is, the intervention study should develop a professional development model that help science teachers to enhance their PCK for teaching, learning and assessment of scientific concepts and skills in the SBA of practical work curriculum. Such suggested research can be used to further verify the conceptual framework and the premise for this present study. On the whole, the goal for the intervention study is to enhance science teachers' perceptions and practices in bridging the intended curriculum and attained curriculum as postulated in the theoretical framework for this present study.

7.6 Researcher's Concluding Remarks

I believe the novelty of this study lies in the integration of the key research areas into a coherent conceptual framework that premised to enhance science teachers' PCK for teaching, learning and assessment of scientific concepts and skills in the SBA of practical work. This study was the first of its kind in Solomon Islands to explore and

document views and experiences of both trainee and practising science teachers about the phenomenon investigated. As such, I believe the results and findings are novel and significant not just for Solomon Islands, but also other countries that use SBA of practical work. The information provided in this study should be useful to most stakeholders and shareholders who inclined to make improvements in science education. In particular, this thesis should provide valid researched information about the significance of enhancing science teachers' PCK to teach and assess scientific concepts and skills in the SBA of practical work.

In essence, the results and findings for this case study were elicited and generated from a triangulation mixed methods research design to address the notion of fitness for purpose. Hence, as the researcher, I was solely responsible to generate both the qualitative and quantitative data from the participants' views and experiences regarding the phenomenon investigated. While I directly interacted with participants, I also took into account their sociocultural context, privacy and voluntary participation with great care, respect and sensitiveness. Subsequently, the data collected were appropriately elicited, managed and analysed in order to generate novel and authentic findings presented in this thesis. In this regard, as the primary researcher, I was responsible in constructing an intelligible and persuasive thesis in fulfilling the purpose of this study.

The explanatory power of this thesis is also subjective to the readers' own interpretations and sociocultural contexts. Nevertheless, it is persuasively reasonable to claim that the results obtained for the purpose of this study is applicable for use as a framework for different subject areas and contexts in high school. Hence, I hope that the results of this study will add another sociocultural perspective to the existing wealth of knowledge as well as provoke further research in other sociocultural and geopolitical contexts. In addition, I hope this thesis will help to support the improvement of teacher training and ongoing professional learning programs for science teachers to enhance their capacity to bridge the gap between intended and attained curriculum. Finally, I believe this thesis has provided necessary information and support to improve the effectiveness of science teaching, learning and assessment which in turn enhances learners' achievement and improves the quality of education in Solomon Islands.

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APPENDICES

Appendix A: School-Based Assessment for Solomon Islands School Certificate 2010 – 2015

1.0 INTRODUCTION

Due to genuine feedback received from both science teachers and learners alike, regarding the severity of lack of proper science equipment and tools in most of the secondary schools, especially, community high schools, the curriculum science advisory committee has come up with this new SBA program in 2009. The program is for the year period 2010-2015. Therefore, schools should begin with it with the 2010 form 4's.

The aim of this new design, is, it hopes to ease out most of the difficulties teachers and learners have in the science laboratory, at least, for now.

At this point, it is important that science teachers and school principals, alike, understand the importance of providing learning opportunities, through availing science resources and equipment for learners to acquire necessary science skills while they are engaged scientific experiments.

As teachers, we must not forget that we are preparing science learners that will, either, go further on in higher science studies or simply return to their various communities in the future. For, either case, I'm afraid there are no short-cuts to acquiring science knowledge, skills and values.

Laboratory practicals, library research & field investigative activities and projects give learners opportunities to learn and master basic science skills. As such it is quite difficult to simply leave these out of any science SBA program we design for science learners.

Therefore, the new SBA program is similar to that of 2005-2009, except, for a reduction in the total number of laboratory practicals (i.e, from 9 to 4) and a new additional task, i.e, the investigative project.

The SBA program contributes 30% towards a learner's final national Solomon Islands School Certificate (SISC) marks. The three (3) hours written examination at the end of form 5 is the External Assessment. It contributes 70% of the total SISC marks.

The SBA program commences at form 4 and must be completed before students sit the Solomon Islands School Certificate (SISC.) This SBA is similar to the one compiled previously for year period 2006 to 2007 and strictly it should be used for the year period 2010 to 2015.

Your official and registered year 10 (F4) students in 2010 should begin with this new School Based Assessment in 2010.

2.0 AIM

The overall aim of the School Based Assessment is to assess the skills necessary to science which are difficult to assess in the written examination. These are practical and research abilities and they include the following performance skills;

1. Observations
2. Follow instructions to carry out an investigation with accuracy
3. record/collect and communicate data accurately
4. interpret data and respond correctly to questions related to the data and
5. draw valid conclusions

3.0 TYPES OF ASSESSMENT

This SBA is made up of three (3) components. They are:-

1. Learner Performed Skill Tasks (LPST)

The four LPST's are Laboratory Practicals. They are:

- 3 Common Assessment Tasks (CAT1, CAT2 & CAT3), and
- 1 Teacher Designed Assessment Task (TDAT)

2. Learner Library Research Skill Project (LLRSP)

- 1 Library Learner Research Skill Project (LRSP) per student
- A report is to be produced.
- The findings in the research are presented in the class.

3. Learner Environmental Investigative Skill Project (LEISP)

- 1 Long Term Environmental Learner Investigative Skill Project (LEISP) per group of students.
- A group of 2-3 learners can be formed to do one investigative issue of interest.
- Each student then produce individual reports

3.1 WEIGHTINGS FOR SCHOOL BASED ASSESSMENTS

The SBA has a total weighting of 30%

- Learner Performed Skill Tasks (LPST's) are awarded 16%
- Learner Library Research Skill Task (LLRST) is awarded 6%.
- Long Term Environmental Investigative Skill Project (LEISP) is awarded 8%

3.2 REQUIRED LEARNER PERFORMANCE SKILL TASKS

A total of four LPST's (i.e, laboratory practicals) are required. Three PSTs are common (i.e, CAT) for all learners and are prescribed from the three science disciplines: *1 Biology, 1 Chemistry* and *1 Physics*. They are set by the PCDO Secondary Science at the Curriculum Development Division and are found in the final section of this booklet. The fourth is the (TDAT), a teacher-designed one. It is up to the teacher to choose which form 4 or 5 topic the practical is chosen from. It is important that this practical is selected from any topic prescribed in the form 4 and 5 syllabus.

- 3 Common Assessment Tasks (CAT)

You are required to perform a total of 3 Common Assessment Tasks (i.e, Laboratory Practicals). It is compulsory that all schools do all these 3 CATs.

It is common for all schools. Each of the 3 CATs is selected from the 3 main science disciplines:

- 1 Biology,
- 1 Chemistry,
- 1 Physics.

THESE CAN BE FOUND LATER IN THE LAST SECTION OF THIS BOOKLET - Section 2: Details of CAT1, CAT2 AND CAT3.

- 1 Teacher Designed Assessment Task (TDAT)

The teacher is required to design 1 Teacher Designed Assessment Task (TDAT.) It can be chosen from any form 4 or 5 topic; and must be designed according to the standard format used in the design of the CAT. The TDAT can, either, be a *Biology*, or *Chemistry* or *Physics* topic. THE TEACHER IS ADVISED HERE TO SEND A COPY OF THE TDAT TO CDD/NESU TOGETHER WITH YOUR PROGRAM SCHEDULE OF YOUR WHOLE SBA PROGRAMME FOR THAT 2 YEARS so that official endorsement by the Science Advisory Committee (SAC) can be done.

- The total marks for the TDAT is 30 marks (20 marks for practical and 10 marks for assessment of required skills.)
- You will be notified (verbally/ in writing) on any approval/ changes of your TDAT before you are allowed to perform all your practicals with your learners.

4.0 BACKGROUND INFORMATION ON THIS NEW SBA (2010 – 2015)

4.1 LEARNER PERFORMED SKILLS TASKS (LPST)

This new SBA is a revised version of the past SBA activities from collective views from workshop participants (June 2008-2009) and consultative meetings by the Science Advisory Committee (SAC). There are some changes that are included in this new SBA. One of the major inclusions is the Learner Investigative Skills Project (LISP).

It is a requirement that the teacher is required to design one learner performed skills task to suit student needs and the availability of materials and equipment/ apparatus at the school. In doing so the science teacher is required to draw up an SBA, programme schedule to realistically outline proposed dates for conducting each of the laboratory practicals.

The Program Schedule should include all four laboratory practicals required (3 CAT and 1 TDAT).

You may include the following dates/weeks, form 4 or form 5 topic, type of practical and importantly materials & equipment/ apparatus required for conducting the practicals. Refer to Sample. You may include other useful information for the practicals. Teachers are advised to return marked practicals to learners only for consultation purposes and must be returned to the teacher for submission of completed samples for the final moderation at the end of the year. These practicals are conducted towards awarding of the final grade in the SISC. All practicals should be collected back from students or should not be given to the students at all. Remember that all practicals are used for the year 11 SISC assessments nationwide.

This new SBA is trying to:

1. promote fairness and justice amongst students,
2. address the growing concerns that most schools do not have the basic consumables and equipment/ apparatus at the secondary schools to conduct standard practicals set by the Secondary Science Advisory Committee of the Curriculum Development Division of the Ministry of Education & human resources development
3. assist schools that do not have qualified science teachers
4. assist schools that do not have appropriate science laboratories and
5. Facilitates learners at form 4 and 5 level to acquire appropriate science skills towards the same at form 6/7 level with the PSSC Internal Assessment Practical and USP foundation studies.

This new SBA is prepared in consideration of the following:

1. Should be easy to organize and performed
2. Should not have excessive demand for science materials and equipment/ apparatus.
3. Improvisation when apparatus is absent
4. Easy to be assessed
5. Involve, use and application of process skills in a hands on situation (practical/ experiment) and
6. Continuation at form 6 PSSC level, form 7 foundation and tertiary studies.

However in order to be consistent with the assessment, this office will provide SBA guidelines for science teachers selecting the required number of practicals and the standard marking criteria/ scheme for the learner performed skills tasks, learner research skills project and learner investigative skills project .

5.0 GUIDELINES FOR SELECTING LEARNER PERFORMED SKILL TASKS DESIGNED BY THE TEACHERS (TDAT)

This handbook is designed purposely to assist science teachers with guidelines on how to plan and design appropriate learner's skills tasks (practicals) that suit the needs of the learners and the availability of equipment/ apparatus and resources at the school.

As science resources and equipment/ apparatus differ widely within our secondary schools, a provision is made to allow science teachers of all secondary schools to design its own learner skill task (practicals) and be implemented under the TDAP component.

The TDAP can be chosen from, either, Biology, or Chemistry or Physics strands. It can be a form 4 or 5 topic from the approved secondary science syllabus (1999 document.) It will be designed by all form 4/5 science teachers throughout the country.

The tasks (practicals) must be properly documented in a programme schedule and must be submitted to the PCDO science for endorsement by Science Advisory Committee (SAC) before you are allowed to perform all 4 tasks (practicals) (i.e, 3 CATs and 1TDAP) with your learners. A copy of your prepared TDAP must be submitted together with the SBA schedule.

The SBA programme schedule should reach PCDO Science (Curriculum Development Division) by or not later than 30th April this year.

The guidelines are as follows:

1. Include a practical from, either, a form 4 or 5 topic in the official secondary science syllabus for forms one to five.
2. The required one (1) practical must be selected from, either, Biology or Chemistry or Physics.
3. It should worth 10 marks each (20 marks from the practical and 10 marks from direct observation of learner's performing the skills as seen with the Common Assessed Task - (CAT).
4. Include the date/ week, forms 4 & 5 unit/ topic, nature of practical and list of materials and equipment/ apparatus. See attached sample
5. Summary of Learner's Performed Skills Tasks and their weighting, and
6. The time allocation for each practical be strictly 50 minutes duration.

5.1 SBA PROGRAM SCHEDULE

The table below should include all four (4) laboratory tasks (practicals), one (1) research project and one (1) investigative project to be assessed in the year period 2010 - 2012. Dates are included. Make sure your plans show realistic dates to complete and submit all your completed tasks and projects.

SAMPLE ONLY

TASK	2010 (Form 4)				2011 (Form 5)				
	Feb Mar	Apr Jun	Jul Sep	Oct Dec	Jan Mar	Apr May	Jun Jul	Aug	Sep Oct
LPST/Practical: CAT1									SISC EXAMS
LPST/Practical: CAT2									
LPST/Practical: CAT3									
LPST/Practical: TDAP									
LLRSP									
LEISP									

5.2 TEACHERS INFORMATION

It is essential; however, that science teachers should bear in mind these practicals involves the teaching and learning processes. If science is to be learnt effectively, it must be experienced. Having said that tasks/practicals in this case are for assessment purposes, therefore the amount of assistance given by teachers during practicals must vary between students depending on the situations. It is worth bearing in mind that the assistance should be minimized to avoid practicals being assessed are of teachers work.

