School of Education

The Impacts of Advancements in Digital Technologies on Students' Self-Regulated Learning

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

December 2021

DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person, except where due acknowledgement has been made. This thesis contains no material that has been accepted for any degree or diploma in any university.

In accordance with the Australian National Health and Medical Research Council's guidelines for research involving humans, ethics approval for this research was obtained in 2012 and 2020. The proposed research study received human ethics approval from the Curtin University Human Research Ethics Committee, Approval Numbers EDU-109-12 and HRE2020-0713.

Signature:

Date : 15 December 2021

Dedicated To:

To my family, my wife Adeline, my kids Alyssa and Nicholas, my parents Alex and Lucy, my mother-in-law Vivian, my brother Tony, and my cousin Nick. You may not know it, but you have all supported me in important ways along this journey. I would not be here today without all of you.

ABSTRACT

The title, *The Impact of Advancements in Digital Technologies on College Students' Self-Regulated Learning*, was selected for this thesis because I believe in the commitment that educators have to improve the quality of student learning. The use of digital technologies has become a staple in both our daily study environment, as well as our personal environment, which has the potential to affect learning positively and negatively, particularly self-regulated learning. Therefore, in order to improve student self-regulated learning, it is necessary to understand the influences that digital technologies have on both these domains.

Currently, there is extensive research on the capacity of digital technologies to support student self-regulated learning, while most of the literature on self-regulated learning appears to focus on pedagogical practices. This quantitative study addresses the need to support student self-regulated learning by taking a holistic approach: that is, by focusing on the two domains that affect student self-regulated learning: the student's personal environment and the educational provider's learning environment. Specifically, this study reviews three factors of the learning environment: namely (1) pedagogical practice, (2) digital technology usage, and (3) learning setting. It examines three factors of the student's personal environment: (1) individual characteristics, (2) digital technology usage, and (3) self-regulation. Data were collected in 2012 and 2020 to answer four research questions regarding student digital technology usage and self-regulated learning from the perspective of the student's personal environment.

The studies identify various factors of the student's personal environment that influence student digital technology usage and self-regulated learning, and confirm that there has been an increase in college students' use of mobile technologies (i.e., phones) for accessing school-related software applications. Additionally, although student self-regulation increased from 2012 to 2020, student self-regulated learning decreased. These findings are significant as they have the potential to enhance and promote how advances in digital technologies can be incorporated in the domain of the student's personal environment and the domain of the educational provider's learning environment to support student self-regulated learning. Student self-regulated learning, as discussed throughout the chapters of this thesis, is a crucial

aspect of learning and academic performance. As advances in digital technologies continue to shape and change the student's personal environment and the educational provider's learning environment, the need for self-regulated learning becomes essential.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank everyone who has made this journey possible. To my supervisors, my family, my friends and my colleagues, this achievement would not have been possible without your support.

Firstly, I would like to thank my supervisors, Associate Professor Susan Blackley and Doctor Audrey Cooke, for your support and guidance. I also wish to acknowledge and thank Dr Sabine Tan for her assistance.

Due to health issues, my thesis was halted. However, after a slow and lengthy but fortunate recovery, I was able to continue with my study. This would not have been possible without the wisdom, encouragement, and dedication of my supervisors. I was very fortunate to have you as my supervisors as I know I would not have reached this point without you. Words cannot describe how grateful I am to you, Susan, for your dedication, even while you were on study leave, in reviewing my chapters, and providing immediate feedback, which allowed me to stay focused, push ahead, and achieve a personal goal I had almost given up on.

To my family: I would like to thank my wife Adeline for always being there for me and supporting me with every crazy idea I have, even if you do not agree with it. We have been through a lot together and we are still having fun. To my children Alyssa and Nicholas, thank you for providing me with the motivation to continue. Alyssa, I started this journey when you were in primary school; you are now in your second year of university. This has taken me a bit longer than expected but I finally got there.

To my parents, Alex and Lucy, and my mother-in-law, I thank you all for your love and support. I am here today because of you. To my brother, Tony, thank you for encouragement and for being there for me. To my cousin Nick, I am thankful that you moved to Perth and that we, as a family, can spend more time together.

To my friends and colleagues, Damion, Jennifer, Kristina, Maria, and Murry, thank you for allowing me into your classrooms. Brandon, Glen, and Yvonne: thank you for your support and encouragement. We often spend more time with our work colleagues than we do with our family, and all of you make work more enjoyable. To Rob, Dec, and Mike, thank you for keeping Confined running and allowing me to focus on completing this thesis. Lastly, to my students: I thank you for taking the time to participate in my research. You are the reason why I became an educator more than 20 years ago.

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Chapter 1: Introduction

The problem to be addressed in this study is the decline of student self-regulated learning at a pathway college in Perth, Western Australia, as a result of increases in usage of digital technologies. Although some studies have shown that digital technologies can support the learning process and self-regulated learning at all levels of education (Robinson & Song, 2019; Wang et al., 2021; Willey & Gardner, 2014;), many studies have noted that the abundance and accessibility of digital technologies have had a negative impact on students academically (Chen et al., 2020; Islam, 2021). Student self-regulation (SR) and self-regulated learning (SRL) are vital traits for academic success (Russell et al., 2020; Thomas, 1980; Weinstein et al., 2011; Zimmerman, 1990) and so it is important to understand the influence of digital technology usage on these traits. The prevalence of digital technology usage, especially amongst adolescents and millennials (Alghafis et al., 2020; Finch et al., 2021; Gusenbauer, 2019) in education, especially during the COVID-19 pandemic, has had a profound and negative impact on student self-regulation and self-regulated learning. It is important to understand the extent of this impact in order to better support student self-regulation and self-regulated learning.

1.1 MY MOTIVATION FOR THE STUDY

As an educator for over 20 years, I firmly believe that a commitment of educational providers is to improve the quality of student learning, and it is this commitment that has been a major driving force for the integration of digital technologies and the development of pedagogical practices at all phases of schooling to support student learning. According to Cheung et al. (2021) and Mihai et al. (2011), advancements in digital technologies, and developments in pedagogical practice, have shaped the educational environment. However, perhaps the biggest factor in recent history that changed the way formal education is conducted has been the worldwide response to the COVID-19 pandemic. A significant impact due to the pandemic, particularly for pathway colleges in Western Australia, is the implementation of government travel restrictions that were introduced to curb the spread of the COVID-19 virus.

These travel restrictions forced educational providers to seek alternative methods for lesson delivery, which included the provision of online and blended classes (Sindiani et al., 2020). This rapid shift from a traditional face-to-face classroom learning environment to online learning and blended learning environments altered the way students interacted and collaborated with their peers and their teachers (Kee, 2021; Niemi & Kousa, 2020). Additionally, during this period, students often struggled with self-regulated learning, more so than in traditional face-to-face classroom environments. According to Barnark-Brak et al. (2011), Dorrenbacher and Perels (2016), and Chen and Wu (2021), self-regulated learning is a factor for academic success in online learning environments. Therefore, to support student self-regulated learning in these alternative learning environments, teachers have experimented with various pedagogies, and utilised digital technologies to provide students with learning resources (Bryson & Andres, 2020). However, it became clear that these approaches were not enough to encourage and / or support student self-regulated learning (Mustapha et al., 2021). A possible explanation for this could be those pedagogical practises and the usage of digital technologies are misaligned with the learning requirements in these alternative learning environments (Khaddage et al., 2021). Further, the advancements in digital technologies have presented new challenges, including exposing student to numerous distractions (Neuwirth et al., 2020); for example, while students use their computer to complete schoolwork, emails, messages, and other distractions could prevent them from staying focused.

From an educational perspective, current research in the field of self-regulated learning focuses on theories, frameworks, and models to enhance our understanding of student self-regulatory behaviour of their learning in order to inform pedagogical practice (see, for example, Schunk, 1985; Winne, 2005; Zimmerman, 2002; Zhao & Johnson, 2012). From a digital technologies perspective, current research has examined the capacity of hardware, such as computers and mobile phones; and software applications, such as Learning Management Systems, computer-based training, and student collaboration systems to support pedagogical practices and student self-regulated learning (Avci & Ergun, 2019; Pakhomova et al., 2021; Panda, 2020). Whilst researchers acknowledge that factors such as the student's learning and personal environment and the student's individual characteristics influence self-regulated learning behaviour and usage of digital technologies, there appears to be a lack of research that takes a holistic approach in examining the interrelationship of these factors. This is the gap in the current self-regulated learning research that this study seeks to address.

Studies from both a neurological and educational perspective have been instrumental in the development of pedagogical practices such as a shift from a teacher-centred learning approach to a student-centred learning approach (Radzali et al., 2018), the provision of scaffolded learning (Miller et al., 2018), the implementation problem-based learning (Shen et al., 2008) and brain-based learning (Jensen, 2008). I firmly believe that, as educators, we must constantly find better ways to support student learning. This includes having a greater understanding of the usage of digital technologies, student self-regulation, and self-regulated learning behaviour.

Due to personal health reasons this study was halted for a number of years, which resulted in an eight-year gap between data collection (2012 and 2020). However, after a slow and lengthy recovery, I am fortunate to be here, able to continue with the study, and able to add to the body of knowledge in supporting student learning. Incidentally, the COVID-19 impact made for an interesting comparison of data collected in 2012 and 2020.

1.2 BACKGROUND

The current body of literature on digital technology usage and student self-regulation and self-regulated learning (Rueda et al., 2017; Suprijandoko, 2020; Turnbull et al., 2019) appears to focus on identifying the benefits of particular software applications or features of programs that can support various self-regulation and self-regulated learning processes, and as such, lacks a holistic view. The holistic view taken in this study aims to address the impacts of digital technologies on student self-regulation and self-regulated learning by examining contributing factors from both a student's perspective and from the perspective of an educational provider. From a student perspective, their personal environment is examined, which includes the usage of hardware and software digital technologies, individual characteristics, and self-regulation / self-regulated learning behaviour. From the perspective of an educational provider, the learning environment is examined, which includes pedagogical practice, digital technology usage, and the learning setting.

In order to provide this holistic view, the following four research questions are posed:

RQ 1: How has digital technology usage changed from 2012 to 2020?

RQ 2: How has the use of digital technologies changed self-regulation and self-regulated learning from 2012 to 2020?

RQ 3: What factors are related to college students' digital technology usage?

RQ 4: In what ways can digital technology usage predict self-regulated learning and academic performance?

1.3 DEFINING TERMS

Digital technologies include hardware and software applications and are commonly used as teaching tools in education to support pedagogical practices, student self-regulation, and self-regulated learning (Raja & Nagasubramani, 2018). Student self-regulation and self-regulated learning, and the use of digital technologies are critical for learning, especially in the current digital learning environment. Self-regulation refers an individual's control of their own actions and behaviours, including self-monitoring, goal setting, organisation, use of help-seeking strategies and self-motivation strategies to achieve a specific goal (Bradley et al., 2017). Individuals who are highly self-regulated, compared to individuals who are less self-regulated, typically apply these behaviours regularly while working towards a goal. The term self-regulated learning (SRL) is used to refer to the application of self-regulation to achieve a learning goal or to successfully complete an academic task (Jivet et al., 2020). According to Zhao and Johnson (2012, p. 5), "self-regulated learning processes include: *comprehending, planning, developing strategies,* and *evaluating strategy effectiveness"*. During these self-regulated learning processes, students must continuously evaluate the effectiveness of their strategies: that is, while working towards a learning goal, students need to self-monitor their progress in order to identify whether adjustments are required in their comprehending, planning, and or strategies.

The current body of research has been integral in developing our understanding of the cognitive processes involved in self-regulation and self-regulated learning. From a neurological construct of self-regulation, these include for example Atkinson and Shiffrin's (1968) multi-store model, Baddeley and Hitch's (1974) model of working memory, Carroll's (1993) Cattell-Horn-Carroll theory of cognitive abilities, and Das et al.'s (1975) planning, attention, simultaneous and success (PASS) model of intelligence. From an educational construct of self-regulated learning, these include for example Schunk's (1985) model of motivated classroom learning of cognitive skills, Winne's (2006) four turning points model of self-regulated learning, Zhao and Johnson's (2012) theoretical framework of self-regulated learning in digital learning environments, and Zimmerman's (2002) three cyclical phases of self-regulated learning.

1.4 CONTEXT OF THIS RESEARCH

The study was conducted at a 'pathway college' in Perth, Western Australia in 2012 and 2020. A pathway college provides preparatory courses, which, upon successful completion, provide students with the necessary requirements for university entry (Aktar & Strong, 2019; De Wit & Jones, 2018). The current study recruited 214 students from the commerce pathway to determine the changes in their usage of digital technologies, self-regulation and self-regulated learning behaviour, and academic performance.

1.5 OVERVIEW

The current research explores the changes in digital technologies over the last decade (2010 and 2020) and identifies changes in hardware and software applications that may affect student usage of these technologies. Next, pedagogical practices, student learning processes, established theories, frameworks and models of self-regulation and self-regulated learning processes are examined to identify how these processes have been incorporated into practice and how they have been supported by digital technologies. Current instruments used to determine student self-regulation and self-regulated learning behaviour and academic performance are reviewed in order to identify the most appropriate to collect data for the study. Statistical analyses were performed on the data and produced descriptive statistics and correlations to describe the data. Additionally, results of partial correlations, independent sample t-tests and regression analysis were used to answer the four research questions.

A quantitative approach was taken for this study to make statistical inferences about the impact of digital technology usage on college student self-regulated learning in 2012 and 2020. The quantitative research methodology involved a study that used self-report instruments and standardised tests to determine students' self-regulation, self-regulated learning, usage of digital technologies, and academic performance for the 2012 and 2020 participating pathway college students. A quantitative approach was selected due to the research properties: that is, it is suitable for large groups, data can be easily compared, data is objectively collected and analysed, and analysed data can be generalised for a larger population (Kumatongo & Muzata, 2021; Rutberg & Bouikidis, 2018). These were important considerations for the study as the sample group size was relatively large (n=214).

Objectivity was important to the researcher, as the aim of the study was to provide a generalisation of college student self-regulated learning as a result of the impact of digital technologies. Additionally, as data were collected in two periods (2012 and 2020), a quantitative approach allowed for comparisons to be made between the groups. The research philosophy of the study was derived from an objectivist ontology and rationalist epistemological perspective. From this paradigm, the view was taken that knowledge can be measured using appropriate methodologies and scientific instruments. As such, while a researcher's perspective and experience are valid (qualitative view), these should not take precedence over the statistics obtained. As such, a quantitative methodology was considered to be more appropriate for the study.

1.6 POTENTIAL BENEFITS OF THE RESEARCH

By contributing to the growing body of research related to self-regulated learning, this research provides a holistic understanding of the interrelated factors affecting student self-regulated learning. For instance, this study extends previous research on pedagogical practices, namely student-centred learning, scaffolding approaches, provision of feedback, brain-based learning, and problem-based learning pedagogies (Bransford et al., 2004; Gulpinar, 2005; Guo et al., 2019; Radzali et al., 2018). Additionally, this study extends past research on digital technologies and self-regulated learning (see, for example, Jackman, 2019; Raja & Nagasubramani, 2018; Rueda et al., 2017; Suprijandoko, 2020; Xidirbaev & Abdurahmanov, 2021); as well as research on student characteristics, learning environment, and personal environment (see, for example, Henderson et al., 2015; Janke et al., 2016; Sabah, 2020; Spranger, 2010; Zadworna-Cieslak, 2018).

Supporting student self-regulation and self-regulated learning becomes increasingly challenging due to the increased complexities afforded by the digital environment, including student's usage of digital technologies, personal environment, and learning environment. It is worth noting that research by Zhang et al. (2020) suggested that student usage of digital technologies has not only impacted students' online behaviour but also their offline behaviour. This finding is significant as it provides some perspective into the enormity of the influence digital technologies can have on student behaviour. Therefore, this holistic research potentially enables educators to identify the factors affecting student self-regulation and self-regulated learning and identify whether the learning environment provided by the educational institute supports the level of self-regulation and self-regulated learning expected of the student. This dual approach will allow an educational institute to examine whether its learning environment, including pedagogical practices, digital technologies, staff skills, and delivery modes are appropriate for supporting self-regulated learning.

The current research adhered to the values and principles of ethical research conduct as outlined by the ethical principles described by the National Health and Medical Research Council (2007): (1) respect, (2) merit and integrity, (3), justice, and (4) beneficence. Student privacy and confidentiality in the research were maintained as students who chose to participate or not to participate did so anonymously; that is, the data collected could not be used to identify a particular participant. Additionally, only the researcher and his Curtin University doctoral supervisors had access to the data collected. The Western Australian pathway college, from which the research participants were recruited, was provided with a summarised version of the collected data. The researcher worked at the college in which the research was conducted, and as such, was able to work closely with the teachers at the college to ensure that the voluntary participating students had sufficient time to complete the quiz and questionnaire of the study while minimising the impacts on the students' learning. Additionally, students were explicitly made aware that their participation in this research was voluntary and anonymous, and they were informed that this research was separate to their learning requirements, and as such, would in no manner affect their class performance or grade. Student anonymity was assured as students were not required to use their student profiles or any distinguishing details to participate in the study.

1.7 LIMITATIONS

The focus of the study was to investigate the impacts of digital technologies on college students' self-regulated learning. As the data were collected in 2012 and 2020, the findings may not be applicable for different time periods. Additionally, it is also suggested throughout the study that the data collected in 2020 may have been affected by the COVID-19 pandemic. The measurement used to identify student usage of digital technologies could be a limitation of the study, as it was a self-reported measure and may not have represented a true picture of students' digital technology usage. Also, the questions relating to digital technologies, that is duration and frequency, may not have been understood by some students. Next, for time considerations, only some scales and subscales were used in the study for collecting data on student self-regulation and self-regulated learning, and it could be argued that this may have unintentionally affected the results. Lastly, it could be argued that when investigating digital technologies, findings should be limited to geographical locations. That is, data was collected in Australia, where the Internet speeds are faster than in other geographical locations, and as such these findings may not be able to be generalised in countries where the Internet connection speeds are considerably lower. Despite these limitations, the results are still valid for the purpose of answering the research questions and make a valuable contribution to the literature in self-regulated learning, especially in regard to Western Australian pathway college students.

1.8 KEY FINDINGS

Mobile phone and computer usage among college students increased from 2012 to 2020 in duration and frequency of usage. These findings are not surprising as they supported previous research showing that increased Internet reliability and speed have contributed to an increase in the popularity of usage for these devices (see, for example, Hinton, 2020; Punchoojit & Hongwarittorrn, 2017). Additionally, increases in the accessibility and functionality of mobile phones and computers contributed to increases in duration and frequency of usage, and these findings are consistent with previous studies (see, for example, Ianos & Oproiu, 2017; Raja & Nagasubramani, 2018). Results also showed that the frequency and duration of mobile phone software application usage, including for schoolwork, increased more than computer software application usage. This finding supports previous research that showed that the popularity of mobile phone software application usage for schoolwork increased due to the mobile phone's portability, convenience, and improved support for schoolwork software applications (see, for example, Peramunugamage et al., 2019; Punchoojit & Hongwarittorrn, 2017; Sherifi & Senja, 2015).

The data also indicated that an overall an increase in student self-regulation levels was accompanied by a *decrease* in self-regulated learning. This finding contradicts previous studies that have suggested a direct relationship between levels of self-regulation and self-regulated learning (Jivet et al., 2020; Schunk & Zimmerman, 2008). A possible explanation for these contradictory results could be the lack of readiness on the part of students, including inexperience with digital learning environments, and a lack of teacher training in preparation for the delivery of lessons in an online environment. Although the COVID-19 pandemic was a unique situation, it has shown the disruption that can be caused by sudden changes to program delivery.

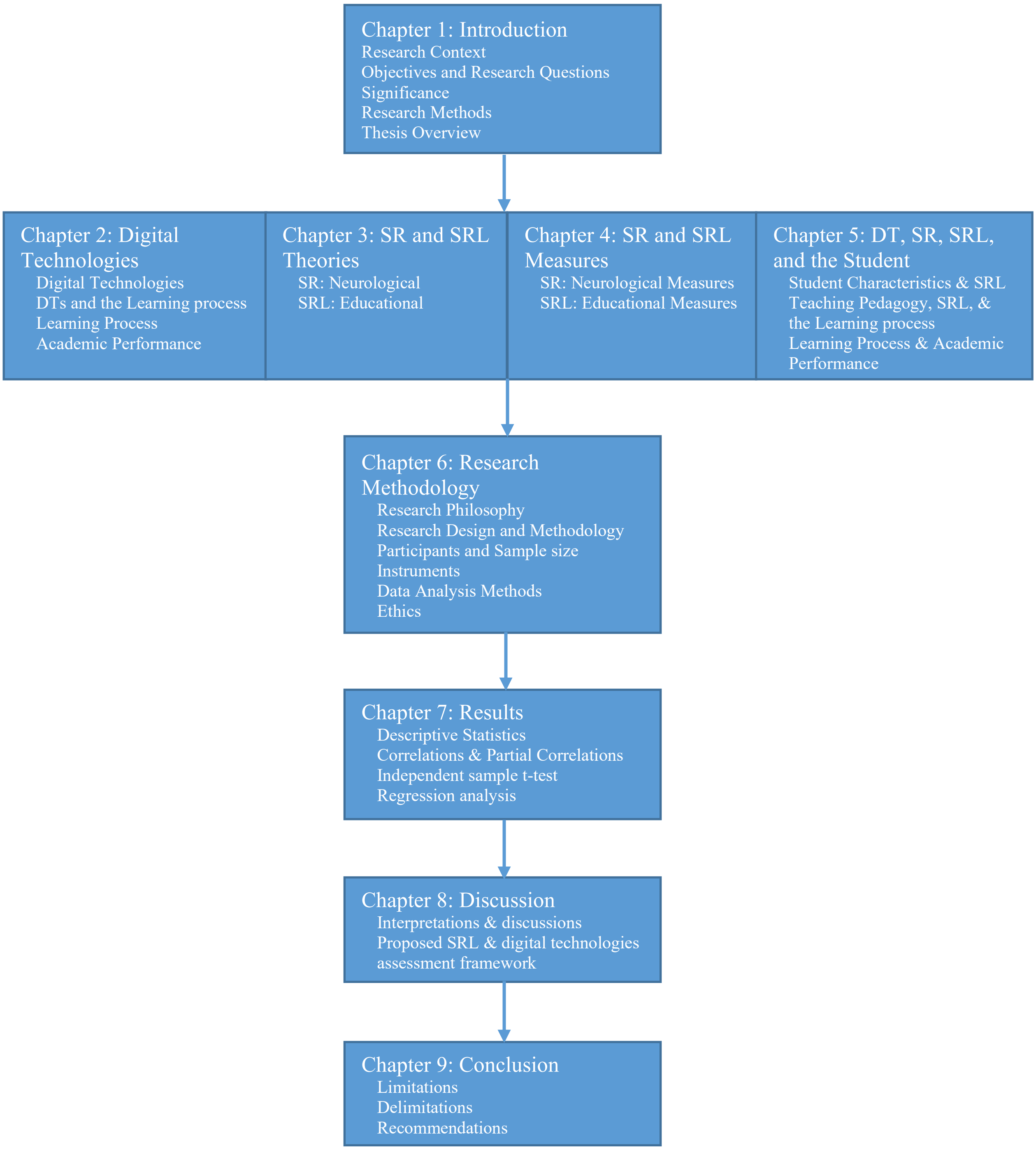
In regard to student characteristics and digital technology usage, the study indicated both positive and negative correlations. For example, a positive correlation occurred with male students and the usage of gaming software usage, although research shows that the trend is changing, with a greater gender balance being reported, and this supports recent findings by the Entertainment Software Association (ESA, 2019). An example of a negative correlation was between students characterised as not having family members with university qualifications and their usage of banking software applications. These findings are consistent with previous studies linking socio-economic status with mobile phone banking application usage (see, for example, Hayashi & Toh, 2020). These data conttribute to the literature by adding layers of analysis to the study of the relationship between student characteristics and software application usge. However, due to the complexity of such a research design, it is suggested that further studies could identify students' characteristics that are most likely to affect the use of the software applications. Finally, results showed that the schoolwork software usage scores *negatively* predicted student self-regulated learning scores, which does not align with previous research that found that the use of schoolwork software applications improved self-regulated learning (for example, Chen & Su, 2019; Lazakidou & Retalis, 2010). However, these findings could be explained by the lack of readiness of the educational provider to deliver content in an online environment, and further supports the notion that self-regulated learning is not an innate trait and can be developed through instruction and coaching (Sitzmann et al., 2009; Zimmerman, 2002).

1.9 IMPLICATIONS

This research has implications for education providers, particularly at post-secondary level, by recognising that the use of mobile technologies to access schoolwork-related software applications appears to be a continuing trend and education providers need to evaluate whether the learning experiences they provide caters for this in a quality way. Further, it is important for educational providers to establish processes to evaluate whether the learning environments support student self-regulated learning in addition to evaluating whether the student's personal environment supports self-regulated learning.

There are still many unanswered questions on how digital technologies impact student behaviour; however, it has been established that digital technologies are altering students' behaviour. Perhaps further research needs to examine whether the impacts of digital technologies are changing what we assume are established learning processes. Such research could potentially enhance how digital technologies are used to support and enhance student learning and self-regulated learning.

1.10 THESIS STRUCTURE



1.11 SUMMARY

This chapter introduced the study and identified the research objectives and research questions, the significance of the study and the research methodology used. Some key findings were presented and their implications for education providers. Chapter 2 introduces the extensive literature review, and examines changes in digital technologies, particularly hardware and software, from 2010 to 2020. This thesis is organised along traditional lines, with the exception of the extended literature review (Chapters 2, 3, 4, and 5). This is followed by Chapter 6 (Methodology), Chapter 7 (Results), Chapter 8 (Discussion), and Chapter 9 (Conclusion).

Chapter 2: Literature Review - Digital Technologies

Chapter 1 introduced the study, identified the research questions and objectives, significance, methodology, and provided an overview of the thesis. Chapter 2 introduces the four-part literature review by examining the changes in digital technologies, specifically, computer and mobile phone hardware and software applications between 2010 and 2020 (Section 2.1). The evolution of computer and mobile phone hardware, including increased processing capacity, speed, and security, have contributed to the continual development and acceptance of application software. As such, section 2.1 also examines the changing purposes of software application usage (i.e., leisure, social, financial, and academic) as well as the frequency and duration of application usage between 2010 and 2020. Also discussed in this chapter is the role of digital technologies in the student learning processes (Section 2.2). Digital technologies are inextricably linked with current educational practices, and as such the focus of this section of the literature review is on the usage of digital technologies, particularly in relation to the student learning, academic performance, engagement, and motivation.

There has been significant literature examining various elements that influence the learning process, such as pedagogical practices, learner characteristics, the student's individual learning needs and various environmental factors (Kauffman, 2015; Kurniawan, 2018; Kyei-Blankson et al., 2019). *Pedagogical practices* refer to teaching styles and approaches that are based on learning theories (Schweisfurth, 2015). *Learner characteristics* are an individual's personal, academic, social, emotional, and cognitive traits, all of which influence learning (Karimi, 2016). The *learning and personal environment* includes the physical setting in which the learning takes place as well as the emotional climate the student experiences (Vasileva-Stojanovskam et al., 2015). In order to support student learning, it is crucial to understand how these elements promote or hinder learning, not only within but also beyond the classroom (Nguyen, 2015).