Science teachers are advised to be strict with the timing involved and to prepare well before a practical session is carried out. The teacher may pre-test the practical before your actual practical classes because it is not only for the teacher to have a sound idea of the unexpected results but also to avoid unnecessary and awkward situations while conducting the practicals.

The marking of the students practical and research projects must be done with professionalism and must be treated with high confidentiality to safe guard your credibility as a teacher and the purpose of the assessment for the students final science grade in the national Solomon Islands School Certificate (SISC) examination.

6.0 GUIDELINES FOR TEACHERS ADVANCED PREPARATION AND IMPLEMENTATION

6.1 ADMINISTRATION AND ORGANISATION LABORATORY PRACTICALS:

It is important for teachers to make advanced planning to ensure the implementation and completion of each practical is as per scheduled. Teachers should follow the following tips to assist him/her prepare well for the laboratory practicals.

- Ensure that the topic related to each practical has been adequately covered before students do each practical.
- It is up to the teacher to decide how the laboratory practical will be administered or organized. However, it is suggested that the teacher may need to set up adequate work stations for all learners to have an opportunity learn.
- Ensure that all materials and apparatus required for each laboratory practical are provided.
- Ensure that sufficient time is given for each laboratory practical
- The teacher must do each laboratory practical (before learners do them) so that you can obtain your schools expected results. The results could be used as a reference to mark your students work.

6.2 TIME ALLOCATION TO CONDUCT LABORATORY PRACTICALS

The time allocation for learners to do each laboratory practical is strictly 50 minutes. This is approximately the duration of one lesson/ period taught in most secondary schools. Of the 50 minutes allocated, 5 minutes should be allowed for reading time. It is important that instructions prepared by the teacher is clear and ensure that learners read instructions carefully before they start

7.0 THE MARKING CRITERIA FOR CAT: LABORATORY PRACTICAL REPORT

A Standard marking criteria/scheme is provided to assist the teacher prepare his/her own marking scheme and allocation of marks based on the given skills to be performed and the possible total marks to be awarded for each task/ question in each laboratory practical. Use this guide to construct your own marking scheme:

The following skills will be performed by learners in all laboratory practicals (3 CAT and 1 TDAP) and therefore should be assessed:

- Ability to follow all instructions (2 marks)
- Ability to use apparatus correctly (2 marks)
- Ability to observe, record and analyse data (4 marks)
- Ability to draw scientific conclusions (2 marks)

When assessing learners performing laboratory practicals, the following marks are awarded:

- **PART 1: laboratory practical report is awarded 20 marks**
- **PART 2: skills performed are awarded 10 marks**

MARKING SCHEME

Part 1: LABORATORY PRACTICAL REPORT	
CRITERIA	POSSIBLE MARKS
Aim: <ul style="list-style-type: none"> • Aim of laboratory practical not explained..... (0) • Aim of laboratory practical explained clearly.....(1) 	1 ()
Method: <ul style="list-style-type: none"> • Method used to conduct laboratory not explained clearly.... (0) • Some attempts to describe the methods to conduct laboratory.....(1) • Complete method used to conduct laboratory explained.....(3) 	3 ()
Results: <ul style="list-style-type: none"> • Attempts to organise results is poor (0) • Attempts to organise the results is evident showing incomplete tables only (1) • Results obtained are organised in a meaningful manner in tables and few graphs (3) • Results obtained are organised in a meaningful manner in tables and some appropriate graphs (5) • Results are well organised in a meaningful manner in accurate tables and most appropriate graphs(7) 	7 ()
Discussion: <ul style="list-style-type: none"> • Attempt to discuss the results was not evident(0) • Attempt to discuss the results is evident showing a few linkage of information and explanation..... (1) • Discussion showing linkage of information to logical explanation..... (3) • Discussion showing linkage of information to logical explanation, some use of own ideas to discuss data(5) • Discussion linking information gathered to logical explanation, correct interpretation of data or information gathered, use own ideas to discuss information/data (7) 	7 ()
Conclusion: <ul style="list-style-type: none"> • No attempt made to draw the conclusion statements (0) • Attempted to provide a logical conclusion(1) • Provide a logical conclusion on what the learner has achieved..... (2) 	2 ()
TOTAL MARKS	/20

PART 2: SKILLS PERFORMED	
CRITERIA	POSSIBLE MARKS
Ability to follow all instructions: <ul style="list-style-type: none"> • Lacks the ability to follow instructions (0) • Evidence of some ability to follow instructions..... (1) 	2 ()

<ul style="list-style-type: none"> Evidence of ability to follow all instructions (2) 	
Ability to use apparatus correctly: <ul style="list-style-type: none"> Lack the ability to use apparatus correctly.....(0) Evidence of some ability to use apparatus correctly (1) Evidence of ability to use apparatus correctly(2) 	2 ()
Ability to observe, record and analyse data: <ul style="list-style-type: none"> Lacks ability to observe, record and analyse data (0) Evidence of some ability to observe, record and analyse data..... (2) Evidence of ability to observe, record and analyse data logically (4) 	4 ()
Ability to draw scientific conclusions: <ul style="list-style-type: none"> Lacks the ability to draw scientific conclusion (0) Evidence of some ability to draw scientific conclusion..... (1) Evidence of ability to draw scientific conclusion accurately(2) 	2 ()
TOTAL MARKS	/10
TOTAL MARKS LABORATORY REPORT	
/20	
TOTAL MARKS SKILLS PERFORMED	
/10	
GRAND TOTAL MARKS	
/30	

8.0 LEARNER MARK BOOK

You must construct your own mark book to record your learner's scores. The mark book should be used to record your learner's scores for both forms 4 and 5.

This means that you have to use this mark book for two years. Keep the mark book in a safe place so that you do not lose your records.

Teachers are advised to record marks in this format for the final marking and moderation of learners' marks.

SAMPLE ONLY

Name	LPST			LPST (TDAP)	Total Raw marks
	CAT 1 (30)	CAT 2 (30)	CAT 3 (30)	TDAT	
1.					
2.					
3.					
4.					
Etc					

It is advisable that all teachers begin the laboratory practicals at the beginning of form 4 and completed in mid- year inform 5 the following year.

Note: PLEASE SUBMIT ONLY RAW MARKS TO NESU FOR MODERATION PURPOSES. HOWEVER, IF YOU WANT TO KNOW THE PERCENTAGES THEN YOU CAN CALCULATE THEM FOR YOUR PURPOSES.

8.1 COMMON ASSESSMENT TASK (CAT):

- The following 3 laboratory practicals (3 CAT) are compulsory and are to be performed and assessed towards the learners SISC grades:

No	Strand	Topic
1	Chemistry : CAT 1	Designing a Scientific Experiment
2	Physics : CAT 2	Simple Machines
3	Biology : CAT 3	Estimating the Population of Grass Species

8.2 TEACHER DESIGNED AND ASSESSMENT PRACTICALS (TDAP)

- The other three (1) laboratory practical is teacher designed assessment practical in which all science teachers are encouraged to design according to the availability of resources and equipment at your school; also in compliance with the guidelines provided in this manual.
- Make sure this laboratory practical is based on any year 10 and five topics in the official and approved Secondary Science Syllabus (1999 document).
- Make sure you prepare and submit a sample of the TDAP. Clearly indicate in the SBA Program Schedule for official endorsement at the beginning of each new academic year for each new form 4 group.
- Teacher Designed Assessed Practical (TDAP) must be designed within in the approved format and should worth 30 marks each (*20 marks for the laboratory practical report and 10 marks for learner performed skills*).
- Should there be any doubt, please consult Science Advisory Committee or PCDO Science for assistance.

9.0 LEARNER LIBRARY RESEARCH SKILLS PROJECT (LLRSP)

It is expected that the final learner's mark is taken from these two components of the research:

- Component 1: The research report
- Component 2: The oral presentation of the findings in the report.

The skills to be tested with the new SBA remain unchanged. However, there are few reminders for teachers to take note of for this new School Based Assessment for 2008 – 2009.

- For transparency and accountability in the assessment of the new SBA, teachers are requested to submit **names of registered students in year 10 (F4) and their research topics** to the PCDO Science or Director NESU not later than **30th October 2008**.
- Students should begin the research project in **form 4 (September/October)** and should be completed in **form 5 (end of April)** the following year. Subject teachers are advised to mark the research work completed by students and must be submitted together with the marks from the practicals by required due date.

9.1 OBJECTIVES OF THE LEARNER LIBRARY RESEARCH SKILLS PROJECT:

The main objective of the library research project is to allow learners display science skills that they can use while in the school system; as well as applying the skills in other fields of work. The intended skills cover the following areas:

- Collecting information from appropriate resources, including references.

- Presentation of information.
- Application of scientific knowledge.
- Interpretation and understanding of data collected, and
- Evaluation.

9.2 GUIDELINES FOR CONDUCTING A RESEARCH PROJECT

9.2.1 *Selection of a research topic*

Learners should be given the opportunity to undertake the research, either, on an issue about the topic they are studying or on another relevant topic (preferably an extension topic).

Learners are encouraged to use textbooks from the school library or may use other resource materials such as magazines, newspapers, radio and other resource materials that are available.

Learners are not expected to conduct a large research. Nor, should they select a broad topic. They should rather conduct a small scale research project, which can be narrowed down to a very small area of interest. The research project that learners wish to undertake should be a review of an interesting current science issue/ topic.

Learners should be given the opportunity to choose their own topics. However, it has to be confirmed by the science teacher. A list of all registered form 4 learners with their topics is to be sent to the PCDO science not later than 30th October in that year.

All science teachers involved are reminded to collect all student research project reports on the final due date which is 30th April of the examination year. The projects are to be marked and recorded. A selected sample of the reports is to be submitted and must reach NFSU, **not later than 30th June in that examination year.**

Late submissions will not be considered for Learner's final grading in the SISC Examination.

9.2.2 Suggested Research Topics:

Learners may select a research topic from the following subject areas: Biology, Chemistry and Physics. They could also opt to choose any new topic of interest other than the topics provided below:

Biology Topics:

- Tree-Planting Programs - a strategy to reverse negative effects of logging in rural Solomon Islands
- Family and Home Hygiene - the start point to produce a healthier and brighter Solomon Islands' population
- Coral farming - its benefits to Solomon Islands.
- Seaweed farming -its benefits to Solomon Islands
- AIDS and HIV Home Awareness Programs- an effective way to curb AIDS and HIV in Solomon Islands
- Eco-tourism - how it helps to conserve biodiversity in Solomon Islands
- Water as an important resource - how to conserve it in Solomon Islands
- Family planning - how it helps to control the population growth of Solomon Islands

- Traditional fishing methods - an alternative to conservation of species in Solomon Islands
- Resettlements of victims of sea and water level rise in Solomon Islands

Chemistry Topics:

- Use of Chemicals and Chemical Products at home - simple strategies to keep our homes chemical-free in Solomon Islands
- Gold Mining at Gold-ridge - a curse or blessing for Solomon Islanders?
- Over fertilization of soil - its disadvantages
- Clean water - its effects to the health of the people and community in Solomon Islands
- Earth Resources and the economic benefits to Solomon Islanders
- Mining activities - its social effects in Solomon Islands

Physics Topics:

- Energy Transfer in modern communication devices/ equipment: landline phones, mobile phones, two-way wireless radio, TV, AM radio, FM radio etc. (Note: select only one communication device.)
- The advantages and disadvantages of generation of electricity in your school or community
- Climate change- its effects to agriculture in Solomon Islands
- Sea-Level rise - its effects on low lying atolls/ or river bank settlements in Solomon Islands
- Solar Panel Technology - its uses and benefits in the rural Solomon Islands homes
- Tsunami - a natural disaster: its threats and how to prepare for it in Solomon Islands
- Hydropower system - a curse or blessing for Solomon Islanders?

10.0 DOING A SURVEY

Conducting surveys is an important skill and one that is not too difficult if a few simpler instructions are followed. For example, a particular learner may wish to investigate the malaria cases in their school for the first six months of any year. Learners may need to be advised that when a survey is to be conducted a questionnaire should be prepared.

The following instructions may guide students who wish to conduct a survey on the selected topic.