Traditionally, educational discourse centred on a top-down *regulated* approach to teaching and learning; that is, teachers were regarded as experts who taught students by delivering knowledge and expertise (Hyun et al., 2017). In this teacher-centred approach to learning, the traditional teacher was an authoritative figure who taught by providing direct instruction, and the traditional student was considered to be a passive recipient of knowledge (Kohonen, 1992, as cited in Kaymakamoglu, 2018). Direct instruction, as a teaching method, is still relevant today. Lau (2019) suggested that a teacher-centred approach was crucial for instructing students who are weak in particular areas. Lau's (2019) study examined the effectiveness of different types of instruction on senior high school students' classical Chinese reading comprehension and motivation. Results of the study showed that the teacher-centred approach had a significant positive effect on reading comprehension compared to a student-centred approach. However, research has identified the need for greater student involvement in the learning process, and there has been a shift, globally, from teacher-centred learning to student-centred learning (Di Felice, 2018; Radzali et al., 2018; Torrisi-Steele, 2020). Student-centred learning not only involves the students having an active role in their learning but also requires teachers to understand individual student's learning requirements (Todorovski et al., 2015). A study by Todorovski et al. (2015) of 15 college students' responses from various countries including Poland, Finland, and Switzerland aimed to understand students' perceptions of classroom applications of student-centred learning. Results of the study showed that 82% of students reported positive benefits of student-centred learning. Students felt that they were more engaged with the learning as they could choose their own study path and felt a sense of responsibility for their learning as they were able to play an active role.

The researchers concluded that advances in digital technologies were an integral part of student-centred learning in tertiary education as they provided convenient, versatile, and functional tools that supported the organisational structure of institutions and helped support their goals and objectives. Similar results were identified in Calderon et al.'s (2020) research, which explored the relationship between a student-centred pedagogy using digital technologies and students' intrinsic motivation in a Physical Education Teacher Education (PETE) program. Results of the study (n = 110), showed that when students were provided with a choice of using digital technologies for learning activities, compared to students who were not given the same choice, their intrinsic motivation and perceived competence increased. As such, the focus of this chapter is to examine changes in the usage of digital technologies over the last decade (i.e., between 2010 and 2020), specifically, computer and mobile phone hardware and software application usage, and how these changes influence pedagogical practices, student self-regulation and self-regulated learning behaviour, learning processes, and the learning environment.

2.1 DIGITAL TECHNOLOGIES: 2010 AND 2020

Digital technologies such as computers, mobile phones, and application software are tools that generate, store, share, and process data efficiently and effectively (Kapur, 2018). Computers and mobile phones utilise application software to perform specific personal, educational, and/or business functions (Bourgeois et al., 2019; Kapur, 2018). Since the invention of the microprocessor by Intel in 1971, the advancements in digital technologies have seen a doubling of computer-processing speed and overall processing performance at a rate of approximately every 18 to 24 months (Ensmenger, 2012; Halili, 2019; Thompson & Parthasarathy, 2006). In 1965 Intel's co-founder, Gordon Moore, predicted this pattern of growth in computer processing speed, which became popularly known as Moore's Law in 1975 (Bourgeois et al., 2019). Numerous researchers and digital industry professionals believe that Moore's Law still applies today but it is slowing down and may need to be adjusted due to the advancement of microprocessors (Theis & Wong, 2017).

Changes in digital technologies from 2010 to 2020 for both computers and mobile phones have included increases in processing power, storage, and size. In 2010, the common Operating System (OS) installed on personal computers was the Microsoft Windows 7 OS (Olusanya et al., 2016). According to the Microsoft Corporation (Microsoft, 2021), the minimum computer hardware requirements needed for the Microsoft Windows 7 OS was 1 gigahertz (GHz) processor, 1 gigabyte (GB) of Random-Access Memory (RAM), 16 gigabytes of hard disk storage space, and a graphics card that contained 3D graphics API (e.g., Direct X graphics card with WDDM 1.0 or higher). Comparatively, in 2020, while Microsoft Windows was still the most common OS (i.e., 76.56% percentage of users globally), Apple's OS increased in popularity due to the growth in global sales of its desktops and laptops (Liu, 2021). Desktop computers in 2020 were more powerful as they had higher specifications compared to the 2012 desktop computers. For example, the common OS installed on desktop computers in 2020 was the Windows 10 OS (Alsop, Statista, 2021). Microsoft Corporation (Microsoft, 2021) noted that to run the Windows 10 OS, the minimum computer hardware required was a 1 (GHz) processor, 2 GB of RAM, 32 GB of hard disk (HD) storage space and a Direct X 9 graphics card. Additionally, mobile computers continued to become lighter and more powerful (Alsop, Statista, 2010). The popularity of mobile computers has overtaken desktop computers and this trend appears to be continuing (Deveci et al., 2018).

In 2012, the time of the initial data collection, the popularity of mobile computers had already commenced overtaking that of desktop computers. According to Lenhart et al. (2010), in 2010, 69% of adolescents (i.e., people aged between 10 and 18) owned a desktop computer, while 73% of adolescents owned a mobile computer (laptop or tablet). Similarly, research by Zickhur (2011) found that 70% of millennials (i.e., people born between 1981 and 1996) owned a mobile computer, while only 57% owned a desktop computer. A similar trend was evident for mobile phones: data from the Australian Bureau of Statistics showed that 79% of Australian adolescents owned a mobile phone (Australian Bureau of Statistics, 2009), and 90% of Australia millennials owned a mobile phone (Powell, 2010). In 2020 the statistics show that 80% of Australian adolescents owned a mobile phone, and 97% of Australia millennials owned a mobile phone (Granwal, 2020).

The vast functionality of computers, mobiles phones, and other digital devices can be attributed to the advancements of the Internet (Chin et al., 2019), which revolutionised the capabilities of digital technologies by providing a powerful medium for communication and information sharing (Caron et al., 2016). The Internet is commonly used for leisure, commerce, communication, education, and social media (Chin et al., 2019), and in regard to educational activities, including research and schoolwork, the Internet has provided a medium for teaching and the facilitation of learning (Alghafis et al., 2020). Additionally, with the increase in Internet reliability, speeds, and the advancements of digital technologies, educational software applications such as Learning Management Systems, which were previously only accessible via a computer, were also accessible via mobile phones (Finch et al., 2021) and therefore provided students with greater flexibility.

In 2010, the average Australian home Internet speed was 15.4 megabits per second (Mbps) (James, 2013) and was ranked 28th in the world (Vicente & Gil-de-Bernabe, 2010). Australian mobile Internet speed was 3Mbps on the 3G (also known as *third generation*) mobile network (Rannar & Mustaniemi, 2019). In 2013, Australia implemented the 4G mobile network, which offered speeds 10 times greater than 3G network (Tankovska, 2021). According to Hinton (2020), in 2020 the average Australian home Internet speed was 58.83 Mbps and was ranked 17th in the world. During this period, the 5G mobile network was rolled out in Australia, and average mobile phone Internet speeds were 67.58Mbps (Hinton, 2020). The improved reliability and speed of mobile Internet connections paved the way for the increased development of mobile phone software applications (Punchoojit & Hongwarittorrn, 2017). Punchoojit and Hongwarittorn (2017) suggested that as mobile phone software applications could be used anywhere, they were more convenient than desktop and laptop software applications. Additionally, the increase in speed and reliability of mobile connections saw an increase in the frequency and duration of mobile phone application usage (Sherifi & Senja, 2015). In 2010, the worldwide average mobile phone usage was 6.22 hours per month (Shaw, 2012). Australia had the highest social media usage, which was more than 7 hours per month (Ofcom, 2010). In 2020, the worldwide average daily mobile phone usage increased significantly, from 6.22 hours per month in 2012 to 145 minutes per day (Tankovska, 2021). Australia's social media usage, on average, was 85 minutes per day (L&A Social, 2020). Research from Tankovska (2021) shows that worldwide social media usage grew significantly from 2010 (970 million users) to 2020 (2.96 billion users). In 2010, social networking platform Facebook had the most users, and the number of users has been continuously rising (Palandrani & Little, 2020). A study by Owusu-Acheaw and Larson (2015) showed that university students mainly used social media to stay in touch with friends and family, and to keep abreast of current events. Kircaburun et al. (2019) suggested that social media usage had not only affected people's online behaviour but also their offline behaviour. For example, a study conducted by Mendoza et al. (2018) examined the use of mobile phones for learning amongst 160 undergraduate psychology students at a college in Arkansas. Results of the study indicated that the ease of social media accessibility reduced student attention spans and increased levels of procrastination.

There are, however, mixed findings in terms of the impact of social media usage and academic performance. For example, a study by Arqawi et al. (2018) into the use of social media and academic performance of college students at a Palestinian Technical University, found that an increase in social media usage could result in a decrease in academic performance, such as the application of knowledge. On the other hand, a study by Stollak et al. (2011) into social media usage of college students in a United States mid-west college, found that social media usage did not affect academic performance: that is, student academic performance (i.e., grades) were not affected, regardless of the duration of time students accessed social media.

2.2 DIGITAL TECHNOLOGIES: STUDENT LEARNING

Advances in digital technologies have played an important role in education, particularly in pedagogical practices and changing learning environments. Digital technologies are widely used in educational contexts to support the learning process by increasing access and improving relevance and quality (Raja & Nagasubramani, 2018). For example, many educators use YouTube, Spotify, and Instagram to provide students with visual and audio materials (Rueda et al., 2017). In Rueda et al.'s (2017) study, researchers tested the role of social media in the learning of 94 management students at a university in Spain, and their findings supported the hypothesis that digital technologies enabled instructors to comprehensively engage with students. The researchers concluded that social media applications amplified the relationship between teachers and students, which in turn increased academic performance and student satisfaction. A study by Jackman (2019) examined the use of YouTube as a supplementary tool for teaching in three psychology classes comprised of 25 students at a university in Trinidad and Tobago. Results of the study found that the use of YouTube supported student learning by providing the following benefits: (1) assisted students with the understanding of presented content, (2) provided visual examples that demonstrated the application of the content being discussed, and (3) supported virtual learning and collaboration. Additionally, digital technologies can support various pedagogical practices, and as discussed previously, a student-centred pedagogy has two requirements, namely: (1) the student must have an active role in the learning process, and (2) the educator understands the student's learning needs.

Studies by Pisoni et al. (2021) and Islam (2019) have identified various software applications that can support both requirements. Pisoni et al.'s (2021) study examined collaboration between university students. Participants were formed into 16 project teams and used the software application Trello to work together. Results indicated that all students found Trello useful for planning, analysing, and tracking the team's progress; however, project groups that spent 40% or more of their time planning found Trello more useful compared to groups that spent less time planning. Islam (2019) studied the use of Google Classroom, Google Drive, and Google Calendar with 60 students at an international university in Bangladesh. Results of the study, which examined student writing, speaking, listening, and reading, found that the use of Google Drive and Google Calendar helped 82% of students in scheduling and assessment submission, and encouraged a collaborative learning environment. Islam (2019), however, noted that the teacher was a key component to facilitating this learning environment.

While many of these applications were not specifically designed for educational purposes, teachers identified their usefulness as resources to support student learning (Dias & Victor, 2017). For example, Google Drive, a free cloud-based storage service, has been successfully integrated in universities to support teaching and learning by providing teachers and students with the facility to store, retrieve, and disseminate course materials anywhere and anytime (Sadik, 2017). Another example is the software application Zoom, a cloud-based video conferencing service designed to facilitate meetings, which has also been successfully utilised by many educational institutions for blended and online learning (Stefanile, 2020).

Student-centred pedagogical approaches can be an effective instructional strategy for enhancing student learning and self-regulated learning; however, they can be resource intensive (Kitiashvili, 2020). That is, student-centred approaches, and many other factors affecting today's educators such as increased number of students per class and additional administrative duties, are placing greater demands on educators. As such, many educational institutions have utilised software applications to support student learning (Akdemir & Ozcelik, 2019). The Learning Management System (LMS) is one such software application. LMSs were developed for the administration, planning, tracking, reporting, and automation of the delivery of educational and training programs (Ilyas et al., 2017; Sulun, 2018; Turnbull et al., 2019). The first Learning Management System, known as the *Teaching Machine*, was developed by Sidney Pressey in 1924 (Nguyen, 2021). Since then, numerous LMSs have been developed including *Blackboard*, *Canvas*, *Moodle*, and *Brightspace*, which are currently the most used (Al-Sharhan et al., 2020). The evolution of Learning Management Systems was a result of advancements in digital technologies, greater understanding of the learning process, research into pedagogical practices, and adaptions to changes in the learning environment (Al-Sharhan et al., 2020). For example, the LMSs *Blackboard*, *Schoolbox*, and *Moodle* allow for the integration of various software applications such as Zoom (Perez-Perez et al., 2020). Moodle is an *open-source software*: that is, its source code is publicly accessible for modification and distribution (Sheshasaayee & Bee, 2017). As such, Moodle has encouraged educators, programmers, and the public to contribute to the functionality of Moodle through the development of *plug-ins* (Costa et al., 2012). A plug-in is an add-on or extension that provides a new functionality to a software application without altering the core software application (Graham, 2014). The functionality of Moodle, as well as most LMSs currently available, are aimed at: (1) providing a medium for content delivery, (2) supporting pedagogical practices, (3) facilitating collaboration, communication, and information sharing, and (4) assisting with the provision of feedback.

2.2.1 Providing a medium for content delivery

As the online software application can be accessed via a computer or mobile phone, LMSs provide a medium to support traditional face-to-face, online, and blended content delivery (Ianos & Oproiu, 2017). Face-to-face delivery is a traditional learning approach typically in situations where the teacher instructs students in a real-time classroom setting (Tularam, 2018). Online delivery involves a learning setting provided solely through digital technologies (Mayer, 2019), and a blended delivery is a combination of both face-to-face and online instruction (Hayward et al., 2020). A study by Syaad and Hidayat (2018) examined the effectiveness of LMSs with face-to-face, blended, and online learning environments with a group of 150 Indonesian engineering students. Results of the study showed that Learning Management Systems were more effective with the engineering students in the face-to-face and online learning modes compared to a blended learning modes. As discussed in Chapter 1, the face-to-face learning setting provided more structure and guidance compared to online and blended learning settings. As such, the findings of Syaad and Hidayat's (2018) study are not surprising. Whether the delivery of the content is carried out in a face-to-face, online, or blended learning mode, it is important for the learners to be actively engaged in the learning process (Halverson & Graham, 2019; Martin & Bolliger, 2018). As discussed previously, student-centred learning requires the learner to be actively engaging in the learning process. LMSs such as Moodle have plugins to support cooperative learning, group discussions and self-evaluation (Leka & Kika, 2021).