- Plan how you are going to collect information required (what, where, when, who, etc.)
- Write the questions (shorter questions are favoured by most people as they are easier to answer, collate and analyse.)
- Before the actual survey is carried out, test your questions out first with someone you know or simply your teacher. This is a check to see areas where improvement is required.)
- Construct only few questions (eg, 10 - 15 Questions) and use it to interview a sample of people (eg, 20 people.)
- Analyse and interpret your data.

11.0 RESEARCH REPORT

Learners may also be allowed to pursue a project through experimentation. For this, learners need to design their own experiments or use experiments from other sources (eg, textbooks).

A research report should include;

- Title of investigation/Activity
- List of materials and apparatus
- Methods used to conduct the investigation/activity
- Literature review on the topic of investigation (2 – 3 paragraphs)
- Results
- Discussion (Including data presentation and analysis).
- Recommendations
- Conclusion

12.0 LITERATURE REVIEW

This refers to a review of a topic that has been investigated by a particular student. For example, AIDS and HIV or Coral Reef Bleaching. Learners will need to find out on how much information has been written about the topic.

The learner should summarize the review in 2 to 3 paragraphs in their report writing. Teachers will need to provide some kind of guidelines to learners so that the review is more specific to the research topic. Refer to section 13 for details on how to write a report.

13.0 WRITING A RESEARCH PROJECT:

Teachers are reminded to provide learners with clear guidelines on how to write a research report. You may use the following as suggested guidelines.

A research report should not be less than three (3) pages and should not exceed more than ten (10) pages.

A research report should have the following sub-headings

- Title
- **Introduction** (description of aim, topic being pursued and method used to collect data and information
- **Main Body** (preferably **literature review** on the topic undertaken or compilation on major information about the topic. For this, you need to refer to textbooks and other resources or references.
- **Discussion** (Discussion on information collected and interpretation of information/data collected
- **Conclusion** (Summary on what the student has discovered or learnt)

When writing a research report, the learners should be reminded of the following;

- Written reports need to be legible and within the page limit suggested. Learners may use a computer, word processor, or a type writer although this is not a requirement.
- Learners are encouraged to be more concise in their writing.

- Do not use or insert great portion of notes/information from the textbooks. It much better to write the information's in your own words.
- Learners should be warned that copying notes word by word from textbooks is not allowed. This is plagiarism. Academically, plagiarism is stealing of somebody else’s work and it is cheating. Therefore, learners are warned that plagiarism is not allowed in schools and is an academic offence
- Always include a bibliography at the end of the report. This is the list of references that learners use in their research work. There are many ways that learners can write bibliographies.

How to write a Bibliography

You may use the suggested guidelines provided below:

- **Author** – Surname first, then initials
- **Title of book or Article** (if it is an article, give name of journal as well)
- **Publisher** (name of publishing company), **Place** (where the article or book is published) **and the date of Publication**, (if it is a journal, then give the journal number, volume and date). It is also useful to give the page references.

Two Example ONLY:

The correct bibliography entry for a book is:

Parks, D., Heinemann Science in context 3. Heinemann Educational
Australia, Port Melbourne, 1992

The correct bibliography entry for a journal is:

Daudau, P (2010). Secondary science education in Solomon Islands in the Indigenous Curriculum Network, Number 2, Volume 32, 2010, pages 7 – 12.

14.0 LEARNER LIBRARY RESEARCH SKILL MARK RECORD

Teachers are advised to keep a record of their learner’s research marks in this format. The two main components of the research skill are.

- Component 1: The research report is awarded 30 marks
- Component 2: The oral presentation of the findings is awarded 10 marks. Learners are encouraged to present the findings of their research work in the class.

Name	Research topic	Total Mark Research (40)	Total % (6)
1. NW Junior	Climate Change – its effects in S.I	22	4.2
2.Tiaran Neldan	Earth Resources in S.I	28	5.3
3.Lian Joy	Benefits of Using Solar Panels in S.I	15	2.9
4.			
5.			
6.			
7.			

15.0 MARKING CRITERIA FOR RESEARCH PROJECTS

A standard marking criteria is not provided as learners' projects may vary from one school to another. For this reason, teachers are asked to design their own marking criteria based on the following guidelines to mark your learners' projects.

- **The Marking Criteria for the Research Report:** The research project should be marked out of 40 marks. Marks should be awarded as follows:

LIBRARY RESEARCH	
MARKING CRITERIA	POSSIBLE MARKS
An accurate table of content (1)	1 ()
Introduction <ul style="list-style-type: none"> • Concise opening statement(2) • Aim of project explained vividly..... (2) • A research question is asked(2) • Hypothetical statements are accurate.....(2) • Method used to conduct project explained.....(2) 	10 ()
Main Body of Research <ul style="list-style-type: none"> • Detailed description of topic (2) • Logical, relevant and sufficient use of information or content..... (2) • Pictures, graphs, diagrams (where appropriate) included to support explanation (3) • Very logical explanation of scientific theory or principle(4) • Evidence of data collection (where appropriate).... (4) 	15 ()
Discussion and Analyses <ul style="list-style-type: none"> • Link information gathered to logical explanation... (2) • Correct interpretation of data or information gathered.....(3) • Use own ideas to discuss information/data(3) 	8 ()
Conclusion/ Bibliography <ul style="list-style-type: none"> • Provide logical conclusion-what the student has achieved (3) • Provide list of text books cited-that is references and information sources appropriately acknowledged.....(3) 	6 ()
TOTAL MARKS	/40

16.0 MARKING CRITERIA FOR LEARNER'S ENVIRONMENTAL INVESTIGATIVE SKILLS PROJECT (LEISP)

A standard marking criteria is not provided as learners' projects may vary from one school to another. For this reason, teachers are asked to design their own marking criteria based on the following guidelines to mark your learners' projects. However, should you think this guidelines fits in well with the chosen projects you may use it to assess your learners with.

ENVIRONMENTAL INVESTIGATIVE STUDY	
MARKING CRITERIA	POSSIBLE MARKS
Title: <ul style="list-style-type: none"> Irrelevant title (0) Relevant title(1) 	1 ()
Aim: <ul style="list-style-type: none"> Aim written is inaccurate (0) Aim written is accurate (1) 	1 ()
Background of the Issue: <ul style="list-style-type: none"> Illogical statement of issue (0) Attempt to make a logical statement of issue (1) A logical statement posed..... (3) 	3 ()
Posed Question: <ul style="list-style-type: none"> Question is inaccurate (0) Attempt to ask accurate question (1) Question is accurate (3) 	3 ()
Hypothetical Statements: <ul style="list-style-type: none"> Statement is inaccurate..... (0) Attempt to state accurately 2 statements (1) Accurate statements posed(3) 	3 ()
Equipment/Apparatus/Materials/Resources: <ul style="list-style-type: none"> No attempt to list materials/equipment and resources (0) Attempt to list incomplete list of materials only (1) A full list of all possible materials is provided(3) 	3 ()
Methodology (Design): Control & Variable Factors: <ul style="list-style-type: none"> No attempt to design the activities in the investigation (0) Attempt to design the activities lacks control (1) Design the activities lacks few variable factors (2) Design has both control and all possible variables... (4) 	4 ()
Results: <ul style="list-style-type: none"> Inaccurate results presented (0) Attempt to present accurate results (2) A complete set of results (4) 	4 ()
Discussions: <ul style="list-style-type: none"> No attempt to discuss findings (0) Attempt to discuss findings is limited.....(2) Accurate discussion of findings is well presented....(4) 	4 ()
Conclusions: <ul style="list-style-type: none"> No attempt to draw conclusions(0) Attempt to draw conclusions is incomplete (1) An accurate and logical conclusion drawn (2) 	2 ()
Recommendations: <ul style="list-style-type: none"> No recommendations stated..... (0) Attempt to state recommendations(1) A complete list of relevant recommendations is made(2) 	2 ()
TOTAL MARKS	/30

ORAL PRESENTATION – ENVIRONMENTAL INVESTIGATIVE PROJECT	
MARKING CRITERIA	POSSIBLE MARKS
Introduction: <ul style="list-style-type: none"> • Introduction not clear(0) • Introduced topic but incomplete (1) • A good and clear opening statement of the presentation..... (2) 	2 ()
Use of Voice: <ul style="list-style-type: none"> • Difficult in getting the message (0) • Attempt to increase voice (1) • Voice is loud and clear (2) 	2 ()
Clarity of Explanation: <ul style="list-style-type: none"> • Poor explanation of issues (0) • Some attempts to explain main points (1) • Explanation of issues are clear (2) 	2 ()
Conclusion: <ul style="list-style-type: none"> • No summary given(0) • Some attempt to sum up the presentation(1) • Presentation well summarised(2) 	
Recommendation: <ul style="list-style-type: none"> • No recommendations given (0) • Missed important points to recommend (1) • Most important points recommended (2) 	2 ()
TOTAL MARK	/10

17.0 LEARNER ENVIRONMENTAL INVESTIGATIVE SKILLS PROJECT (LEISP)

The aim of this task is to give an opportunity for learners to learn the skills of collecting primary data from the field or the science laboratory. In contrast to the library research task, the data obtained in the field belong to the learner scientist, the one who actually carried out the experiment; in this case, the learner of that particular school. In return, the school would feel good and satisfied that their learners are able to perform activities which give important first-hand information.

17.1 COMPONENTS OF THE INVESTIGATIVE PROJECT:

The components of the investigative project are:

- A report (5%) – between 4 – 7 pages
- A log book (3%) – must be completely filled in.

The total percentage allocated for this task is 8%. Samples of the investigative report are to be sent to NESU – 2 top, 2 middle, 2 bottom.

17.2 SUGGESTED FORMAT OF INVESTIGATIVE REPORT (5%):

- a. Title
- b. Aim
- c. Background of the issue
- d. Question
- e. Hypothetical statement [True (1) & Alternative (2)]
- f. Equipment/Apparatus/Materials/Resource
- g. Methodology (Design – variable factors/control factors) – THE PLAN
- h. Results – Data organised in tables, graphs, etc

- i. Discussions – Discuss results collected/obtained
- j. Conclusion
- k. Recommendations – suggest ways to improve the practical, why encountered errors and how to remove errors, etc.

17.3 **FORMAT OF LOG-BOOK (3%):**

(An example only: 1 page of the book)

Date	Activity	Observation	Remarks

Other General Comments:

NOTE:

- The log-book will contain the summary information from learner’s research, questions and ideas for their investigation, draft planning, raw data.
- The teacher to assist learners to choose a topic and design the practical – give learners advice.
- Choose a topic from either bio, chem, phy strands in the current official syllabus document.
- You would realize that this is similar to what is done at form 6. So if your school has form 6 it is helpful to consult your form 6 science teachers.
- Submit (report + log-book + samples).

18.0 SCHOOL BASED ASSESSMENT RESULT

You should post or deliver your students’ SBA MARKS and SAMPLES to the *Director of National Examination and Standard Unit*. The SBA marks should reach the Director of NESU on the specific due dates before the learners sit the SISC Examination. The address is:

**The Director
National Examination and Standard Unit
Ministry of Education and Human Resources Development
PO Box G28,
Honiara**

Your learners’ SBA results must be accompanied with the following documents and must reach the above address **by or not later than 30th of August in that examination year.**

LEARNER PERFORMED SKILLS TASKS (LABORATORY PRACTICALS):

- A marking scheme used to mark each practical (4)
- Sample of learners’ practicals (2 top, 2 middle, 2 bottom)
- A brief report on the practicals
- Learners practical mark sheet.

LEARNER LIBRARY RESEARCH SKILLS PROJECT:

- A marking scheme for the research report (1)
- A Brief report on the research project.
- Sample of learners' research reports (2 top, 2 middle, 2 bottom)
- Learners research mark sheet

LEARNER ENVIRONMENTAL INVESTIGATIVE SKILLS PROJECT:

- Marking scheme for the research report (1)
- A brief report on the research project.
- Sample of learners' investigative reports (2 top, 2 middle, 2 bottom)
- Learners' investigative mark sheet.

Any late submission would not be considered for final grading in the SISC Examinations

Appendix B: Sample of a Physic Practical Work for SBA

PHYSICS COMPONENT: SIMPLE MACHINES

Practical: Using Pulleys

Background

Machines are often used to magnify the force or effort that we supply. The mechanical advantage (MA) of a machine tells us how much the force is magnified. Pulleys are devices we used to give us a mechanical advantage, and they help us to lift objects that would normally be too heavy. To operate a pulley system, one uses effort to pull on the rope. The rope slides on the pulley, turning the wheel and the load is lifted.