A study by Peramunugamage et al. (2019) reviewed the effectiveness of a mobile plugin for Moodle to assist with problem-based learning for engineering students at a university in Columbo. Forty engineering students were assigned to groups and were required to work together to complete tasks. Results of their study found that the mobile plugin provided students with more control over their learning and was useful in supporting group-based activities and collaboration between students. These findings show that sound pedagogy and appropriate usage of digital technologies were useful in supporting student self-regulated learning; however, it is unclear whether the increased control and flexibility provided to students through mobile plugins would be beneficial to students with lower levels of self-regulated learning.

2.2.2 Supporting pedagogy

In selecting pedagogical strategies, educators begin by considering student learning requirements and trying to understand how to cater for these requirements (Teo, 2019). Learning is influenced by a range of factors within the student's personal environment, including student characteristics, digital technology usage behaviour and experience, and self-regulation characteristics including motivation, attitudes, attention span, stress, capacity to retain and process information, and a myriad of other behavioural traits. For example, a person's stress level or mood can be a strong inhibitor of learning (Zakaria, 2019). As such, many studies have shown the effectiveness of relaxation techniques such as listening to soothing music, playing games, or watching a movie on YouTube to destress and help with concentration (see, for example, Hu et al., 2021; Poy & Garcia, 2019; Zaidi et al., 2018).

Numerous researchers, particularly in psychology, neuroscience, and cognitive science, seek to understand how the brain learns (Kriegeskorte & Douglas, 2018; Mayer, 2017). Researchers such as Sousa (2016), and Mendoza et al. (2019) suggested that an understanding of how the brain works can provide guiding principles for teaching. As such, the theory behind *brain-based learning* is the application of teaching strategies that are based on scientific research that seeks to understand how the brain processes information and considers factors that support or prohibit this information processing (Bonomo, 2017; Handayani & Corebima, 2017; Uzezi & Jonah, 2017). A brain-based learning pedagogical approach therefore considers the factors affecting students' ability to learn in order to cater for individual learning requirements (Al-Balushi & Al-Balushi, 2018; Mekarina & Ningish, 2017; Riskiningtyas & Wangid, 2019; Yagcioglu, 2014). However, such customised learning and individual attention is extremely resource-intensive and is often unachievable due to the increasing workloads of teachers and growing class sizes (Garrick et al., 2017). As such, the support mechanisms provided by digital technologies, such as LMSs, to support teaching and learning should not be overlooked. For example, a scaffolding pedagogical approach is an effective but time-consuming approach. Scaffolding is a process by which new concepts are introduced in a staggered format to assist with learning by providing support to students on an as-needs basis and reducing this support or assistance as student competencies increase (Bransford et al., 2004; Cheng et al., 2009; Hogan & Pressley, 1997; Van Der Stuyf, 2002; Wood & Wood, 1999). A scaffolded pedagogical approach can be supported by various software applications such as gradebooks, for monitoring student progress, the use of LMS quiz plugins to evaluate student understanding, and computer-based training applications that provide tailored guidance to individual students based on their responses (see, for example, Janson et al., 2017; Kang, 2018). Group work is an important element in the learning process as it can help strengthen students' knowledge and understanding (Robinson et al., 2017; Wong, 2018). Students may be required to work in groups for problem-based learning that uses real-world simulated tasks for skill development (Phungsuk et al., 2017). Similar to a brain-based learning pedagogy, a problem-based learning pedagogy is resource-intensive and may sometimes be unachievable. For example, Li and Stylianides' (2018) investigation of the implementation of problem-based learning, in a primary school, identified that facilitators reverted to instruction-based lessons, as opposed to problem-based learning, due to the difficulty of managing the class. In this regard, Shipman and Duch (2001) suggested that for successful problem-based learning to occur in large classes or groups, more structure is required, and this can be achieved. By using selected digital technologies. Collaborative software applications such as Zoom, which can be integrated into LMSs, and were commonly used by educational institutions globally, especially during the COVID-19 pandemic, as a useful digital tool for online teaching and group work. A feedback pedagogical approach refers to a comparative process that allows students to identify errors and/or misconceptions during their learning, which in turn highlights the performance gaps of both students and instructors (Higgins et al., 2002; Ramprasad, 1983; Ryan et al., 2019; Sadler, 1998; Uribe & Vaughan, 2017). The Grades and Quiz features in most LMSs are an example of the facility of software applications to provide feedback. The Grades feature allows teachers to enter an assessment grade for students and provide feedback (Gamage et al., 2019; Kc, 2017). Additionally, some quizzes in Moodle can be created to provide automatic feedback based on the student answers (Essel & Wilson, 2017).

2.3 SUMMARY

Following the review of changes in digital technologies between 2010 and 2020 (Section 2.1), this chapter discussed the role of digital technologies in the student learning process as a medium for the delivery of material, and for supporting pedagogical practices (Section 2.2). To understand the outcomes of various pedagogical practices and the use of digital technologies in supporting student learning, the 2012 Year 9 National Assessment Plan – Literacy and Numeracy (NAPLAN) was used as a measure of student performance. The NAPLAN is a standardised series of assessments designed to measure whether students in Australia are achieving primary and secondary school curriculum outcomes. Sample Year 9

NAPLAN Literacy and Numeracy items (ACARA, 2012), which were the highest level of the NAPLAN questions, were used as a measure of student academic performance in 2012 and 2020 to compare student Numeracy and Literacy (language conventions and reading comprehension) scores. The next chapter, Chapter 3, discusses self-regulation and self-regulated learning theories, frameworks, and models. This is followed by a review of instruments to measure self-regulation and self-regulated learning (Chapter 4), and a review of the literature on student characteristics in relation to self-regulation and self-regulated learning, the learning process, and academic performance (Chapter 5).

Chapter 3 - Literature Review – Self-Regulation and Self-Regulated Learning

This chapter focusses on the role of digital technologies in student learning, particularly in self-regulation and self-regulated learning. Self-regulation and self-regulated learning are crucial traits in the learning process; students need to have a sufficient level of both in order to manage and initiate the required processes to successfully undertake and complete academic tasks. This chapter examines established theories, models, and frameworks of self-regulation as a neurological construct, and self-regulated learning as an educational construct.

A fundamental concept in self-regulation and self-regulated learning is the *primacy of self* (Zhao & Johnson, 2012). This refers to an individual's own actions and behaviours, and their control of these actions and behaviours while working towards a goal or during their engagement with a learning experience. These behaviours include self-monitoring and self-assessment; goal setting; organising and rehearsal of information; seeking help; and utilising self-motivational strategies (Bradley et al., 2017). As discussed in Chapter 2, the need for greater student involvement in learning processes has been identified in all phases of schooling and is highlighted by the shift from teacher-centred to student-centred practices.

Zarouk et al. (2020) defined student-centred learning as a pedagogical approach that requires students to take the main role in the active learning process. In their research, Zarouk et al. (2020) studied the impact of a student-centred project-based learning task on self-regulated learning with 120 university students in Portugal. Results of the study showed that various pedagogical practices, including flipped project-based learning, were able to engage and support student self-regulation and self-regulated learning behaviours. Additionally, data from their study confirmed previous research findings that showed student learning was positively impacted by pedagogies that provided support in self-regulation and self-regulated (see, for example, Bransford et al., 2004; Handayani & Corebima, 2017; Li & Stylianides, 2018; Uribe & Vaughan, 2017). Not only has it been established that pedagogical practices that emphasise greater student involvement in the learning process support student self-regulation and self-regulated learning behaviour, but research by Ramdass and Zimmerman (2011) specifically indicated that, at the college level, the practice of assigning homework tasks and encouraging students to complete these tasks can improve student self-efficacy for learning, thereby enabling them to take more responsibility for their academic performance.

Many researchers and educators have explored the affordances of various pedagogical approaches to support and promote self-regulation and self-regulated learning. For example, Matsuyama et al. (2019) examined whether changing from a teacher-centred to a student-centred approach could improve undergraduate medical students' self-regulated learning. Their study, conducted with 13 participants in a Japanese university, had one group of seven students remaining in a teacher-centred curriculum while the other group transitioned to a student-centred curriculum. Results of this qualitative study showed that student-centred learning promoted self-regulated learning by supporting: (1) the formation of individual identity as an independent learner, (2) the development of self-reflection, and (3) the use of diverse learning strategies. Although the sample size in this study was small, the results of the study are consistent with previous studies exploring the benefits of student-centred learning to promote student self-regulated learning (see Chapter 2).

Lastly, a study by Zhu et al. (2016) examined the influence of tertiary students' self-regulation, self-regulated learning, and self-control on academic learning outcomes in an Information Communications and Technology blended learning course. *Self-control* in this context refers to the ability maintain and regulate one's own impulses when challenged with internal or external pressures (Kotabe & Hofmann, 2015). The researchers found that student self-control influenced the activation of self-regulation and self-regulated learning strategies such as motivation and the use of cognitive and metacognitive strategies, which supports the performance / volitional control phase of the three cyclical phases of self-regulated learning model (Zimmerman & Moylan, 2009; as cited in Nawastheen et al., 2020). The level of student self-control influences performance and initiation of self-regulated learning strategies. Zimmerman's (2002) three cyclical phases of self-regulated learning, discussed further in Section 3.3.2, is an established model of self-regulated learning, which has been used extensively in research and practise to illustrate the processes of self-regulated learning (see, for example, Adam et al., 2017; Callan & Clearly, 2019; Callan et al., 2021; Cleary et al., 2018).

The term *self-regulation* first appeared in educational literature in the 1960s (Chen, 2002), with early studies identifying the relationship between self-regulation and the learning environment, including the level of academic rigour, and perceived safety of the learning environment. For example, Coelho and Murphey (1963) investigated the self-regulatory behaviour of high school students in the United States transitioning into a college environment, and specifically looked at how students with different levels of self-regulation coped with the more rigourous college academic learning environment. Results showed that students who managed their time performed better academically in college, and the researchers concluded that time management, a key to self-regulatory behaviour, was especially needed to deal with the diverse academic requirements of post-secondary education. While this finding may seem obvious in our current understandings of self-regulation and academic learning, it was early studies like this one that helped to initiate self-regulated learning research. This includes a later study by Bakal et al. (1968) that revealed a distinct relationship between self-regulation and student perceived safety within the learning environment: that is, a learning environment in which students felt physically and emotionally protected. Their study showed that students who perceived that they were in a safe learning environment exhibited greater self-regulatory actions and behaviours, such as help-seeking and motivation, compared to students who felt that they did not have a safe learning environment. This is one example of how the student's external environment affects their learning and self-regulated learning behaviour.

As the relationship between self-regulation and the learning environment became apparent, more research, including that of Bandura (1986) and Schunk (1985), was dedicated to promoting self-regulation from an educational or academic perspective. This led to the term *self-regulated learning* appearing in educational literature in the 1980s, such as Thomas' (1980) research into student agency and performance, and Zimmerman's (1990) research into self-regulated learning and academic performance, and this term gained prominence in the 1990s (Dinsmore, 2008). While self-regulation refers to the collective actions and behaviours required to progress toward a desired goal, self-regulated learning refers to the use of self-regulation in an educational context (Jivet et al., 2020).

3.1 SELF-REGULATION: NEUROLOGICAL CONSTRUCT

Neurological perspectives of self-regulation examine the cognitive functioning of the brain. Although the study of cognitive processes can be traced back to Aristotle (Bronstein, 2016), much of the research into cognitive development has been influenced by Vygotsky's work on the Zone of Proximal Development (ZPD) in the 1920s, and Piaget's (1936) theory of cognitive development (Semmar & Al-Thani, 2015). From a neurological perspective, self-regulation is associated with brain function, particularly with respect to psychological and behavioural control (Lewis & Todd, 2007), and involves higher-order cognitive control (i.e., executive control) over lower-order planning and executive processes (Vohs & Baumeister, 2016). Executive control functions are necessary for the cognitive control of behaviour. This includes working memory (i.e., active information being processed); memory (i.e., retrieval of stored information); attention; choice; decision making and control of emotions, which includes motivation. Neurological research is a field of neuroscience that investigates the area of the brain (i.e., prefrontal cortex [PFC]) that controls the self-regulation of thoughts and actions (Vohs & Baumeister, 2016), and as such, theoretically, self-regulation can be evaluated through clinical and cognitive neurological assessments (Graziano et al., 2015; Pandero & Romero, 2014).

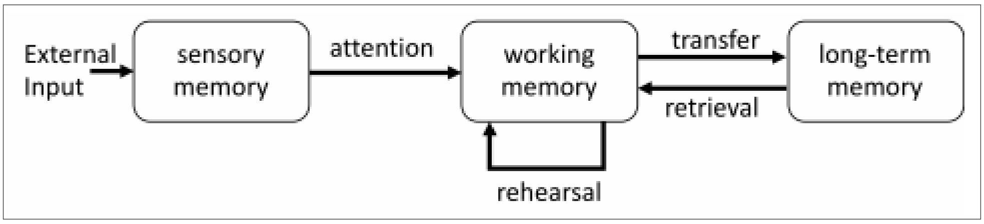
As discussed previously, self-regulation and self-regulated learning involve processes whereby individuals set goals and work towards achieving these goals, and therefore are crucial to learning and academic performance. Building on the work of Vygotsky's 1920 Zone of Proximal Development and Piaget's (1936) theory of cognitive development, the four self-regulation theories and models reviewed in section 3.1 provide a greater scientific undertanding of the brain's cognitive processing for self-regulation. Established self-regulation theories and models, from a neurological perspective, were important as they greatly contributed to the understanding of the components and processes associated with human cognition. These cognitive processes in turn were fundamental in the development of self-regulated learning theories, models, and frameworks from an educational perspective, discussed in Section 3.2.

3.1.1 Multi-Store Model

Atkinson and Shiffrin's (1968) *multi-store model* (also known as the *memory model*) conceptualises memory as three separate stages: (1) sensory stores, (2) short-term stores, and (3) long-term stores (see Figure 1). The first stage, sensory store, is activated once external stimuli (i.e., input signals) are received and registered, and these input signals are then transformed into physical and chemical signals for processing (Hong et al., 2015).

Figure 1

Atkinson and Shiffrin's Multi-Store Model (1968)



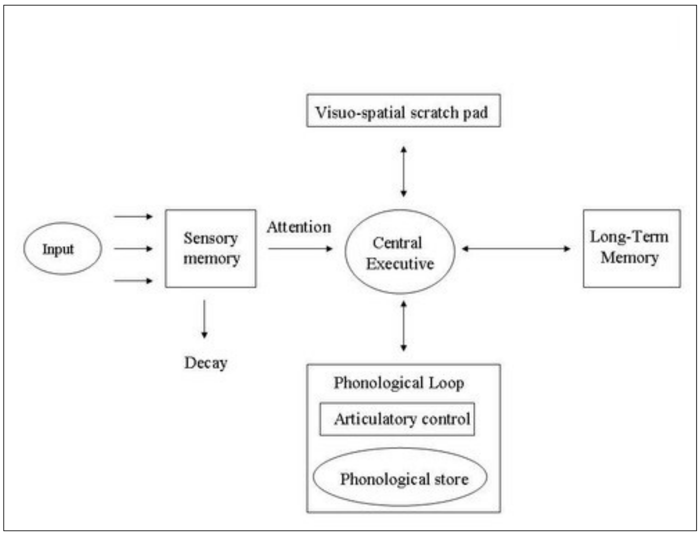
Plancher and Barrouillet (2019) explained that physical and chemical signals provide input information that is retained in sensory stores of the brain for only several hundred milliseconds before entering stage two, short-term stores. As reported by Plancher and Barrouillet (2019), information held within the short-term stores decays and completely disappears after 15 to 30 seconds if not actively maintained. Short-term stores are where the input information undergoes the processes of encoding, rehearsal, retrieving, and responding. *Encoding* is defined as "the set of processes involved in transforming external events and thoughts into both temporary and long-lasting neural representations" (Craik & Rose, 2011, p.2). Atkinson and Shiffrin (1968) described *rehearsal* as the function of maintaining a small set of items in short-term stores by repetition; and the transferral, to some degree, of any information stored in the short-term stores and long-term stores. *Retrieval* occurs between long-term stores and short-term stores. It is the process of recalling of information or events have been previously encoded and stored in long-term memory (Craik, 1983). Lastly, *responding* refers to the output, from short-term stores, of an appropriate response. The third stage, long-term stores, refers to the *retention* of information and skills for an extended period of time. This could be from a few minutes to a lifetime. Similar to short-term stores, information retained within the long-term stores decays and disappears if not reinforced (Hong et al., 2015). The *responding* process of Atkinson and Shiffrin's (1968) multi-store model is consistent with Piaget's (1936; as cited in Alahmad, 2020) theory of cognitive development, which outlines that the retention of information and skills is reinforced through three processes: (1) assimilation, (2) accommodation, and (3) equilibration. In an educational setting, learning tasks need to be planned and new learning actively reinforced with students to assist with retention. As illustrated by the multi-store model (Figure 1), the mix of short-term processing and long-term maintenance allows a person to produce sensitive and stable responses to complex stimuli / inputs. When the external environment is continuous and steady, short-term store processing is fast and produces immediate responses. However, if there is a sudden change in stimuli / input, information remembered by the long-term store is retrieved, which helps to stabilise the output. The ability to associate past experiences with current situations allows humans to take reasonable actions in response to different and changing environments (Hong et al., 2015). The multi-store model illustrates the cognitive processes associated with retaining, processing, and responding to information and other stimuli. These processes are influenced by individual characteristics: for example, a student's past experiences, stress levels, and ability to ignore distractions will influence their self-regulation and self-regulated learning behaviour, and the way the interpret and approach academic tasks.

3.1.2 Model of Working Memory

Baddeley and Hitch's (1974) model of working memory (Figure 2) consists of three distinct components: (1) central executive, (2) phonological loop, and (3) visuo-spatial sketchpad (Gray et al., 2017).

Figure 2

Baddeley and Hitch's Model of Working Memory (1974)



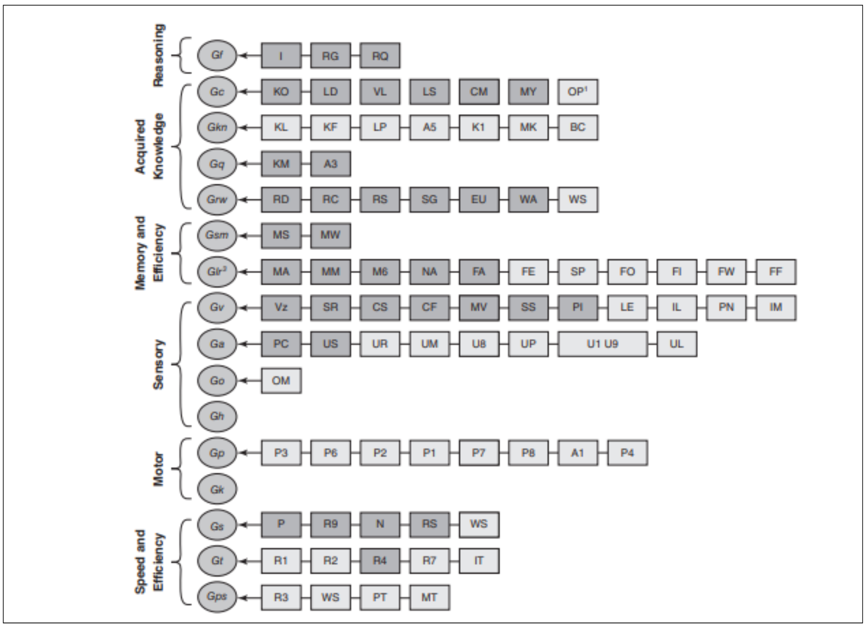
The central executive component is responsible for monitoring and coordinating activities (Salthouse, 1994). That is, it controls the performance of the other two components (i.e., phonological loop and visuo-spatial sketchpad) by allocating a limited capacity of memory to each component based on demand (Funahashi, 2017). For instance, if visuo-spatial processing becomes more demanding than phonological processing (e.g., language processing), more memory will be allocated to visuo-spatial processing. Baddeley (1996) suggested that the central executive component has a limited capacity and is responsible for attention control. Attention control is the processing related to goal-directed behaviour and the control of the complex cognition of working memory, especially in routine situations (Banich, 2009). The second component, phonological loop, is defined as a short-term store concerned with verbal and acoustic information (Yang et al., 2014). The third component, visuo-spatial sketchpad, is the visual equivalent of the phonological loop (Baddeley, 2003). This component may maintain visual codes of written words during reading (Logie, 2003), and spatial/motoric representations of the action sequences (Gathercole et al., 2008). The model of working memory illustrates the cognitive processes associated with monitoring and coordinating activities, attention control, dealing with external stimuli and retaining memory, all of which influence a person's self-regulation and self-regulated learning behaviour.

3.1.3 Cattell-Horn-Carroll Theory of Cognitive Abilities (CHC Model)

The Cattell-Horn-Carroll theory of cognitive abilities (Figure 3), also known as the CHC model, is a factor analysis–based model (Schneider & McGrew, 2018). The model is the result of an integration of John Carroll's (1993) exploratory factor analytical review of over 460 data sets, and Raymond Cattell and John Horn's (1966) literature on intelligence, and scholarly work on fluid and crystallised intelligence, that is, Gf-Gc Theory (McGrew, 2005; Jewsbury et al., 2017). The CHC model describes the major (broad abilities) and minor (narrow abilities) factors of individual cognition (Jewsbury et al., 2017). Broad abilities are defined as "basic constitutional and long-standing characteristics of individuals that can govern or influence a great variety of behaviours in a given domain" (Carroll, 1993, p. 663), whereas narrow abilities "represent greater specialisation of abilities, often in quite specific ways that reflect the effects of experience and learning, or the adoption of particular strategies of performance" (Carroll, 1993, p. 663). The 16 broad, general intelligence abilities of the CHC model are: (1) Fluid reasoning - Gf, (2) Crystallized intelligence - Gc, (3) General knowledge – Gkn, (4) Quantitative knowledge - Gq, (5) Reading and writing ability – Grw, (6) Short-term memory - Gsm, (7) Long-term storage and retrieval – Glr, (8) Visual processing - Gv, (9) Auditory processing - Ga, (10) Olfactory abilities – Go, (11) Tactile abilities - Gh, (12) Psychomotor abilities - Gp, (13) Kinaesthetic abilities - Gk, (14) Processing speed - Gs, (15) Decision speed / reaction time - Gt, and (16) Psychomotor speed – Gps. Each broad ability consists of several narrow or specific abilities (81 in total). The CHC model provides a framework for designing and evaluating an individual's educational strengths and abilities. Broad abilities include student characteristics and specific traits, and narrow abilities are developed through past experiences; both broad and narrow abilities influence student self-regulation and self-regulated learning behaviour. For example, a high-motivation student would put in the effort required to achieve a particular task. In contrast, a student who has previously had a bad experience may avoid the task due to fear of failure.

Figure 3

Carroll-Horn-Cattell (CHC) Theory of Cognitive Abilities (1993)

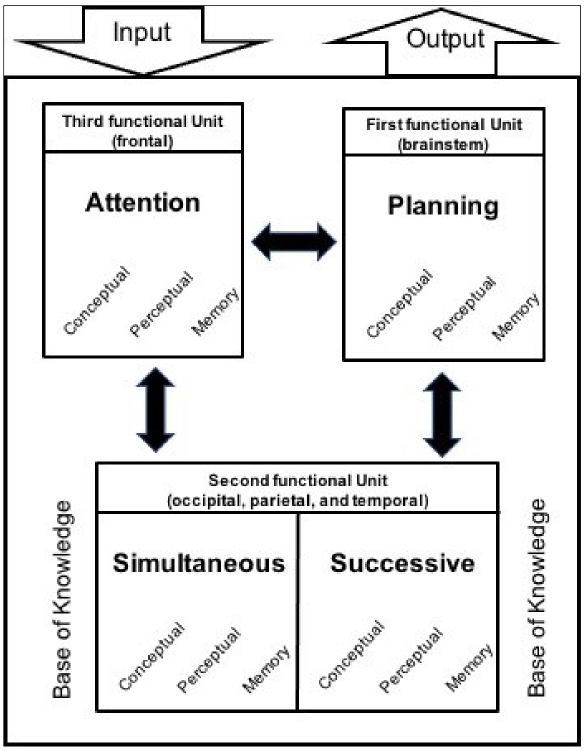


3.1.4 Planning, Attention, Simultaneous and Successive (PASS) Model of Intelligence

The planning, attention, simultaneous and successive (PASS) model of intelligence (Figure 4) was first proposed by Das et al. (1975), and was based on Luria's (1973) research into neurological functioning (Kendeou et al., 2015). The PASS model of intelligence is used to describe human cognitive processes within a framework of three functional units of the brain that are necessary for all mental activity (Das, 2004).

Figure 4

Planning, Attention, Simultaneous and Successive (PASS) theory of cognitive processing (1975)



Adapted from "Assessment of Cognitive Processes: The Pass Theory of Intelligence", Das (2010 p. 108)

The first functional unit, *planning*, which is located in the frontal lobe of the brain, provides for the regulation of behaviour such as metacognition and impulse control (Goldstein et al., 2014). The second functional unit, simultaneous and successive processing, receives, analyses and stores information (Das, 2004). During *simultaneous processing*, which is associated with the occipital-parietal areas of the brain, environmental stimuli are interpreted in relation to each other, and meaning is attained when all elements are processed simultaneously (e.g., locating a seat in a crowded room). *Successive processing*, which is associated with the frontal-temporal areas of the brain, involves interpretation of stimuli in a specific serial order (i.e., understanding language syntax). The third functional unit, *attention*, which is located in the brain stem and reticular activating system, provides the brain with appropriate levels of arousal that direct attention (Naglieri & Otero, 2018). Das' (2004) research indicated that school-based learning is particularly dependent on the third functional unit of the brain, which provides humans with the capacity to plan, question, solve problems and evaluate experience, all of which are identical to the processes associated with self-regulated learning. According to Das (2004), the PASS model of intelligence may be a valid framework to assess self-regulated learning as it links human cognition to specific neurological structures, such as intelligence and behaviour.

3.2 SELF-REGULATED LEARNING AS AN EDUCATIONAL CONSTRUCT

Nodoushan (2012) described self-regulated learning as the use of self-regulatory behaviour in an academic context to achieve a learning objective. As such, while self-regulation from a neurological perspective examines cognitive development from the perspective of brain functionality, self-regulated learning from an educational perspective examines a person's application of cognitive behaviour. In this regard, Knowles (1975) first described *self-directed learning*, also known as independent learning, as "a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes" (p. 18). Winne (2006) argued that a fundamental objective of education is to enhance students' capacity for independent learning (i.e., self-regulated learning). Self-directed learning and independent learning were previously associated with adult education, whereas the term *self-regulated learning* originated from an educational and cognitive psychology perspective (Saks & Leijen, 2013). However, these terms have both been used to describe the same behaviour: for example, as indicated in studies by Robertson (2011) and Siadaty et al. (2012). In recent literature, the term self-regulated learning (see, for example, Dontre, 2020; Wang & Zhang, 2021; Wu & Xie, 2018) is more common, perhaps because it is becoming significant across all educational levels and not just in adult learning.