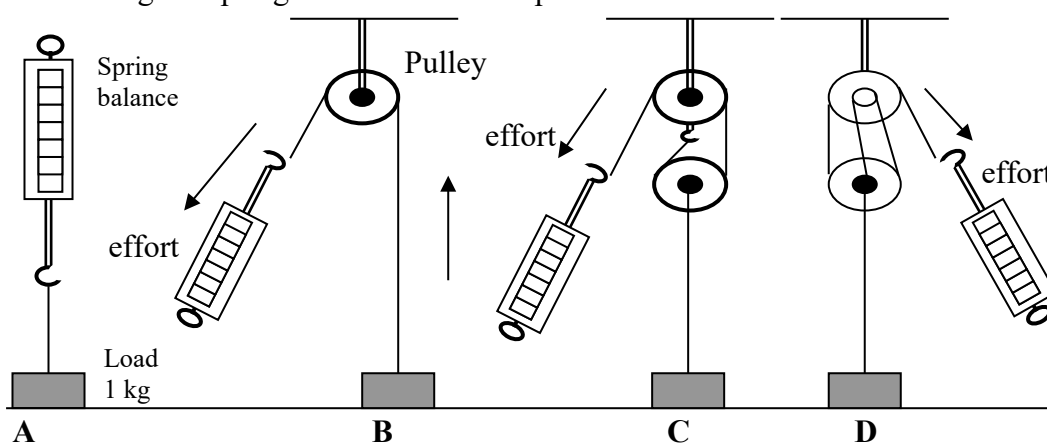
To measure forces we use a spring balance. Force is usually measured in Newton (N). If your spring balance is graduated in grams or kilograms, use the following approximation conversion:

$$1 \text{ Kg} = 10 \text{ N and } 100 \text{ g} = 1 \text{ N}$$

Materials required:

One 1Kg mass, Pulleys, Spring Balance, Trolley, Inclined Plane.

1. Set up each of the following systems. In each case you will be lifting a 1 Kg mass vertically off a bench. You have to measure the effort required to this by using the spring balance. Do the experiments in the order shown.



2. Complete the following table of results.

Experiment	Load (in Newton)	Effort (in Newton)	MA = load / effort
a. No pulley			
b. One pulley			
c. Two pulleys			
d. Three pulleys			

Calculations and Analysis of Data

3. What does MA stands for?
4. Which experiment requires the greatest effort? Why do you think this was?
5. Which experiment requires the least effort? Why do you think this was?
6. As the number of pulleys increased, what happened to:
 - a). the effort?
 - b). the MA?
7. Give two examples of everyday situations where pulleys are used to lift loads.
 1.
 2.

B The incline plane

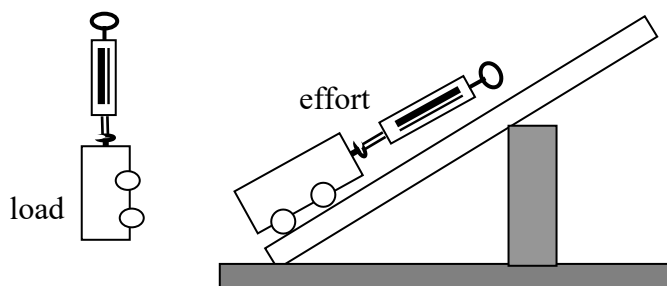
A ramp, a slope and a hill are examples of inclined planes. We often use ramps to lift heavy loads up a height.

8. Use a spring balance to measure the force required to lift a small trolley vertically.

Force required = Load = N

9. Measure the effort required to pull the same trolley up an incline plane.

Effort required = N



10. Is the effort smaller than the load?

11. What is the mechanical advantage (MA) of the plane?

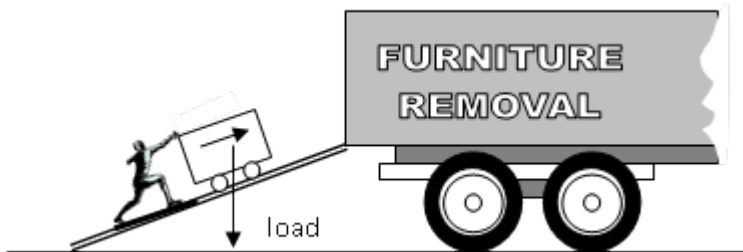
MA = load / effort =

12. Why do you think the ancient Egyptian used inclined planes to build pyramids?

.....
.....

13. Why do people (eg furniture removalists) use ramps to move goods into their vans?

.....
.....



Practical: Simple Machines

Aim:

REPORT SHEET FOR INVESTIGATION

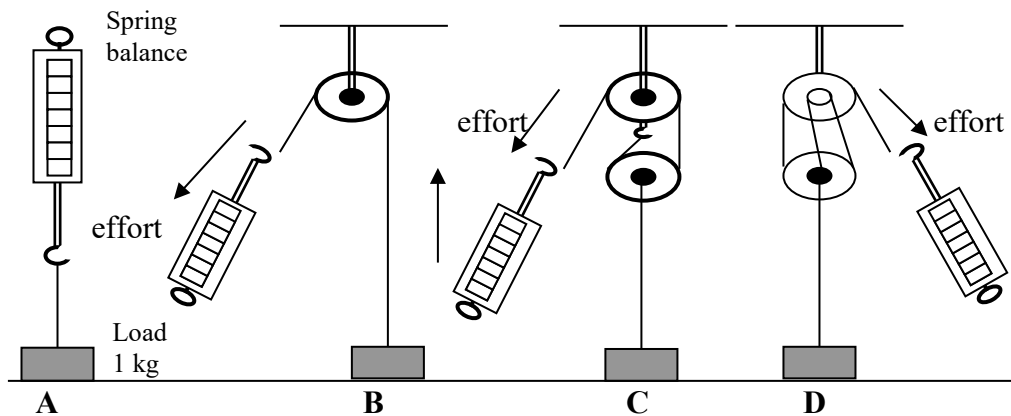
(1 mark)

A Brief Description (Write a brief discussion on what you did)

(2 mark)

Results

Set up each of the following systems. In each case you will be lifting a 1 Kg mass vertically off a bench. You have to measure the effort required to this by using the spring balance. Do the experiments in the order shown.



2. Complete the following table of results.

Experiment	Load (in Newtons)	Effort (in Newtons)	MA = load / effort
a. No pulley			
b. One pulley			
c. Two pulleys			
d. Three pulleys			

(4 marks)

Calculations and Analysis of Data

3. What does MA stands for?

(1 mark)

4. Which experiment requires the greatest effort? Why do you think this was?

.....

(1 mark)

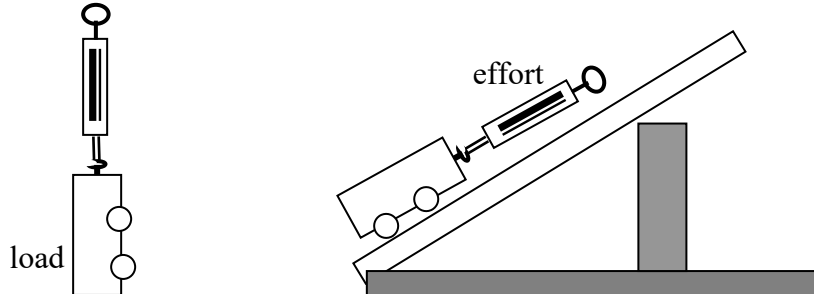
5. Which experiment requires the least effort? Why do you think this was?

 (1 marks)
6. As the number of pulleys increased, what happened to:
 a) the effort?
 b) the MA?
 (1 marks)
7. Give two examples of everyday situations where pulleys are used to lift loads.
 1.
 2.
 (1 marks)

B The incline plane

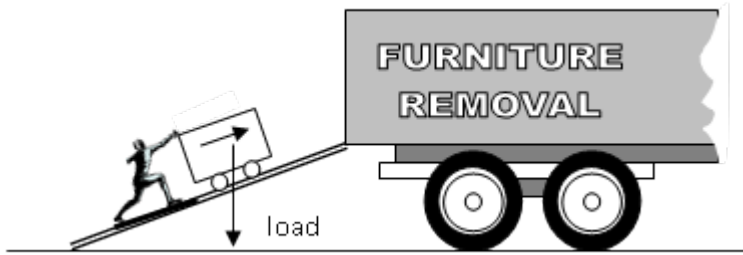
A ramp, a slope and a hill are examples of inclined planes. We often use ramps to lift heavy loads up a height.

8. Use a spring balance to measure the force required to lift a small trolley vertically.
 Force required = Load = N (1 mark)
9. Measure the effort required to pull the same trolley up an incline plane.
 Effort required = N (1 mark)



10. Is the effort smaller than the load?
 ... (1 mark)
11. What is the mechanical advantage (MA) of the plane?
 $MA = \text{load} / \text{effort} = \dots\dots\dots$ (1 mark)
12. Why do you think the ancient Egyptian used inclined planes to build pyramids?

 (1 mark)
13. Why do people (eg, furniture removalists) use ramps to move goods into their vans?



(1 mark)

14. Write a conclusion for this activity?

(2 marks)

OFFICIAL USE ONLY

Assessment of student skills

Skills	Marks/Possible Mark
1. Ability to follow instructions	/2
2. Ability to collect, record, calculate and analyse data	/4
3. Ability to use equipment correctly	/2
4. Ability to draw appropriate conclusions	/2
TOTAL MARKS	/10

Total Marks for Practical 9: Simple machines – Using Pulleys

Marks for Physics practical	/20
Marks for student skills	/10
TOTAL MARKS FOR PRACTICAL 9	/30

Appendix C: Data Collection Instruments

C1 – Survey Form for Practising Science Teachers

Science Teacher PCK Survey



- Thank you for participating in this survey.
- There are no right or wrong answers. It is your opinion that is sought here.
- Please respond to each item to the best of your knowledge.

Section 1: Brief Background Information (Please tick '✓' and write your responses to the following items)

Name: _____ Male Female

I am currently teaching at (name of school): _____

I am teaching this/these subjects: _____

I teach forms: _____, My qualification(s): _____

Training institution(s): _____

I have been teaching science for (length of time): _____ Weeks, _____ Months, _____ Years

I am familiar with Form 4 & 5 science SBA: NO / YES, If yes, how long: _____ weeks/months/years

I am currently employed as: a trained teacher / an untrained teacher.

Section 2: Pedagogical Content Knowledge (PCK)

Please indicate your level of agreement with each statement below by circling the number '①' in the right column.

To change your choice simply put an 'X' over your previous choice and circle the number of your new choice.

Key: SD - Strongly disagree, D - disagree, UN - Uncertain, A – Agree, SA – Strongly Agree

For example: If you agree, circle '④' under column A -

SD	D	UN	A	SA
①	②	③	④	⑤

	SD	D	UN	A	SA
I understand how to use demonstrations to explain physics concepts.	①	②	③	④	⑤
I understand how to use appropriate diagrams and graphs to explain physics concepts.	①	②	③	④	⑤
I am able to use computer simulations to help learners understand physics concepts.	①	②	③	④	⑤
I am confident in using familiar everyday examples to explain physics concepts.	①	②	③	④	⑤
I am confident in using stories to explain physics concepts.	①	②	③	④	⑤
Presenting a physics concept in multiple ways to explain the concept are tools for effective physics teaching.	①	②	③	④	⑤
Physics learning is enhanced when the teacher is good at representing the physics concepts in multiple ways.	①	②	③	④	⑤
Physics teachers should spent time on developing or finding multiple representations of a physics concept.	①	②	③	④	⑤

	SD	D	UN	A	SA
Textbooks or curricular material should embody physics concepts in multiple ways.	①	②	③	④	⑤
In my physics teaching, I use multiple representations to teach a physics concept.	①	②	③	④	⑤
I use stories to explain physics concepts in my teaching.	①	②	③	④	⑤
I use familiar everyday real objects to help learners' understanding of the physics concepts in my teaching.	①	②	③	④	⑤
Multiple representations of a physics concept can help to explain abstract concepts.	①	②	③	④	⑤
Multiple representations of a physics concept can lead to misunderstanding of the concept.	①	②	③	④	⑤
Multiple representations of a physics concept can support physics learning when all the representations show all the information about the concept.	①	②	③	④	⑤
I know how to use learners' preconceptions of a physics concept in planning in my lessons.	①	②	③	④	⑤
I am able to identify learners' related abilities and skills in learning a physics concept.	①	②	③	④	⑤
I understand how to use learners' difficulties in planning my lessons to teach a physics concept.	①	②	③	④	⑤
Physics teaching is effective when the teacher is able to identify concepts that are abstract to learners.	①	②	③	④	⑤
Determining learners' likely preconception related to a physics concept is important in planning for effective teaching.	①	②	③	④	⑤
It would be helpful when textbooks or curriculum highlight learners' difficulties related to a physics concept.	①	②	③	④	⑤
In my teaching, I use knowledge of learners' preconceptions of a physics concept.	①	②	③	④	⑤
I use the knowledge of related abilities and skills of my learners in learning a physics concept in my teaching.	①	②	③	④	⑤
I use knowledge of learners' difficulties in solving problems related to a physics concept in my teaching.	①	②	③	④	⑤
Learners' preconceptions are difficult to overcome.	①	②	③	④	⑤
Learners' come to the classroom with their naïve knowledge of physics concepts.	①	②	③	④	⑤
It is easy to teach a physics concept since all learners have the same abilities and skills in learning the physics concept.	①	②	③	④	⑤
I know how physics theories or principles have been developed.	①	②	③	④	⑤
I understand physics concepts well enough to teach physics effectively.	①	②	③	④	⑤