From an educational perspective, self-regulated learning involves cognitive strategies such as rehearsal, elaboration, organisation, and metacognition (Broadbent & Poon, 2015). These cognitive self-regulated learning strategies are the same as the cognitive self-regulatory strategies; however, from an educational perspective the focus has been on the application of these strategies, whereas from a neurological perspective the focus has been on the application of the strategies as well as the processing behaviour of the brain. A framework by Zhao and Johnson (2012) illustrated that self-regulated learning involves the following steps: (1) comprehending, (2) planning, (3) formation of strategies, and (4) evaluating strategy effectiveness. *Comprehending* is the student's understanding of the required academic objectives and expectations. Once the student has comprehended or understood the academic requirements, they may move on to the next step, *planning*. Planning requires devoting time to the academic tasks and the formation of strategies to achieve the tasks (Yang, 2006). *Planning* and *strategy formation* are critical to the processes involved in working towards and achieving goals (Spruce & Bol, 2015). Once a plan has been devised and a strategy has been formulated, students would need to continuously evaluate the effectiveness of their strategy. *Evaluating strategy effectiveness* (i.e., self-monitoring) is necessary to determine progress in order to make any necessary adjustments to learning behaviour while working towards a learning goal (van Gog et al., 2020). Weinstein et al. (2011) reiterate the importance of the relationship between self-regulated learning and academic performance by stating that "self-regulation is both the glue and the engine that helps students manage their strategic learning on both global and real-time levels" (p. 47). A *global level* refers to the holistic approach students take, such as managing time, seeking help, and maintaining motivation, and *real-time level* described the routine actions or processes students apply in the self-regulated learning process such as managing anxiety, intrinsic monitoring, adjusting strategies and applying attention-focussing skills to achieve the desired outcome.

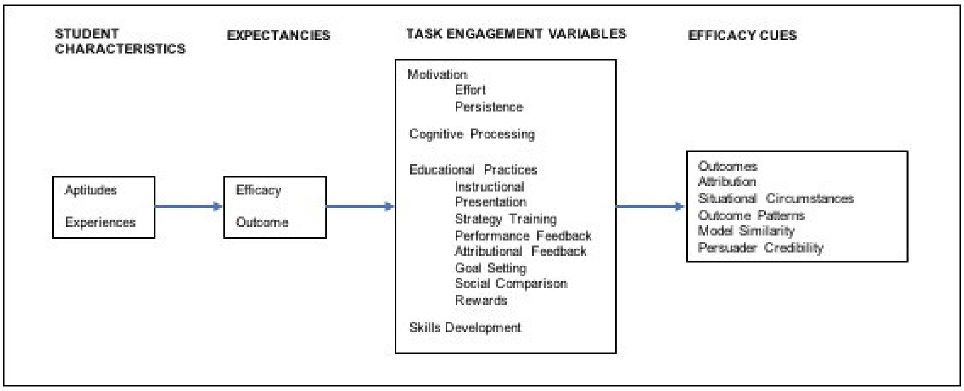
As such, from an educational perspective, a self-regulated student intentionally exerts effort toward managing and directing complicated learning activities (Tuysuzoglu & Greene, 2015). Several models of self-regulated learning have been developed over the years, including the (1) the Model of Motivated Classroom Learning of Cognitive Learning Skills (Schunk, 1985), (2) the Three Cyclical Phases model of Self-Regulated Learning (Zimmerman, 2002), (3) the Four Turning Points Model (Winne, 2005), and (4) the Comprehensive Model of Self-Regulated Learning with Web-Based Technologies (Zhao & Johnson, 2012), that underpinned this current research. This model examined the student self-regulated learning processes and also addressed the role of digital technologies and student characteristics as important influencers of self-regulated learning.

3.2.1 Model of Motivated Classroom Learning of Cognitive Skills

Schunk's (1985) Model of Motivated Classroom Learning of Cognitive Skills is based on theories of social learning, attribution, and instructional psychology (Bandura, 1982; Corno & Mandinach, 1983; Schunk, 1984). Schunk (1985) suggested that four important elements: (1) student characteristics, (2) expectancies, (3) task engagement, and (4) efficacy, influence learning and self-regulated learning, and could assist with furthering the understanding of student learning. Figure 5 illustrates the interactive relationship between all four elements within Schunk's model.

Figure 5

A Model of Motivated Classroom Learning of Cognitive Skills



Adapted from "Self-efficacy and classroom learning", Schunk (1985, 210).

The first element, student characteristics, recognises that students have various aptitudes (i.e., general abilities, task-specific skills, interests, attitudes, and personality characteristics) and prior experiences, that influence their approach to learning (Beheshitha et al., 2015; Desai et al., 2016). While each aptitude, physical or mental, can be independent of each other, aptitudes and prior experiences are interdependent (Porntip, 2018; Welch & Carter, 2020). For example, a student's literacy and numeracy ability or interest may have developed through previous encouragement from teachers or parents, which in turn may influence self-efficacy and future learning (Cleary & Kitsantas, 2017; Wang, 2015). *Self-efficacy* refers to the personal judgements of performance capabilities to accomplish a given activity, and as such affects the choice and effort directed to various activities (Bandura, 1997). As a result, aptitude and prior experiences contribute to element two of the model, *expectancies*, which includes efficacy and outcome expectations. Evaluation of an individual's efficacy (i.e., self-efficacy) is acquired from performance accomplishments, vicarious (observational) experiences, and physiological states (Bandura et al., 1996).

Self-efficacy is an important component of self-motivation (one's own beliefs about learning), and therefore crucial to self-regulated learning. Outcome expectations refers to the anticipated consequences, either positive or negative, that may result through engaging with a task (Lent, 2017). Schunk (1985) suggested that outcome expectations and self-efficacy are often related (e.g., students who perceive themselves as capable and receive a positive reaction from their teachers will demonstrate increased self-efficacy), and this contributes to element three of the model (i.e., task engagement). This third element of the model includes motivation, cognitive processing, educational practices, and skill development. Motivation initiates, guides, and maintains students' goal-oriented behaviour (Schunk et al., 2014). As such, motivation is what causes us to act, and therefore motivational beliefs exert a significant influence on student learning behaviour and vice versa (Pintrich & Schrauben, 1992). Schunk (1985) concluded that the level of student task engagement is related to student characteristics and outcomes expectations (i.e., task-value – perception of the usefulness, importance, and cost), and contributes to element four, *efficacy cue*s. This element of the model, efficacy cues, is a student's individual judgement of their own capabilities. A student's comparison of their actual performance against their perceived performance influences their self-efficacy. That is, if a student's actual performance is greater than their perceived performance, this may result in an increase in self-efficacy and their beliefs of their own capabilities. However, if a student's actual performance is lower than their perceived performance, this may result in a decrease their self-efficacy and their beliefs of their capabilities.

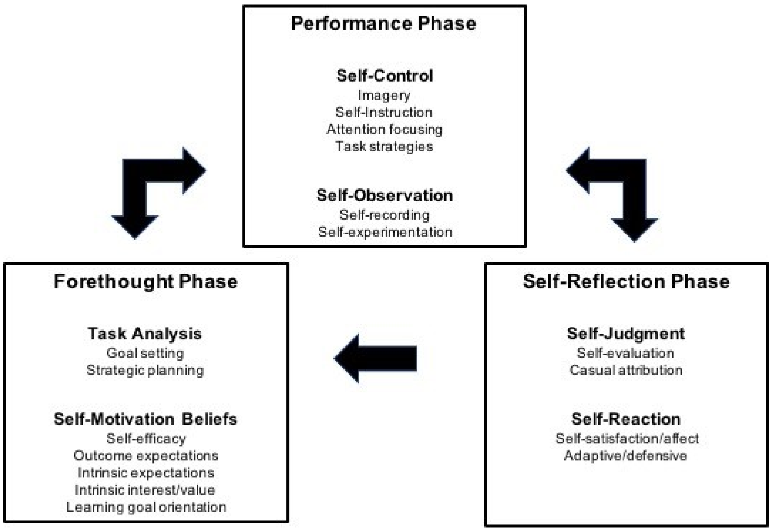
Alternatively, if a student's actual performance is higher or equal to their expectations, their self-efficacy could increase. Additionally, student self-efficacy can be influenced by feedback from teachers, parents, peers, culture, and society in general, and the students' intrinsic feedback (Ryan et al., 2015; Summers et al., 2017). The potential impact of these sources on self-efficacy may be dependent on a student's perceived credibility of the source of feedback (i.e., how reliable they perceive the feedback to be). The four elements addressed in Schunk's model influence self-regulated learning and have been impacted by the use of digital technologies. For example, studies have shown that students with previous experience or task-specific skills in certain digital technologies performed better in tasks that required the use of specific software applications compared to students who did not have the same experience (see for example, Chapter 5, Shyr and Chen, 2018). In order to address the impacts of digital technologies on student self-regulated learning, it is necessary to understand how student characteristics, behaviour, and attitudes influence their digital technologies usage.

3.2.2 Three Cyclical Phases Model of Self-Regulated Learning

Zimmerman (2002) proposed a Three Cyclical Phases Model of Self-Regulated Learning (see Figure 6) and explained that these three phases are crucial to self-regulated learning.

Figure 6

Three Cyclical Phases Model of Self-Regulated Learning



Note. Adapted from "Becoming a self-regulated learner: An Overview", Zimmerman, (2002, 67)

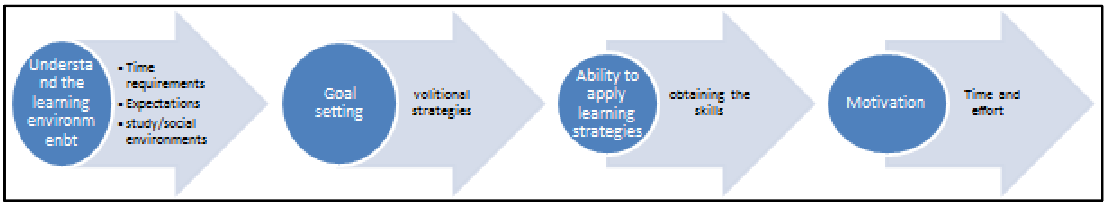
The first phase, *forethought*, which initiates the cyclical process, includes self-motivation and task-analysis processes such as goal setting and strategic planning. Self-motivation stems from a student's beliefs about learning, including self-efficacy beliefs, outcome expectation, intrinsic interest/value, and learning goal orientation (Bandura, 1997). The second phase, *performance*, involves self-control and self-observation. Self-control refers to the use of specific strategies such as imagery, self-instruction, attention focusing, and task strategies (Alvi et al., 2016). Self-observation includes self-monitoring, time management, and study habits (Swendeman et al., 2015). The third phase, *self-reflection*, includes self-judgement and self-reaction. Self-judgment involves self-evaluation, which is a comparison of self-observed performance against a performance standard (Miller, 2009; Shen et al., 2008) and causal attribution, which is a measure of success and failure (Hareli & Hess, 2008). Self-reaction can either be defensive or adaptive, depending on an individual's performance evaluation (Fauzi & Widjajanti, 2018). Defensive reactions include withdrawing or avoiding opportunities to learn (Moos & Azevedo, 2006), while adaptive reactions include changing learning strategies or behaviours to increase the effectiveness of learning (Artino & Stephens, 2009). Digital technology usage and teachers' pedagogical practices impact students' self-regulated learning behaviour at each of the phases illustrated in Zimmerman's model. For example, digital technologies, that utilise software applications to provide students with a means for self-assessment in turn can influence student self-efficacy beliefs (see for example, Chapter 5, Chen and Su, 2019), in this regard, the self-regulated learning behaviours identified in each of the phases of Zimmerman's model may be used as a guide for identifying appropriate digital technologies to support various self-regulated learning behaviour. In regards to pedagogical practices, such as scaffolding, and the provision of feedback, studies have shown that digital technologies can support a scaffolding pedagogy by providing student with assistance on an as need basis (see for example, Chapter 5, Perez-Sanagustin et al., 2020). In order to provide a holistic approach to supporting student self-regulated learning, it is important to not only address student individual behaviours for self-regulated learning but also to identify the pedagogical practices and usage of digital technologies in the learning setting that influence student self-regulated learning behaviours.

3.2.3 Four Turning Points Model

Winne's (2005) Four Turning Points Model illustrates four specific actions and behaviours that are critical for learning and self-regulated learning (Figure 7). Winne (2005) concluded that these specific actions and behaviours, called *turning points*, are necessary for achieving academic learning goals.

Figure 7

Four Turning Points Model



Note. Adapted from "Key Issues in Modelling and Applying Research on Self-Regulated Learning", Winne (2005, p. 235).

Turning Point 1 – understand the learning environment, refers to the need for students to be aware of the factors (e.g., time requirements, course expectations, and environmental influences) that could affect their ability to achieve academic success. Turning Point 2 – goal setting, refers to the identification of academic goals and the development of volitional strategies for achieving these goals. According to Turner and Husman (2008), volitional strategies support students' motivation similar to the ways that learning strategies and self-regulation of learning activities do (e.g., planning, monitoring, understanding) support student learning (Corno, 2004; Husman et al., 2000; McCann & Turner, 2004; Snow et al., 1996). Therefore, volitional strategies may work in tandem with student academic self-regulation processes. For example, Turner and Husman (2008), suggest that by using approach or avoidance self-talk (e.g., reminding oneself of past successes or thinking about the outcomes of potential failure) as well as anxiety-reducing strategies (e.g., relaxation techniques such as deep breathing or listening to calming music), students can garner the motivation they need to refocus their attention and commitment to the learning task. Student cognitive engagement with course materials can be initiated or maintained by using volitional strategies to support motivation, (e.g., Heckhausen & Kuhl, 1985; McCann & Turner, 2004). According to Boekaerts and Corno (2005), "accessible volition strategies function something like the switching track of a railway system; by turning all other lights to red they can keep students on the mastery track or re-route them toward goals for productive mastery in the face of detracting environmental cues." (p. 206).

Turning Point 3 – ability to apply learning strategies, refers to obtaining the necessary skills needed to progress towards achieving an academic goal identified in the previous turning point. Turning Point 4 – motivation, refers to the exhibiting of necessary behaviours required for the commitment of time and effort to pursue an academic goal. The four turning points are arranged in a linear pattern and shows that each subsequent turning point cannot commence until the previous one has been satisfied. Winne (2005) suggested that the learning behaviours and actions of the Four Turning Points model occur within each of the Zimmerman's (2000) Three Cyclical Phases Model, and can be thought of as a continuation of Zimmerman's (2002) self-regulated learning model.

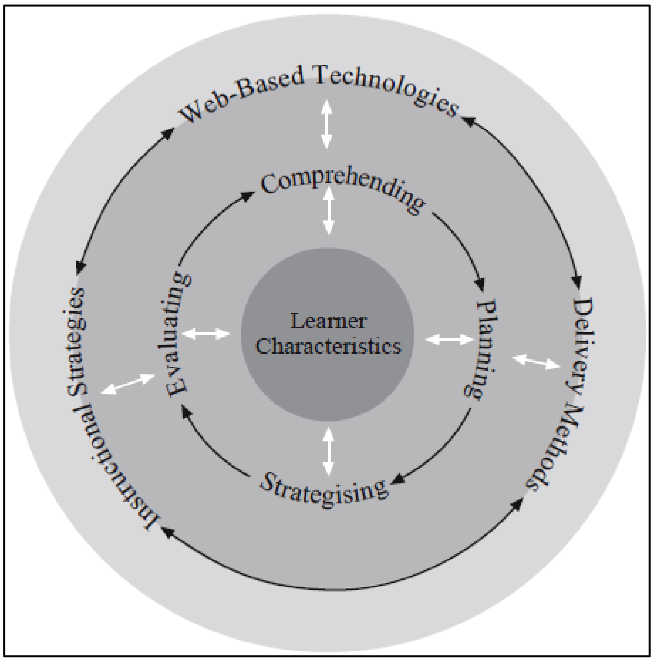
The turning points illustrated in Winne's (2005) model of self-regulated learning are important as they identify the necessary triggers for self-regulated learning processes to procced; that is, the initiation of each turning point can proceed only when the previous turning point has been satisfied. Winne's (2005) Four Turning Points Model is therefore important for this study, not only is it important to understand the activation mechanisms for the initiation of each of the self-regulated learning processes, it is also important to identify how the use of digital technologies can further support these activation mechanisms in students. For example, the first Turning Point in Winne's (2005) model is *Understanding the Learning Environment*, this turning point can be supported by the use of digital technologies to provide timely and accessible information about the required learning task.

3.2.4 Comprehensive Model of Self-Regulated Learning with Web-Based Technologies

Zhao and Johnson's (2012) Comprehensive Model of Self-Regulated Learning with Web-Based Technologies (see Figure 8) was a result of research into established self-regulation, self-regulated learning theories, and digital technology usage in education, and proposed that self-regulated learning behaviour is a consequence of digital learning environments and learner characteristics. The model consists of three connected layers: (1) digital learning environments; outer circle, (2) self-regulated learning; centre circle, and (3) learner characteristics; inner circle, and has been cited in subsequent self-regulated learning research in face-to-face learning environments that utilise digital technologies, in online and blended-learning settings (see, for example, Hallam, 2015; Ishikawa et al., 2015; Perera, 2020; Sykes & Roy, 2017).

Figure 8

Comprehensive Model of Self-Regulated Learning with Web-Based Technologies



(Zhao & Johnson, 2012 p.5)

The *digital learning environment*, outer circle of the model, includes web-based technologies, delivery methods, and instructional strategies. Winne (2006) stressed that learning requires the use of tools (e.g., cognitive operations and physical devices) and materials (e.g., text, diagrams, video, and audio). As such, Zhao and Johnson (2012) proposed that web-based technologies provide the digital tools for facilitating self-regulated learning. Examples of web-based technologies include software applications, such as Learning Management Systems, computer-based assessment, computer-based training, and a multitude of collaboration software (e.g., Zoom, Google Documents, and Microsoft Teams) (Binyamin et al., 2019; Shute & Rahimi, 2017). Zhao and Johnson's (2012) model illustrates that web-based technologies are platforms that facilitate the provision of instructional strategies through various delivery methods (i.e., hardware and software applications). The center-circle of the model illustrates the student self-regulated learning processes of comprehending, planning, strategising, and evaluating. Zhao and Johnson (2012) stated that these self-regulated learning processes are enhanced through the use of web-based technologies to facilitate the delivery of instructional strategies. That is, web-based technologies need to be embedded into the pedagogical design of self-regulated learning with a focus on student task comprehension, planning, strategising, and evaluating the effectiveness of that plan. Lastly, the inner circle of the model shows that *learner characteristics* influence the application of self-regulated learning processes and the use and acceptance of web-based technologies.

Zhao and Johnson's (2012) research identified the significant role of web-based technologies in the learning environment, particularly for student self-regulated learning. This current study seeks to add to this research, developing their model of self-regulated learning by expanding on the factors influencing student self-regulated learning. That is, it will provide a holistic approach to supporting student self-regulation and self-regulated learning. While Zhao and Johnson (2012) identified student characteristics as an influencing factor on self-regulated learning, this current study seeks to investigate additional factors affecting student self-regulated learning including :(1) student characteristics, (2) digital technology usage, and (3) self-regulation. Additionally, in Zhao and Johnson's (2012) model, the digital learning environment, referred to in this study as the *learning setting*, is only one factor of the learning environment that needs to be considered in order to support student self-regulated learning. As such, additional factors of the learning environment provided by an educational institution, including *pedagogical practices*, *digital technology usage*, and *learning setting* (face-to-face, online, and blended) need to be considered in order to provide a holistic approach to supporting student self-regulated learning.

The importance of the digital technologies in supporting student self-regulated learning has been established (see for example, Adeyinka & Mutula, 2010; Pollard et al., 2010; Sahin Kizil & Savaran, 2016; Tsai, 2009; Venkatesh et al., 2003), and the capacity of digital technologies to support self-regulated learning behaviours by facilitating comprehension of academic learning requirements, guiding planning activities, promoting the formation of strategies, and encouraging ongoing evaluation of effort has been recognised. Several studies have shown positive effects between digital technology usage and student self-regulated learning; for example, Sahin Kizil & Savran (2016) focused on the use of digital technologies and self-regulated learning outside formal instructional settings (i.e., away from the classroom), and investigated the relationship between digital technology usage and self-regulated learning in 777 English as a Foreign Language students at a Turkish university. In particular, the researchers examined the use of digital technologies and self-regulated learning in terms of goal commitment, affect, social connections, resource regulation, metacognitive skills, and culture learning. Data were collected through student responses to a 28-item Likert scale self-report survey, and the researchers found that most of the participating students had a positive association with usage of digital technologies, application of self-regulated learning skills, and goal achievement. Additionally, results of the study showed that 75.2% of students reported that they relied on the digital technologies for *affect regulation* (e.g., regulation of emotions, moods, and feelings), and *resource regulation* (e.g., regulation of resource management and time management). However, results showed that fewer positive attitudes were reported by students in relation to the usage of digital technologies for facilitating social connections, metacognitive skills, and culture learning.

However, not all studies of digital technology usage and student self-regulated learning have found digital technologies to be effective for promoting student self-regulated learning. One such example is a study by Yot-Domínguez and Marcelo (2017) into university students’ use of digital technologies (e.g., Internet information searching and instant communication tools). The results of the study indicated that students, even those who frequently used digital technologies, did not tend to use the digital technologies for self-regulated learning, nor did they show any increase in self-regulated learning strategies while using these technologies. The researchers, however, reported that this might be due to the teachers in the study not requiring or encouraging the use of digital technologies for self-regulated learning. This conclusion by the researchers is very significant, as discussed in Chapter 3 and 5, as the perception of teachers' digital technology usage and provision of self-regulated learning guidance are important factors influencing students' beliefs about and their acceptance of the technologies, as well as on their self-regulated learning behaviour.

The findings of the study are in line with Zhao and Johnson's (2012) view on web-based technologies and self-regulated learning; that is, the researchers suggested that web-based technologies can only promote self-regulated learning if they are designed and implemented for the purpose of facilitating and supporting self-regulated learning (i.e., comprehending, planning, strategising, and evaluating). In this regard, web-based technologies by themselves do not promote self-regulated learning; instead, web-based technologies may assist in promoting self-regulated learning by supporting instructional strategies and enhancing the delivery of these instructional strategies. Maderick et al. (2016) supported this view by stressing that courses that only focus on technical skills and not on the pedagogical aspects of digital technologies are repeatedly reported as being inefficient in supporting student learning and self-regulated learning. As such, the holistic approach taken in this current research aims to address the issues related to inefficient or ineffective digital technology usage in supporting student self-regulated learning by identifying the factors that need to be addressed from the perspectives of a student's personal environment and an educational provider's learning environment.

3.3 SUMMARY

This chapter reviewed self-regulation from a neurological perspective (Section 3.1) and self-regulated learning from an educational perspective (Section 3.2). According to Cruz-Cunha and Moreira (2011) and Delgado et al. (2015), in education, digital technologies are the digital resources such as hardware (e.g., electronic devices), software (e.g., programs and application) and infrastructure (e.g., networks, protocols and procedures) to support educational goals and foster interaction. Additionally, Winne (2006) suggested that learning requires the use of tools (e.g., pen and notepad) and materials (e.g., course notes). In essence, just like a pen, notepad and course notes, educational digital technologies such as note taking software and Learning Management Systems are tools that support and facilitate learning, self-regulation, self-regulated learning, academic performance, and the changing learning environment. Further, the review of Zhao and Johnson's (2012) Comprehensive Model of Self-Regulated Learning in Web-Based environments (Section 3.2) identified the interrelated factors affecting student learning and self-regulated learning. For example, self-awareness, an important factor in decision making, influences an individual's self-regulated learning actions and engagement with digital technologies. Student personal factors and external factors, such as pedagogy, were noted as important influences on student self-regulation, self-regulated learning, and digital technology usage. As such, in order to support student self-regulated learning, not only is it important to understand the level of self-regulation and self-regulated learning exhibited by a student, but it is also equally necessary to have an understanding of the capacity of an educational provider to support student self-regulated learning.

In this regard, the following chapter (Chapter 4) examines established instruments to measure self-regulation and self-regulated learning in students. This is followed by Chapter 5, which reviews the literature on student characteristics, pedagogical practices, and usage of digital technologies of educational providers to support student self-regulation, self-regulated learning, learning process, and academic performance.

Chapter 4 Literature Review: Instruments for Measuring Self-Regulation and Self-Regulated Learning

In Chapter 3, a review of the literature established the importance of self-regulation and self-regulated learning in the learning process and for academic achivement. Additionally, as digital technologies, pedagogical practices, students' personal environment, and the learning environment were identified as factors influencing student self-regulation, self-regulated learning,and academic performance, an accurate measurement of student self-regulation and self-regulated learning is needed. The ability to reliably measure student self-regulation and self-regulated learning is a vital first step for determining various approaches in supporting and promoting learning. Measures of self-regulation from a neurological perspective, including the Cognitive Assessment System, Tower of Hanoi, Tower of London, Wisconsin Card Sorting Task, and Wechsler Scales, have typically been used to assess cognitive skills, including memory, attention, processing speed, problem-solving, and language functions (Harvey, 2012). Measures of self-regulated learning from an educational perspective have traditionally been via self-report instruments such as the Motivated Strategies for Learning Questionnaire, Learning and Study Strategies Inventory Scale, Academic Self-Regulated Learning Scale, Online Learning Values and Self-Efficacy Scale, and the Online Self-Regulated Learning Questionnaire (Roth et al., 2016). As suggested by Roth et al. (2016) and McCoy (2019), self-report instruments are more suitable than observational assessment methods for measuring self-regulated learning in tertiary education environments as they are less time-consuming and have good psychometric properties in relation to responses from adults and older children, and as such, they are the most frequently used measure of self-regulated learning.

This chapter of the literature review is divided into two sections: Section 4.1 examines established instruments used to measure self-regulation from a *neurological* perspective, and Section 4.2 examines established instruments used to measure self-regulated learning from an *educational* perspective. Both the self-regulation and self-regulated learning instruments discussed in this chapter are assessed against various criteria in order to determine their suitability for the current study.

4.1 MEASURES OF SELF-REGULATION: NEUROLOGICAL PERSPECTIVE

From a neurological perspective, that is, a study of cognitive abilities of the brain, researchers use a variety of measures for assessing self-regulation, including observational methods, self-reports, other reports (e.g., reports from teachers and parents), and direct assessment such as tests (McClelland et al., 2010; McCoy, 2019). *Observational* assessment is one of the newest measures for assessing self-regulation and therefore is less studied than the other measures mentioned (McCoy, 2019). Observational assessment occurs when an assessor observes a participant as they engage in an activity or task, rates the participant's skills, and provides feedback (McCoy, 2019). Observational assessment generally takes longer than other assessment methods as it requires both an observation period and the time to complete a report (McCoy, 2019). However, as opposed to other offline measures, such as questionnaires and interviews administered either before or after task performance, observations do not rely on introspection with the associated validity problems (Veenman & van Cleef, 2019).

Self-report assessment requires the participants themselves to report on their self-regulatory behaviour in a particular situation, while other reports require other adults to reflect on the participants' self-regulatory behaviour in a particular situation (McCoy, 2019). Self-reports and other reports differ from observational assessment as the researcher relies on the recollection of the participant instead of directly observing a participant. McCoy (2019) adds that self-reports and other reports generally require less time than observational assessment, yet generally take longer to complete than direct assessment. Additionally, psychometric evidence such as test–retest reliability, internal consistency, factor structure, and invariance of adult reports and reports from older children, is largely positive, which implies they are a valid and reliable method of data collection (Gioia et al., 1996; Rothbart et al., 2001; Sherman & Brooks, 2010; Sulik et al., 2010; as cited in McCoy, 2019). Lastly, methods of direct assessment, including tests such as the CAS planning subtest, are tangible, objectively scored, and usually assessed based on a standard criterion. Zelazo et al. (2016) noted that direct assessments were originally developed as laboratory and clinical research tools; however, as they are relatively quick to administer, an increasing number of these assessments are being used in the natural environment and practical work situations, such as studies in the field.