	SD	D	UN	A	SA
I know how to relate physics to everyday science and technology	①	②	③	④	⑤
I know how to teach the history behind the discoveries of physics concepts.	①	②	③	④	⑤
Physics learning is enhanced when the teacher has a good grasp of physics contents.	①	②	③	④	⑤
Physics textbooks should include how physics concepts were discovered.	①	②	③	④	⑤
Understanding how physics theories or principles are developed will enhance physics learning.	①	②	③	④	⑤
In my physics teaching, I can use the knowledge of how physics theories or principles have been developed.	①	②	③	④	⑤
I can tell the history behind the discoveries of physics concepts in my teaching.	①	②	③	④	⑤
I can relate the physics concept learned to the use of technology and its impact on society in my teaching.	①	②	③	④	⑤
Knowing how physics is related to science and technology will motivate learners to learn physics.	①	②	③	④	⑤
An effective physics teacher knows the relationships of central concepts in physics.	①	②	③	④	⑤
Knowing the historical development of physics helped me understand the content better.	①	②	③	④	⑤
I can teach lessons that appropriately combine physics contents with teaching approaches.	①	②	③	④	⑤
I can select multiple representations to use in my classroom that enhance what I teach, how I teach, and what learners learn.	①	②	③	④	⑤
I can use strategies in my classroom that combine physics content and teaching approaches that I learned about in my past studies.	①	②	③	④	⑤
I can provide leadership in helping others to coordinate the use of content and teaching approaches at my school.	①	②	③	④	⑤
I can choose effective teaching approaches to guide learners thinking process of physics contents.	①	②	③	④	⑤
I can select appropriate assessment activities that will demonstrate learners understanding of physics concepts.	①	②	③	④	⑤
I use formative assessment to enhance learners understanding of physics concepts.	①	②	③	④	⑤
I use multiple representations when teaching physics concepts.	①	②	③	④	⑤
I use school-based assessment for both summative and formative assessment.	①	②	③	④	⑤
I use school-based assessment for effective teaching and learning in my classroom.	①	②	③	④	⑤

Please turn over.

Please circle one letter A, B, C, D or E which corresponds to a statement you agree with.

1. Two metal balls are the same size, but one weighs twice as much as the other. The balls are dropped from the top of a two storey building at the same instant of time. The time it takes the balls to reach the ground below will be:
 - A. About half as long as for the heavier ball.
 - B. About half as long as the lighter ball.
 - C. About the same time for both balls.
 - D. Considerably less for the heavier ball, but not necessarily half as long.
 - E. Considerably less for the lighter ball, but not necessarily half as long.

2. A large box is being pushed across the floor at a **constant speed** of 4.0 m/s. What can you conclude about the forces acting on the box?
 - A. If the force applied to the box is doubled, the constant speed of the box will increase to 8.0 m/s.
 - B. The amount of force applied to move the box at a constant speed must be more than its weight.
 - C. The amount of force applied to move the box at a constant speed must be equal to the amount of the frictional forces that resist its motion.
 - D. The amount of force applied to move the box at a constant speed must be more than the amount of the frictional forces that resist its motion.
 - E. There is a force being applied to the box to make it move but the external forces such as friction are not “real” forces they just resist motion.

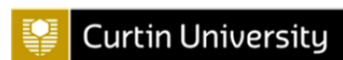
3. If the force being applied to the box in the preceding problem is suddenly discontinued, the box will;
 - A. Stop immediately.
 - B. Continue at a constant speed for a very short period of time and then slow to a stop.
 - C. Immediately start slowing down to a stop.
 - D. Continue at a constant velocity.
 - E. Increase its speed for a very short period of time, then start slowing to a stop.

4. Imagine a head-on collision between a large truck and a small compact car. During the collision,
 - A. The truck exerts a greater amount of force on the car than the car exerts on the truck.
 - B. The car exerts a greater amount of force on the than the truck exerts on the car.
 - C. Neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
 - D. The truck exerts a force on the car but the car doesn't exert a force on the truck.
 - E. The truck exerts the same amount of force on the car as the car exerts on the truck.

Please write any comments you have about this survey in the box below.

Thank you very much.

C2 – Survey Form for Trainee Science Teachers



Science Trainee Teacher PCK Survey

- Thank you for participating in this survey.
- There are no right or wrong answers. It is your opinion that is sought here.
- Please respond to each item to the best of your knowledge.

Section 1: Brief Background Information (Please tick '✓' and write your responses to the following items)

Name: _____ Male Female

I am currently doing my (study program at SINU): _____

I study to teach this/these subject(s): _____

Practicum experience: NO / YES, If yes; at - Primary, Junior High, Senior High
(Note: Junior High School – Year 7 to Year 9 & Senior High School – Year 10 to Year 13)

Duration of practicum experience: _____ Weeks, _____ Months, _____ Years, None

I have taught before: NO / YES, If yes; as trained teacher or untrained teacher.

I taught this/these subject(s): _____, None

Section 2: Pedagogical Content Knowledge (PCK)

Please indicate your level of agreement with each statement below by circling the number '①' in the right column.

To change your answer simply put an 'X' over your previous choice and circle the number of your new choice.

Key: SD - Strongly disagree, D - disagree, UN - Uncertain, A – Agree, SA – Strongly Agree

For example: If you agree, circle '④' under column A-

SD	D	UN	A	SA
①	②	③	④	⑤

	SD	D	UN	A	SA
I understand how to use demonstrations to explain physics concepts.	①	②	③	④	⑤
I understand how to use appropriate diagrams and graphs to explain physics concepts.	①	②	③	④	⑤
I am able to use computer simulations to help learners understand physics concepts.	①	②	③	④	⑤
I am confident in using familiar everyday examples to explain physics concepts.	①	②	③	④	⑤
I am confident in using stories to explain physics concepts.	①	②	③	④	⑤
Presenting a physics concept in multiple ways to explain the concept are tools for effective physics teaching.	①	②	③	④	⑤
Physics learning is enhanced when the teacher is good at representing the physics concepts in multiple ways.	①	②	③	④	⑤
Future teachers should spent time on developing or finding multiple representations of a physics concept.	①	②	③	④	⑤

	SD	D	UN	A	SA
Textbooks or curricular material should embody physics concepts in multiple ways.	①	②	③	④	⑤
In my future physics teaching, I will use multiple representations to teach a physics concept.	①	②	③	④	⑤
I plan to use stories to explain physics concepts in my future teaching.	①	②	③	④	⑤
I will use familiar everyday real objects to help learners' understanding of the physics concepts in my future teaching.	①	②	③	④	⑤
Multiple representations of a physics concept can help to explain abstract concepts.	①	②	③	④	⑤
Multiple representations of a physics concept can lead to misunderstanding of the concept.	①	②	③	④	⑤
Multiple representations of a physics concept can support physics learning when all the representations show all the information about the concept.	①	②	③	④	⑤
I know how to use learners' preconceptions of a physics concept in planning in my lessons.	①	②	③	④	⑤
I am able to identify learners' related abilities and skills in learning a physics concept.	①	②	③	④	⑤
I understand how to use learners' difficulties in planning my lessons to teach a physics concept.	①	②	③	④	⑤
Physics teaching is effective when the teacher is able to identify concepts that are abstract to learners.	①	②	③	④	⑤
Determining learners' likely preconception related to a physics concept is important in planning for effective teaching.	①	②	③	④	⑤
It would be helpful when textbooks or curriculum highlight learners' difficulties related to a physics concept.	①	②	③	④	⑤
In my future teaching, I will use knowledge of learners' preconceptions of a physics concept.	①	②	③	④	⑤
I will use the knowledge of related abilities and skills of my learners in learning a physics concept in my future teaching.	①	②	③	④	⑤
I plan to use knowledge of learners' difficulties in solving problems related to a physics concept in my future teaching.	①	②	③	④	⑤
Learners' preconceptions are difficult to overcome.	①	②	③	④	⑤
Learners' come to the classroom with their naïve knowledge of physics concepts.	①	②	③	④	⑤
It is easy to teach a physics concept since all learners have the same abilities and skills in learning the physics concept.	①	②	③	④	⑤
I know how physics theories or principles have been developed.	①	②	③	④	⑤
I understand physics concepts well enough to teach physics effectively.	①	②	③	④	⑤

	SD	D	UN	A	SA
I know how to relate physics to everyday science and technology	①	②	③	④	⑤
I know how to teach the history behind the discoveries of physics concepts.	①	②	③	④	⑤
Physics learning is enhanced when the teacher has a good grasp of physics contents.	①	②	③	④	⑤
Physics textbooks should include how physics concepts were discovered.	①	②	③	④	⑤
Understanding how physics theories or principles are developed will enhance physics learning.	①	②	③	④	⑤
In my future physics teaching, I will use the knowledge of how physics theories or principles have been developed.	①	②	③	④	⑤
I plan to tell the history behind the discoveries of physics concepts in future teaching.	①	②	③	④	⑤
I will relate the physics concept learned to the use of technology and its impact on society in future teaching.	①	②	③	④	⑤
Knowing how physics is related to everyday science and technology will motivate learners to learn physics.	①	②	③	④	⑤
An effective physics teacher knows the relationships of central concepts in physics.	①	②	③	④	⑤
Knowing the historical development of physics will help me understand the content better.	①	②	③	④	⑤
I can teach lessons that appropriately combine physics contents with teaching approaches.	①	②	③	④	⑤
I can select multiple representations to use in my classroom that enhance what I teach, how I teach, and what learners learn.	①	②	③	④	⑤
I can use strategies in my future classroom that combine physics content and teaching approaches that I learned about in my course.	①	②	③	④	⑤
I can provide leadership in helping others to coordinate the use of content and teaching approaches at my future school.	①	②	③	④	⑤
I can choose effective teaching approaches to guide learners thinking process of learning physics contents.	①	②	③	④	⑤
I can select appropriate assessment activities that will demonstrate learners understanding of physics concepts.	①	②	③	④	⑤
I can use formative assessment to enhance learners understanding of physics concepts.	①	②	③	④	⑤
I can use multiple representations when teaching physics concepts.	①	②	③	④	⑤
I can use school-based assessment for both summative and formative assessment.	①	②	③	④	⑤
I can use school-based assessment for effective teaching and learning in my classroom.	①	②	③	④	⑤

Please turn over.

Please circle one letter A, B, C, D or E which corresponds to a statement you agree with.

1. Two metal balls are the same size, but one weighs twice as much as the other. The balls are dropped from the top of a two storey building at the same instant of time. The time it takes the balls to reach the ground below will be:
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 - E. There is a force being applied to the box to make it move but the external forces such as friction are not “real” forces they just resist motion.

3. If the force being applied to the box in the preceding problem is suddenly discontinued, the box will:
 - A. Stop immediately.
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 - C. Immediately start slowing down to a stop.
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 - A. The truck exerts a greater amount of force on the car than the car exerts on the truck.
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 - C. Neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
 - D. The truck exerts a force on the car but the car doesn't exert a force on the truck.
 - E. The truck exerts the same amount of force on the car as the car exerts on the truck.

Please write any comments you have about this survey in the box below.

Thank you very much.

C3 – Practising Science Teachers Interview Schedule

Science Teacher Interview Schedule

Solomon Islands Case Study



Curtin University

The following interview questions will firstly involve gathering a brief background from you, the teacher participant.

Can you please tell us:

- i. How long have you been teaching science in high school? _____
- ii. Where did you have your pre-service teaching education? _____
- iii. How long have you been conducting science SBA? _____

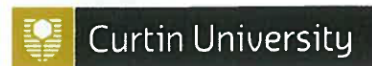
-
1. What do you think is important about science education?
 2. What are some things you want your students to learn or develop from science?
 3. What are your views and experiences of teaching and learning physics in science?
 4. How do you think students learn physics concepts?
 5. What do you think are effective ways to teach physics concepts?
 6. What are some ways you teach physics concepts in class?
 7. What aspects of students learning in physics do you think is important to assess?
 8. Tell me about your views and experiences with the SBA of physics?
 9. What main things should students learn and be assessed for in SBA of physics?
 10. How would you use SBA to improve student learning and assessment in physics?
 11. What are your views about formative and summative assessment in students learning?
 12. What do you think about science teacher's pedagogical content knowledge (PCK)?
 13. What do you understand about physics concepts in high school science?
 14. Are you confident to teach and assess physics concepts in high school?
 15. Do you have any opinion about the aims of the science curriculum?
 16. What kind of assessments do you prefer for the science SBA?

Thankyou for your time, the interview session is now complete.

You are most welcome to give further comments if you wish.

C4 – Trainee Science Teacher Interview Schedule

Science Training Teacher Interview Schedule Solomon Islands Case Study



The following interview questions will firstly involve gathering a brief background from you, the pre-service science teacher participant.

Can you please tell us:

- i. At which form did you leave high school? _____
- ii. Which high school did you attend before SINU? _____
- iii. What courses and subject do you study at SINU? _____

-
1. What do you think is important about science education?
 2. What are some things you want your students to learn or develop from science?
 3. What are your views and experiences about teaching and learning physics in science?
 4. How do you think students learn physics concepts?
 5. What do you think are effective ways to teach physics concepts?
 6. What are some ways you can teach physics concepts in class?
 7. What aspects of students learning of physics do you think is important to assess?
 8. Tell me about your views and experiences concerning the SBA of physics?
 9. What main things should students learn and be assessed for in the SBA of physics?
 10. How would you use SBA to improve students learning and assessment of physics?
 11. What are your views about formative and summative assessment in students learning?
 12. What do you think about pedagogical content knowledge (PCK)?
 13. What do you think about the physics content in high school science?
 14. Are you confident to teach and assess physics concepts in high school?
 15. Do have any opinion about the aims of science curriculum?
 16. What kind of assessments do you prefer for the science SBA?

Thank you for your time, the interview session is now complete.

You are most welcome to give further comments about this interview if you wish.

Appendix D: Research Permits

D1 – Curtin University Protocol Approval



Memorandum

To	Lionel Cliff Kakai, SMEC
From	Mun Yin Cheong, Form C Ethics Co-ordinator Faculty of Science and Engineering
Subject	Protocol Approval SMEC-35-14
Date	24 June 2014
Copy	Tony Rickards, SMEC

Office of Research and Development
Human Research Ethics Committee
Telephone 9266 2784
Facsimile 9266 3793
Email hrec@curtin.edu.au

Thank you for your "Form C Application for Approval of Research with Low Risk (Ethical Requirements)" for the project titled "School-based Assessment of Physics Concepts in Science Education. A Solomon Islands Case Study". On behalf of the Human Research Ethics Committee, I am authorised to inform you that the project is approved.

Approval of this project is for a period of 4 years **23rd June 2014 to 22nd June 2018**.

Your approval has the following conditions:

- (i) Annual progress reports on the project must be submitted to the Ethics Office.
- (ii) **It is your responsibility, as the researcher, to meet the conditions outlined above and to retain the necessary records demonstrating that these have been completed.**

The approval number for your project is **SMEC-35-14**. Please quote this number in any future correspondence. If at any time during the approval term changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.

Regards,

Mun Yin

MUN YIN CHEONG
Form C Ethics Co-ordinator
Faculty of Science and Engineering

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved under Curtin University's process for lower-risk Studies (Approval Number xxxx). This process complies with the National Statement on Ethical Conduct in Human Research (Chapter 5.1.7 and Chapters 5.1.18-5.1.21). For further information on this study contact the researchers named above or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.


**D2 – Research Permit from Solomon Islands Ministry of Education
and Human Resources Development**

**THE RESEARCH ACT 1982
(No. 9 of 1982)**

RESEARCH PERMIT

Permission is hereby given to:

1. Name: Lionel Cliff Kakai
2. Country: Solomon Islands
3. Research subject areas: Explores how the teaching, learning and assessments of Science can be improved in the Science classrooms.
4. Ward (s): Honiara, Auki
5. Province: Honiara City and Malaita
6. Conditions:
 - a. To undertake research only in subject areas specified in 3 above.
 - b. To undertake research only in the ward (s) and Province (s) specified in 4 and 5 above.
 - c. To observe with respect at all times local customs and the way of life of people in the area in which the research is carried out.
 - d. Not to take part at any time in any political or missionary activities or local disputes.
 - e. To leave four (4) copies of your final research report in English with the Solomon islands Government Ministry responsible for research at your own expense.
 - f. A research fee of SBD500.00 and deposit sum of SBD200.00 must be paid in full or the Research Permit will be cancelled. (See sec. 3 subject 7 of the Research Act).
 - g. This permit is valid until **4th June 2015** provided all conditions are adhered to.
 - h. No live species of plants and animals to be taken out of the country without approval from relevant authorities.
 - i. A failure to observe the above conditions will result in automatic cancellation of this permit and the forfeit of your deposit.

Signed: 
Minister of Education and Human Resources Development

Date: 15/05/15

D3 – Research Permit from Solomon Islands National University



SOLOMON ISLANDS NATIONAL UNIVERSITY

School of Education and Humanities

P. O. Box R113, Honiara, Solomon Islands.

☎: (677) 30111 ext. 304. (677) 30502

My Ref:

Your Ref:

May 8th, 2015

Re: Research Study Request, Solomon Islands' National University (SINU)

Dear, Mr. Kakai,

I am pleased to inform you that the SINU Research Committee met on Thursday, May 7th, 2015, to discuss your research proposal entitled, *School-based assessment of physics concepts in science education: A Solomon Islands' case study*, and voted unanimously to approve it with the following amendments:

- 1). A follow-up letter to all SINU participants, i.e., our students to ensure that no harm came to them as a result of participating in this study.
- 2). That a copy of your study will be submitted to the School of Education and Humanities for the purpose of being permanently housed in our library collection.

I will be in touch with the Head of the Science Department, Mr. Andrew Misitom, who will be in touch with you. Mr. Misitom can also be reached as follows: Andrew.[Misitom@sinu.edu.sb](mailto:Andrew.Misitom@sinu.edu.sb)

On behalf of the Committee, I would like to wish you ever imaginable success with your doctoral studies, and all the best in the future as you move to the next stage of this important research study.

Please don't hesitate to contact me if you have any questions.

Sincerely,

A handwritten signature in blue ink, appearing to read 'Joan M. Nesbitt', is written over a horizontal line.

Dr. Joan M. Nesbitt

Dean, School of Education and Humanities, SINU

joan.nesbitt@sinu.edu.sb

Cc: Dr. Dusti Becker
Ms. Verzilyn Isom
Mr. Toncan Eli
Captain Starling Daefa
Dr. Glynn Galo
Mr. Donald Masala
Mr. Andrew Misitom

D4 – Research Permit from the Church of Melanesia



THE CHURCH OF MELANESIA

(The Anglican Church in Solomon Islands and Vanuatu)

Church Headquarters,

P.O. Box 19, Honiara,

Solomon Islands.

Cables: 'Melanesia Honiara' Telephone: 21892/3/4
Fax: (677) 24098

Please address all correspondence to General Secretary

Your Ref:

Our Ref:

Date:

4th May, 2015

Mr. Lionel Kakai

Science and Mathematics Education Centre,

Curtin University'

P.O.BOX U1987

Perth 6845, Australia.

Dear Lionel,

Research Approval at Selwyn College, 2015.

I write to formally inform you that following your application for research at the above secondary school, approval has been granted for you to undertake your research as part of your Doctor of Philosophy Research thesis for a period up to one (1) week only as requested whenever you are available from the 4th May, 2015. The research is to be conducted in accordance with the ethical guidelines of the Curtin University of Australia with the rights and integrity of all participants and the Church fully respected.

I wish you all the best in your research.

Yours Sincerely,

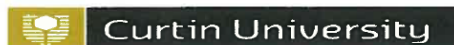
James Memua
Education Secretary

For: General Secretary

Cc: Principal – Selwyn College

Appendix E: Letters Seeking Permissions

E1 – Ministry of Education and Human Resources Development



CHAIRPERSON

Research Committee
Ministry of Education and Human Resources Development
P. O. Box G28,
Honiara,
Solomon Islands.

Dear Sir/Madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN SCHOOLS

My name is Lionel Kakai. I am a PhD student at the Curtin University in Perth, Western Australia. The research I wish to conduct for my Doctoral thesis involves the exploration of school-based assessment of physics concepts in science education in the Solomon Islands. This research will be conducted under the supervision of Dr Tony Rickards of the Science and Mathematics Education Centre at Curtin University.

I hereby seek your permission to approach a number of secondary schools and the Solomon Islands National University (SINU) to provide participants for this research.

I have provided you with a copy of my candidacy proposal which includes copies of the information sheet and consent forms to be given to participants in the research process. I have also provided a copy of the approval letter which I received from the Curtin University Human Research Ethics Committee (Approval Number **SMEC-35-14**).

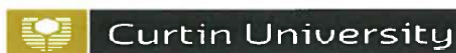
Upon completion of the study, I undertake to provide the Ministry of Education with a bound research report. If you require further information, please do not hesitate to contact me on mobile +61 449529413 or email l.kakai@postgrad.curtin.edu.au or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

Thank you for your time and consideration in this matter.

Yours Sincerely,

Lionel Kakai (17558282)
Science and Mathematics Education Centre, Curtin University, Perth, WA

E2 – Solomon Islands National University (SINU)



CHAIRPERSON

Research Committee
Solomon Islands National University (SINU)
P. O. Box R133,
Honiara,
Solomon Islands.

Dear Sir/Madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT SINU

My name is Lionel Kakai. I am a PhD student at Curtin University in Perth, Western Australia. The research I wish to conduct for my Doctoral thesis involves the exploration of school-based assessment of physics concepts in science education in Solomon Islands. This research will be conducted under the supervision of Dr Tony Rickards of the Science and Mathematics Education Centre at Curtin University.

I hereby seek your permission to approach and involve trainee science teachers at the Solomon Islands National University (SINU) for this research.

I have provided you with a copy of my candidacy proposal which includes copies of the information sheet and consent forms to be given to participants in the research process. I have also provided a copy of the approval letter which I received from the Curtin University Human Research Ethics Committee (Approval Number **SMEC-35-14**).

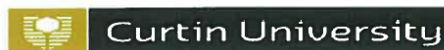
Upon completion of the study, I undertake to provide the SINU with a bound research report. If you require further information, please do not hesitate to contact me on mobile +61 449529413 or email l.kakai@postgrad.curtin.edu.au or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

Thank you for your time and consideration in this matter.

Yours Sincerely,

Lionel Kakai (17558282)
Science and Mathematics Education Centre, Curtin University, Perth, WA

E3 – Chief Education Officer



Chief Education Officer
Education Authority

Honiara,
Solomon Islands.

Dear Sir/Madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT YOUR SCHOOLS

My name is Lionel Kakai. I am a PhD student at Curtin University in Perth, Western Australia. The research I wish to conduct for my Doctoral thesis involves the exploration of school-based assessment of physics concepts in science education in Solomon Islands. This research will be conducted under the supervision of Dr Tony Rickards of the Science and Mathematics Education Centre at Curtin University.

I hereby seek your permission to approach and involve practising science teachers at your high schools for this research.

I have provided you with a copy of my candidacy proposal which includes copies of the information sheet and consent forms to be given to participants in the research process. I have also provided a copy of the approval letter which I received from the Curtin University Human Research Ethics Committee (Approval Number **SMEC-35-14**).

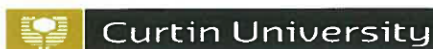
If you require further information, please do not hesitate to contact me on mobile +61 449529413 or email l.kakai@postgrad.curtin.edu.au or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

Thank you for your time and consideration in this matter.

Yours Sincerely,

Lionel Kakai (17558282)
Science and Mathematics Education Centre, Curtin University, Perth, WA

E4 – Principals



Principal

Solomon Islands.

Dear Sir/Madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT YOUR SCHOOL

My name is Lionel Kakai. I am a PhD student at Curtin University in Perth, Western Australia. The research I wish to conduct for my Doctoral thesis involves the exploration of school-based assessment of physics concepts in science education in Solomon Islands. This research will be conducted under the supervision of Dr Tony Rickards of the Science and Mathematics Education Centre at Curtin University.

I hereby seek your permission to approach and involve practising science teachers at your high school for this research.

I have provided you with a copy of my candidacy proposal which includes copies of the information sheet and consent forms to be given to participants in the research process. I have also provided a copy of the approval letter which I received from the Curtin University Human Research Ethics Committee (Approval Number **SMEC-35-14**).

If you require further information, please do not hesitate to contact me on mobile +61 449529413 or email l.kakai@postgrad.curtin.edu.au or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

Thank you for your time and consideration in this matter.

Yours Sincerely,

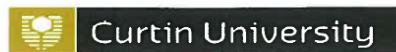
Lionel Kakai (17558282)

Science and Mathematics Education Centre, Curtin University, Perth, WA

Appendix F: Participant's Information and Informed Consent

F1 – Participant's Information Sheet

PARTICIPANT INFORMATION SHEET
Science and Mathematics Education Centre



My name is Lionel Kakai. I am currently completing a piece of research for my degree of Doctor of Philosophy (PhD) at Curtin University in Perth, Western Australia.

Purpose of Research

I am exploring ways to improve the school-based Assessment (SBA) of physics concepts in science education in the Solomon Islands.

Your Role

I am interested in constructing a better understanding from your perceptions about teaching, learning and assessment of physics concepts in the context of the SBA for the SISC.

Firstly, I would like you to complete a Pedagogical Content Knowledge (PCK) survey. The survey has 54 items and it will take about 30 minutes to complete.

I would also like to invite you at a later time for an interview on an individual basis. The interview will be on voluntary basis as well. The interview process will take about 40 minutes.

Consent to Participants

Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or responsibilities. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentiality

The information you provide will be kept separate from your personal details, and only myself and my supervisor will only have access to this. The interview transcript will not have your name or any other identifying information on it. In adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least seven years, before a decision is made as to whether it should be destroyed.

Further Information

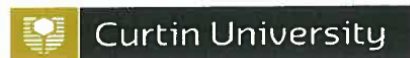
This research has been reviewed and given approval by the Curtin University Human Research Ethics Committee (Approval Number **SMEC-35-14**). For further information on this study contact Lionel Kakai on telephone 9266 3792 or email lkakai@postgrad.curtin.edu.au or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

Thank you very much for your involvement in this research.

Your participation is greatly appreciated

F2 – Participant’s Informed Consent Form

CONSENT FORM
Science and Mathematics Education Centre



- I understand the purpose and procedures of the study.
- I have been provided with the participant information sheet.
- I understand that the procedure itself may not benefit me.
- I understand that my involvement is voluntary and I can withdraw at any time without problem.
- I understand that no personal identifying information like my name and address will be used in any published materials.
- I understand that all information will be securely stored for at least 7 years before a decision made as to whether it should be destroyed.
- I have been given the opportunity to ask about this research.
- I agree to participate in the study outlined to me.

Name : _____

Signature : _____

Date : _____

Appendix G: Detailed Context of Solomon Islands

Geo-Political Context

This present study was conducted in Solomon Islands. An Island sovereign nation situated at 8 00 South and 159 00 East within the South Pacific Ocean, about 2134 kilometres northeast of Brisbane, Australia (Central Intelligence Agency [CIA], 2016). Solomon Islands comprises six large islands and 992 smaller chain of islands, out of which only 347 islands are inhabited (Jones, 2001). The six big islands from west to east are Choiseul, New Georgia, Santa Isabel, Guadalcanal, Malaita, and San Christabel (Makira). The geographical remoteness and smallness of the islands in Solomon Islands is a challenge. Hence, this study was only conducted with participants from schools in and around the capital city, Honiara, located on Guadalcanal, as well as two schools on the island of Malaita. These two location are geographically convenient given the limited time to do this study under my Doctor of Philosophy program at Curtin University.

Basically, Solomon Islands is the third largest archipelago in the South Pacific region. It has a total land area of 27,986 square kilometres with a coastline that stretches to a total length of 5,313 kilometres from Shortland in the northwest to the Santa Cruz Islands in the Southeast (CIA, 2016). The islands along this long stretch of ocean are small, scattered and quite remote from each other. While planes are also used to travel between some of the islands, boats and ships are the main form of cheaper and versatile transportation. However, with poor infrastructure and transportation, travelling between the islands can be difficult and inconvenient. This has contributed a lot of negative effect on education in Solomon Islands as well. For instance, school officials or leaders have to undertake long hours of travelling from their schools to their closest urban centres or the capital city for administrative purposes. This is the same for delivering and collecting materials such as: the transportation of examination papers during national external examinations and collecting of documents like school-based assessment samples for moderation within a certain timeframe at the National Education Assessment Division (NEAD) office in Honiara.

I had also experienced these difficulties during my field trip to collect data for this study. I also included a rural community high school that is geographically convenient

and close to my home village on the Island of Malaita. A such, I had to travel for six hours by boat for a distance of just 114 km north east from Honiara on Guadalcanal to Auki, the provincial capital of Malaita. Then I had to travel for another 108 km for almost five hours by truck to the school that is situated on the North-eastern side of Malaita. The slowness of the travel was due to the speed of the vessels as well as, the condition of the sea and road. This experience is typical to what education officers, teachers and learners in schools around most of the remote and rural regions in Solomon Islands experience on a regular basis. The maps below, figure 1G shows the location of Solomon Islands in the Oceania region while figure 2G shows the political map of the Solomon Islands indicating the nine provinces, the archipelago of the scattered islands and their remoteness from each other.



Figure 1G. The location of Solomon Islands in relation to other countries in the Pacific region (<http://www.infoplease.com/atlas/pacificislandsandaustralia.html>)

Solomon Islands is a young developing nation. It was not until 1568 that the south eastern islands were first visited by the Spanish explorer, Álvaro de Mendeña de Neira. Upon his arrival he found alluvial gold on Guadalcanal. Hence, believing that these islands were the source of the Biblical King Solomon’s gold and wealth, he gave the name Solomon Islands (Solomon Islands Visitors Bureau (SIVB), 2016). The current chain of islands became the Solomon Islands British Protectorate in 1900. During the Second World War in the Pacific, Japan invaded Solomon Islands in 1942 as part of

their intended advance to Australia but the Allied forces won in 1945 (Bennett, 2002). It was after the war that Solomon Islands formed its first legislative council in 1976 and eventually became independent from the Great Britain on July 7, 1978 (SIVB, 2016). After independence, Solomon Islands remained part of the commonwealth countries with the Queen of England as the head of state represented by a Governor General. Subsequently, Great Britain had a lot of influence with the type of government and education system during the inception of Solomon Islands as an independent country.

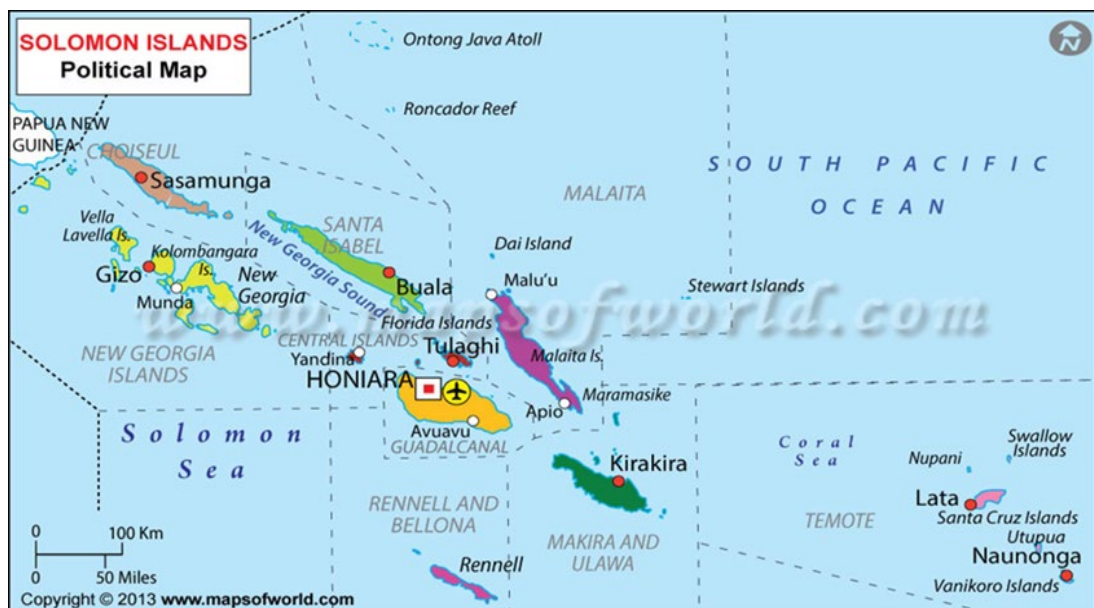


Figure 2G. Political Map of the Solomon Islands indicating the nine provinces (<http://www.mapsofworld.com/solomon-islands>).

Consequently, Solomon Islands has a Westminster form of a democratic government and constitution with one legislative national parliament and nine provincial governments. Currently, the parliament comprises of 50 democratically elected members representing 50 constituencies (Moore, 2010). The constituencies are politically demarcated regions within the nine provinces in Solomon Islands and every four years constituents elect their member for parliament under the first-past the post voting system (Moore, 2010). The Prime Minister is elected by a simple majority of members of Parliament within a coalition of political parties to form the Executive government. The Executive appoints Ministers who oversee Ministerial portfolios within the Solomon Islands Government machinery. Every Executive over the years

have had own policies depending on their priorities whenever they took power. As such, there were many changes to policies over the years. Such a frequency of changes have had both negative and positive effects on education policies. Negative in a sense that good education policies may not continue or positive in sense that new policies can be formulated and implemented as a better change for the future.

Demographic and Socio-economic Context

It was estimated that as of January 2016, the population of Solomon Islands was about 600,052 people and it is increasing by 36 persons daily (Countrymeter, 2016). Known as the melting pot in the South Pacific the population is comprised of a mixture of about 95.3 percent Melanesians, 3.1 percent Polynesians, 1.2 percent Micronesians, and 0.3 percent of other races (CIA, 2016). With such a mixture of races there are about 86 different native languages and 120 dialects. However, English is the official language which is recommended as the language for instruction in schools and in the formal sector (Honan & Harcombe, 1997). The widely spoken and most common language for communication in everyday life is the Pidgin, also known as the broken English (CIA, 2016). As such, most people in the Solomon Islands can speak three different languages. This poses a challenge for language transitions in classroom learning, teaching and assessment in formal schooling (Lotherington, 1998).

Recent statistics indicated that only 25 percent of the population are employed in the industry and civil service sectors while about 75 percent involved in the agriculture, fisheries and forestry sector. Basically, most Solomon Islanders live in the rural areas and depend very much on agriculture, fishing and forestry for most of their subsistence livelihood as well as for income (CIA, 2016). However, due to tropical weather anomaly and pressure on land for cultivation and the shift to cash economy, most people are more dependent on manufactured and processed goods that are mostly imported. Most of Solomon Islands natural mineral resources like gold, nickel, zinc and lead are undeveloped. The relatively small and undiversified economy depends mainly on the export of fish, cocoa beans, copra, palm kernels, timber and round logs as well as, Aid from donor partners. Seemingly over the years, the Gross Domestic Product (GDP) per capita were relatively low compared to other developing countries. This weak economic environment is inextricably linked to the kind of household

income and living standards (UNICEF, 2005). Subsequently, most households do not have the financial capacity to cater for their children's high school education.

This study investigated an educational phenomenon that will impact children between ages 14 to 17 years old who attend formal schools in Solomon Islands. This age group falls within the 20 percent of Solomon Islands population who also make up about 75.1 percent dependency ratio (CIA, 2016). Add to that, the annual rate of urbanization in 2015 was 4.2 percent. That means, Solomon Islands has a growing and mostly dependent population who are gradually drifting to the urban areas (CIA, 2016). This poses a challenge for education in the urban centres along with the issue of nearly 50 percent of learners dropping off formal education at the end of the external examination classes (Department of Foreign Affairs and Trade [DFAT], 2014). As such, one main challenge is to provide the learners with adequate knowledge and skills for life-long learning that they would use in their everyday civic lives.

Education in Solomon Islands was further scrutinised when ethnic tension between militia factions' from two mainly populated provinces, namely Guadalcanal and Malaita broke out into a civil crisis in 1999 (UNICEF, 2014). The crisis started in 1999, and got international attention in year 2000. Particularly, when the Malaita Eagle Force (MEF) had the Solomon Islands Prime Minister and Governor General under house arrest on June the fifth that year. MEF also got hold of arms and ammunition from the only fortified police armoury in Honiara. Law and order was sabotaged and Solomon Islands was declared a failed state through to 2003 when an intervention by the Regional Assistance Mission to Solomon Islands (RAMSI) finally brought back law and order (DFAT, 2014). It was after the restoration of law and order that Solomon Islands developed the "Education Sector Reform Programme (ESIRP)" (MEHRD, 2011, p. 1), which puts more emphasis on "education for life" (p. 1). The outcome of ESIRP is the shift in the education curriculum from objective based to outcome based education beginning in 2004. Add to that, the 1978 Education Act was also reassessed and reviewed as of 2012.

Solomon Islands Education System

Before Western influence and the introduction of formal education, Solomon Islands indigenous production of knowledge and its "transmission in traditional forms of

Solomon learning and teaching was not strictly egalitarian” (Watson-Gegeo & Gegeo, 1992, p. 11). Expert individuals with different ranks and status within the social structure of the society had control over certain forms of knowledge. As such, indigenous transmission of certain knowledge was restricted to certain individuals depending on the future prospects by the experts of the knowledge to pass it on to whom they see fit (Watson-Gegeo & Gegeo, 1992). In general the transmission of knowledge and understanding in Solomon Islands was socially and culturally constructed. The knowledge was actually passed on through practical social interaction between the novices and the expert in situ or real life contexts. That was seen as a more practical way to prepare the learners for real life learning and for future endeavours in their livelihood. That was quite similar to the socio-cultural and constructivist ideas that underpin the new educational approach in Solomon Islands (MEHRD, 2011). The outcome-based education approach which focuses more on the abilities of learners to demonstrate the intended learning outcomes. This approach acknowledges the notion that “development of knowledge, understanding, concepts, skills and values is a lifelong process” (p. 1).

Formal education was introduced after the establishment of British Protectorate over Solomon Islands in 1893. Schools were mainly operated by missionaries and labour traders. Curricula for most of the mission schools were chiefly concerned with converting local Solomon Islanders to Christianity as well as, for training future missionaries. Although, mission schools provided formal education, they did not meet the colonial administration training needs. The need to train more civil servants (Watson-Gegeo & Gegeo, 1991). As such, the first education department was established in 1946 with a strong cooperation with the mission schools. The first government school was established in Auki, on the island of Malaita in 1949. The Solomon Islands government assumed more control of formal education over most schools in 1974, mainly providing subsidise funding, curriculum and teacher training (Searle, 1970). This arrangement is still evident with the Ministry of Education and Human Resources Development (MEHRD) as the umbrella body overseeing all the mission, private and provincial Education Authorities (EA).

Since the first establishment of the education department the Solomon Islands government had placed more focused on training teachers and civil servants. That was

to address the need to produce more qualified teachers and employees in the civil services (Searle, 1970). In 1959, the Solomon Islands fully established “The Teacher and Vocational Training College and the British Solomon Islands Training College, along with other training institutions in Honiara” (Moore, 2013). Those were the precursors to the Solomon Islands Teacher College and Honiara Technical College before the Act of Parliament 1984 combined them under the Solomon Islands College of Higher Education (SICHE). In 2008, another Act of Parliament included other new schools which paved the way for the establishment of Faculties when SICHE eventually was initiated as the Solomon Islands National University (SINU) in 2012 (SINU, 2017). That said, this study also involved participants who were training at the SINU to become science teachers in Solomon Islands.

The Solomon Islands education system is undergoing major restructuring and reform beginning in 2004. There were some changes to the structure within its education system when this thesis was written. The new structure of education have six levels which include Early Childhood Education (ECE), Primary School (PS), Junior Secondary Education (JSE), Senior Secondary Education (SSE), Vocational or Technical Education (TVET) and Tertiary Education (TE) (MEHRD, 2011). As part of addressing one of the United Nations’ Sustainable Development Goals (SDG) in Solomon Islands, all children should have access to basic education which encompasses ECE to JSE (MEHRD, 2007b; MEHRD, 2017). That said, this study placed more focus the three types of schools within the JSE and SSE levels. In 2014, the three types of schools comprised 223 Community High Schools (CHS), 15 Provincial Secondary Schools (PSS) and 12 National Secondary Schools (NSS). In the same year, there were 43 TVET institutions and one National University in the Solomon Islands (MEHRD, 2015).

The different types of secondary schools use the same syllabus (MEHRD, 2011). The national secondary schools (NSS) are schools that were first established and administered by the Government and the missions. They usually enrol learners with higher academic merits from all over the country. The provincial secondary schools (PSS) were initially established by the Government in 1976 in the provinces mainly for teaching and training of technical and vocational knowledge and skills. However, due to some criticism between 1982 and 1985 they adopted the NSS curriculum as

well. They are administered by their respective provinces and they mainly enrol learners within their own provinces. Community high schools (CHS) were initiated as part of primary schools in 1995, an alternative progressive path into secondary education. They are managed and administered by community based school boards and assisted by other stakeholders like the churches and provincial government. The curriculum and syllabus for all these schools are centralised and is facilitated under the Ministry of Education and Human Resources Development as the umbrella body (MEHRD, 2011).

However, over the years limited access to higher formal education has left Solomon Islands with a low literacy rate of around 17 percent and high unemployment among young people (DFAT, 2014). Many learners who enrolled in the ECE and Primary schools do not usually go on to further their formal education at the higher education levels. Basically, learners have to complete three years (age 3 to 5 years old) at the ECE and six years (age 6 to 12 years old) at the Primary level of education before enrolling at the junior secondary education level. In 2016, there were 132,402 learners enrolled into primary schools and only 33,474 enrolled into junior secondary education while only 18,557 learners enrolled into senior secondary education (MEHRD, 2017). Add to that, in 2016, only 33.7 percent of learners in Form Five (Year 11) had placements in Form Six (Year 12) and only 18 percent of Form Six learners had placements in Form Seven (Year 13).

This reduction of enrolment is a concerning trend for education in Solomon Islands since many of the learners who would not continue on with formal education are very young. For example, most learners in junior secondary education are 13 to 15 years of age and most learners in senior secondary education are 16 to 19 years of age. Subsequently, majority of young people below the age of 20 years left formal education to start their civic livelihood in their societies that are greatly influenced by science and technology.

Appendix H: Tables for Item –Total Statistics

Table 1H

Item - Total Statistics for Scale One

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
i01	56.61	25.31	.28	.71
i02	56.63	24.67	.39	.70
i03	57.45	24.93	.13	.74
i04	56.59	23.38	.45	.69
i05	56.66	23.65	.46	.69
i06	56.30	22.55	.55	.68
i07	56.08	23.52	.52	.69
i08	56.00	25.48	.29	.71
i09	56.18	25.58	.24	.71
i10	56.63	23.74	.33	.71
i11	56.65	24.16	.29	.71
i12	56.24	24.51	.40	.70
i13	56.35	23.61	.45	.69
i14	57.96	25.73	.04	.75
i15	56.29	24.41	.37	.70

Scale one comprises item 1 to item 15 – a total of 15 items

Table 2H

Item –Total Statistics for Scale Two

Item No	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
i16	41.11	21.16	.50	.61
i17	40.92	22.43	.33	.64
i18	41.01	21.29	.46	.62
i19	40.58	21.81	.31	.64
i20	40.54	22.50	.27	.65
i21	40.71	22.70	.20	.66
i22	41.18	20.09	.52	.60
i23	40.98	20.72	.50	.61
i24	41.01	19.28	.58	.59
i25	41.96	23.28	.05	.69
i26	41.15	23.25	.09	.68
i27	42.17	21.15	.15	.69

Scale Two comprises item 16 to item 27 – a total of 12 items.

Table 3H

Item – Total Statistics for Scale Three

Item No	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
i28	50.00	24.54	.46	.82
i29	49.70	25.54	.35	.83
i30	49.50	25.80	.44	.82
i31	50.12	22.04	.69	.80
i32	48.83	27.31	.24	.83
i33	49.01	25.65	.42	.83
i34	49.06	25.32	.47	.82
i35	49.46	23.54	.65	.81
i36	49.82	22.25	.62	.81
i37	49.47	25.11	.45	.82
i38	48.98	26.10	.42	.83
i39	49.01	25.86	.46	.82
i40	49.33	24.47	.52	.82

Scale Three comprises item 28 to item 40 – a total of 13 items.

Table 4H

Item – Total Statistics for Scale Four

Item No	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
i41	36.54	24.27	.51	.89
i42	36.57	21.87	.72	.87
i43	36.50	22.94	.62	.88
i44	36.67	22.40	.71	.87
i45	36.51	23.07	.69	.88
i46	36.32	23.80	.58	.88
i47	36.41	23.01	.63	.88
i48	36.85	22.31	.65	.88
i49	36.56	22.28	.64	.88
i50	36.59	22.81	.54	.89

Scale four comprises item 41 to item 50 – a total of 10 items.

Appendix I: Tables for Factor Analysis

Table II: Factor Matrix

	Factor			
	1	2	3	4
i01		.552		-.311
i02	.372			-.415
i03		.320		
i04	.333		.318	-.300
i05	.423			
i06	.516		.453	
i07	.362		.528	
i08			.302	
i09				
i10	.505			
i11	.399			
i12	.509			
i13	.416		.518	
i14				
i15	.440		.473	
i16	.330	.577		
i17	.509			
i18	.475	.410		
i19	.386			.310
i20	.401		.371	
i21				
i22	.376	.411		.374
i23	.430	.363		
i24	.408	.505		.387
i25				
i26				
i27			-.324	
i28	.455			
i29	.367			
i30	.468			-.358
i31	.604			
i32	.302			
i33	.415			
i34	.464			
i35	.605			
i36	.625			
i37	.491			
i38	.451			.320
i39	.457			.356
i40	.552			.357
i41	.542			
i42	.724			
i43	.669			
i44	.670		-.375	
i45	.648			
i46	.564			
i47	.501		-.327	
i48	.682			
i49	.477	-.407	-.301	
i50	.409	-.313	-.320	

Extraction Method: Principal Axis Factoring.
a. 4 factors extracted. 5 iterations required.

Table 2I: Rotated Factor Matrix

	Factor			
	1	2	3	4
i01			.667	
i02			.638	
i03				
i04			.594	
i05			.469	
i06		.515	.479	
i07		.594		
i08		.404		
i09		.427		
i10	.381			.316
i11	.448			
i12	.384			
i13		.635		
i14				
i15		.660		
i16			.432	.518
i17	.324		.366	
i18			.519	.323
i19		.338		.315
i20		.558		
i21		.410		
i22				.619
i23				.549
i24				.715
i25				
i26				
i27				
i28			.482	
i29			.374	
i30	.390		.437	
i31	.445		.388	
i32		.398		
i33	.330	.308		
i34	.344	.449		
i35	.534			.343
i36	.386			.421
i37			.346	.306
i38		.417		.305
i39		.412		.336
i40	.382	.322		.434
i41	.445			
i42	.631			
i43	.520			.349
i44	.779			
i45	.656			
i46	.559			
i47	.637			
i48	.595		.326	
i49	.707			
i50	.621			

Extraction Method: Principal Axis Factoring.
 Rotation Method: Varimax with Kaiser Normalization.a
 a. Rotation converged in 9 iterations.

Table 3I: Factor Transformation Matrix

Factor	1	2	3	4
1	.693	.445	.441	.357
2	-.425	-.383	.609	.549
3	-.559	.765	.259	-.188
4	-.162	.267	-.606	.732

Extraction Method: Principal Axis Factoring.

Rotation Method: Varimax with Kaiser Normalization.

Table 4I: Mean Scores for Five Scales

Themes	Trainee Teachers	Practising Teachers
Knowledge of Teaching Physics	items 1 – 15 Mean score = 4.07	All items 1 – 15 Mean score = 4.01
Knowledge of Learners' Understanding	All items 16 – 27 Mean score = 3.83	All items 16 – 27 Mean score = 3.63
Knowledge of Content and Purpose of Physics Concepts	Items 28 – 40 Mean score = 4.27	Items 28 – 40 Mean score = 3.82
Pedagogical Content Knowledge of Physics	Items 41 – 50 Mean score = 4.46	Items 41 – 50 Mean score = 4.02
Understanding Force Concepts	Items 51 – 54 Mean score = 0.17	Items 51 – 54 Mean score = 0.38

Notes: The mean scores for all except 'Understanding Force Concepts' are higher for the trainee teachers than for the practising teachers.

The mean score for 'Understanding Force Concepts' is very low compared to a maximum possible score of 4.