As discussed in Chapter 3, self-regulation from a neurological perspective is the higher-order cognitive control of lower-order processes responsible for planning and execution of behaviour (Voh & Baumeister, 2016). The following sections examine five commonly-used direct neurological assessments of self-regulation: (1) Cognitive Assessment System, (2) Tower of Hanoi, (3) Tower of London, (4) Wisconsin Card Sorting Task, and (5) Weschler's Scales of Intelligence. Due to the long history of laboratory and clinical research tools, the pychometric properties of direct assessment tools have strong evidence supporting their reliability, validity, and metric variance (Zelazo et al., 2016). The suitability of each of these five instruments for use in this study was evaluated based on the constructs that the instrument was designed to measure, ease of online administration, time requirements for administration, and ease of use for the researcher and participants.

4.1.1 Cognitive Assessment System (CAS)

Naglieri and Das (1997) developed the Cognitive Assessment System (CAS) that consists of 12 scales and is based on the Planning, Attention, Simultaneous and Successive (PASS) model of cognitive processing for individuals between the age of 5 and 18 years. Das (1984) explained that the PASS cognitive processing model links human cognition to specific neurological structures. This means that individuals may adjust cognitive processes, including cognitive development, executive functions, monitoring, and adjustment. Cognitive models, such as the CAS, address the relationship between brain functions and aspects of self-regulation including planning and problem solving (Murry et al., 2019). According to Strauss et al. (2006, as cited in Janssen et al., 2010) and Vakil and Heled (2016), the CAS could be used as a measure of self-regulated learning in traditional face-to-face, fully online, and blended learning settings. As this study is focused on the planning aspect of self-regulation, only the planning scale of the PASS model is discussed.

The planning scale of the CAS model measures the participant's cognitive processing ability to create a plan of action, apply the plan, verify that an action conforms to the original goal, and modify the plan as needed (Goldstein & Beers, 2003). The CAS planning scale is composed of three subtests: (1) Planned Codes, (2) Planned Connections, and (3) Matching Numbers. The Planned Codes subtest requires participants to identify a matching code for each letter that is provided. The Planned Connections subtest requires participants to connect a series of numbers or letters in a correct sequence as quickly as possible within a time limit: for example, 1-A-2-B-3-C and so forth. Scores are calculated based on time taken and correctness. The Matching Numbers subtest presents participants with a sequence of similar numbers. Participants are required to identify and underline the two numbers that are exactly the same; for example, as shown in Figure 9, the number that is repeated is 6982 (i.e., B and D should be underlined). According to Johnson et al. (2007) the Matching Numbers tasks become increasingly difficult as the length of number increases (i.e., from one digit to seven digits).

Figure 9

Number Matching Subtest Example (1997)

9682	6982	6928	6982	9628	6962
A	B	C	D	E	F

Adapted from "Planning Subtest: Naglieri and Das (1997 p.8)

According to Natur (2009), the internal reliability of the CAS standard scale ranges from a low of .95 to a high of .97, the Planning and Attention scales are both .88, and the Simultaneous and Successive scales are both .93. The full-scale scores range from .85 to .90 with average reliabilities of .85 for the scales, and subtest reliabilities range from .75 to .89 (Naglieri, 2001). A study by Woodcock et al. (1990) examined the extent to which the CAS full-scale scores and the four PASS processing scores correlate with various types of achievement in children between five and 17 years of age. This study showed that the Pearson product–moment correlation between the CAS full scale and the Woodcock-Johnson revised skills cluster was .71 for the standard and .70 for the basic CAS scores, providing evidence for the construct validity of the CAS (Naglieri & Rojahn, 2004).

Performance on each of the CAS subtests, that is, planning, attention, successive and simultaneous processing, is measured in terms of speed and efficiency in completing each subtest (Das, 2004). The speed and efficiency in completing each subtest is assumed to assess an individual's strength in terms of their capacity to plan and solve problems (Johnson, 2008). Generally, such measures do not require verbal skills or awareness by the individual of their use of the cognitive capacity under examination. Such cognitive measures are typically scored in terms of objective characteristics of performance (e.g., time to completion and number of errors), and the objective scoring criteria of these instruments overcomes many of the limitations of assessments by self-report instruments. For example, success on CAS planning subtests requires a person to develop a plan of action, evaluate the value of the method, monitor its effectiveness, and revise or reject a previous plan as the task demands change, and control the impulse to act without careful consideration (Naglieri & Otero, 2018). As such, according to Johnson (2008), the CAS planning subtest may be able to assess self-regulated learning in an academic context (i.e., self-regulated learning in a teaching and learning environment). Johnson's (2008) study measured cognitive planning by adapting Das' (2004) Cognitive Assessment System Planning Number Matching subtest for group administration. The Matching Numbers subtest requires similar processes to self-regulated learning, that is, it requires an individual to (1) create and apply a plan of action, (2) evaluate, and (3) modify the plan as needed. In this regard, Johnson (personal communication, October 27, 2012) posited that these are the same actions and behaviours for self-regulated learning, and as such, the CAS Matching Numbers subtest may theoretically be able to assess self-regulated learning as well or perhaps better than the Motivated Strategies for Learning Questionnaire (MSLQ).

4.1.2 Tower of Hanoi

The Tower of Hanoi, another measure of cognitive planning, first published in 1883 by Edouard Lucas as a mathematical puzzle and requires an individual to reach a goal through the execution of a series of moves (Hinz, 1992). The Tower of Hanoi is a complex problem-solving task that is popular in clinical settings and is used in neuropsychology as an accepted measure of executive functioning associated with the prefrontal cortex of the brain (Schiff & Vakil, 2015; Welsh & Huizinga, 2005). It is agreed that performance of the task requires the activation of cognitive processes, specifically, task performance, which includes planning, executing, monitoring, evaluating, working memory, and inhibition (Ruiz-Diaz et al., 2012; Schiff & Vakil, 2015). The puzzle provides a quantitative index of planning ability because of the number of steps that are involved in the solution (Bishop et al., 2001; Donnarumma et al., 2016).

4.1.3 Tower of London

The Tower of London was originally developed by Shallice (1982) as a modification of the Tower of Hanoi (Nitschke et al., 2017). The Tower of London is one of the most widely-used tests for assessing executive functioning in clinical and experimental neuropsychology (Boccia et al., 2017; Michalec et al., 2017; Uterrainer et al., 2019). The Tower of London measures: (1) planning ability, (2) visuo-spatial problem-solving, and (3) capability to adhere to a set of rules, all of which are activities associated with the prefrontal cortex of the brain (Boccia et al., 2017). Several versions of the Tower of London have been developed over time and differ in a number of aspects, such as physical appearance of the apparatus (real vs. computer simulation), administration, scoring, time-limit and number of items (Berg et al., 2006). These include the (1) Five-Disc ToL, (2) Tower of London Revised (ToL-R), (3) Tower of London-Drexel (ToL-DX), and (4) Tower of London-Frieburg (ToL-F).

4.1.4 Wisconsin Card Sorting Task

The Wisconsin Card Sorting Task (WCST) was originally developed by Berg (1948) for assessing abstract reasoning and cognitive flexibility (Tanabe et al., 2014). The WCST is consistently utilised in neuropsychology as a valid and reliable measure of executive functioning and is used for both diagnostic and research purposes with individuals aged five to 89 years old (Baron, 2018). Two limitations have been identified in relation to the test: (1) very little is known about the reliability of the WSCT, and (2) as reliability relates to the sample from which it is estimated, this means the score cannot be easily generalised (Kopp et al., 2019). As with the CAS Planning subtests, the Tower of Hanoi and the Tower of London, the Wisconsin Card Sorting Task measures executive functioning including planning and problem solving.

4.1.5 Wechsler Scales

The Wechsler Scales are used to determine "the aggregate or global capacity of an individual to act purposefully, to think rationally, and to deal effectively with his (or her) environment" (Wechsler, 1939, p. 3, as cited in Benisz et al., 2015). First introduced as the Wechsler-Bellevue Intelligence Scale by Dr David Wechsler in 1981 (Wechsler, 1995), it has since been developed into many different versions over time, including the Weschler Adult Scale of Intelligence Fourth Edition (WAIS-IV; see Wechsler, 2008a) and the Wechsler Individual Achievement Test Third Edition (WIAT-III; see Pearson, 1990). The WAIS-IV is currently the latest edition of this scale, and according to Canivez (2013) and Kuo and Eack (2020), the WAIS-IV scale is used to assess cognitive abilities, including subtests for: (1) working memory, (2) digital span, and (3) arithmetic.

Summary of Neurological Instruments

The criteria for instrument selection were: (1) measures planning and problem solving, (2) suitable for online administration, (3) appropriate time requirements for data collection, 30 minutes was allowed for the study, and (4) ease for group administration and automated scoring. All instruments evaluated in this chapter assess cognitive functions *planning* and *problem solving*; however, the CAS Matching Numbers subtest was selected for this current research as it met all of the criteria for this study (see Table 1). Similar to Johnson's (2008) study, the age of the participating pathway college students, discussed further in Chapter 6, would most likely exceed the eight to 18 age range reported on the Matching Numbers subtest; however, this was not considered an issue as the students were not being compared with study norms. The second edition of the CAS (CAS2) developed by Naglieri et al. (2014), was not available at the time of the first data collection in 2012 and, in order to maintain instrument consistency, was not used in 2020. The Tower of Hanoi and the Tower of London were not selected due to the difficulties of group administration and scoring, and online administration using the existing pathway college Learning Management System, Moodle. The WSCT was not selected due to difficulty of online administration, group administration, and the time-consuming nature of explaining the test to individuals. The WAIS-IV was not selected as it did not meet any of the selection requirements for the study.

Table 1

Cognitive Assessment System Planning Subtest Selection Criteria

	Cognitive Assessment System Planning subtests				
Criteria	Measures: Planning and problem solving	Suitable for online administration using College Learning Management System (Moodle)	Appropriate time requirements	Ease of group administration	Ease of automated scoring
Planned Codes (PCd)	✓	×	✓	×	×
Planned Connections (PCn)	✓	×	✓	×	×
Number Matching (Mn)	✓	✓	✓	✓	✓
Tower of Hanoi (ToH)	✓	×	×	×	×
Tower of London (ToL)	✓	×	×	×	×
Wisconsin Card Sorting Task (WCST)	✓	×	×	×	×
Weschler Adult Scale of Intelligence Fourth Edition (WAIS-IV)	×	×	×	×	×

4.2 MEASURES OF SELF-REGULATED LEARNING: EDUCATIONAL PERSPECTIVE

Many researchers (see, for example, Broadbent & Poon, 2015; Carson, 2011; Esnaashari et al., 2020; Puzziferro, 2008) have administered traditional self-regulated learning instruments in digital learning environments. For example, Puzziferro (2008) investigated the relationship between self-regulated learning and academic grades of online liberal arts students and found that those who scored higher on the subscales of *effort regulation* and *time management* received higher final grades. However, none of the other self-regulated learning strategies employed (rehearsal, elaboration, organisation, critical thinking, metacognition, peer learning, or help-seeking) were found to be significantly related to grade. Similarly, Carson (2011) examined the self-regulated learning of a large sample of 4909 first-year online students and found that *effort regulation* and *time management*, as well as *metacognition,* had a small positive correlation with grade. Finally, a meta-analysis by Broadbent and Poon (2015) found that only four learning strategies were significantly, though weakly, associated with online learners' grades: namely metacognition, time management, effort regulation, and critical thinking.

Overall, a positive, although weak, association can be observed between self-regulated learning strategies in a digital learning environment and academic achievement. However, as cautioned by Broadbent and Poon (2015), it should not be assumed that online learning fosters or develops the use of self-regulated learning strategies. In light of this, the focus would be better placed on developing student self-regulated learning through appropriate pedagogical practices, using digital technologies, and understanding individual student characteristics (Teo, 2019; Ianos & Oproiu, 2017). This section of the literature review focusses on describing the most frequently used educational measures of self-regulated learning in digital learning environments in the existing literature. The suitability of each of the four instruments considered for use in this study, namely the Motivated Strategies for Learning Questionnaire (MSLQ), the Learning and Studies Strategies Inventory (LASSI), the Academic Self-Regulated Learning Scale (A-SRL-S), and the Online Self-Regulated Learning Questionnaire (OSLQ), was evaluated based on the constructs that the instrument was designed to measure, ease of online administration, time requirements for administration, and ease of use for the researcher and participants. Finally, the rationale supporting the choice of the Motivated Strategies for Learning Questionnaire (MSLQ) for this study purposes is provided.

4.2.1 Motivated Strategies for Learning Questionnaire (MSLQ)

Pintrich et al. (1991) developed the Motivated Strategies for Learning Questionnaire (MSLQ) based on Weinstein and Mayor's (1986) model of learning and information processing, and Pintrich's (1989) social cognitive model of motivation. According to researchers from various eras, for example, Pintrich and De Groot (1990), Sungur and Tekkaya (2006), Edens (2008), and Kramarski and Michalsky (2010), the MSLQ is the most commonly used measure of self-regulated learning in traditional and online learning environments. Additionally, more recent studies, including Dent and Koenka (2016) and Cazan (2017), found empirical evidence supporting the validity of the MSLQ as a measure of self-regulated learning. The MSLQ has been used in part or in its entirety in more than 50 different countries and is considered appropriate for measuring college students' motivational orientation and their use of different learning strategies (Pintrich et al., 1991). Recent researchers who have administered the MSLQ to reliable measure self-regulated learning include, for example, Broadbent (2017), Bonanomi et al. (2018), Soemantri et al. (2018), and Park and Kim (2021). Broadbent (2017) administered the MSLQ to 140 university students enrolled in various online courses and 466 university students enrolled in various blended learning courses. The results showed that online students utilised self-regulated learning strategies more often than the other students, with the execption of *peer learning* and *help-seeking*. Bonanomi et al.'s (2018) study showed that an Italian version of the MSLQ proved to be a reliable measure, suitable for Italian high school students of different ages, genders, and schools. Lastly, Park and Kim's (2021) study indicated that a Korean version of the MSLQ was a reliable measure of self-regulated learning in a Korean undergraduate education course that utilised a flipped-classroom pedagogy.

The full scale MSLQ instrument, originally presented in a pencil-and-paper format, included 81 items conceptualised to measure three scales of *motivation* (expectancy, value, and affect), and three scales of self-regulated learning (cognitive, metacognitive, and resource management). Students were required to rate, on a 7-point Likert scale, how well an item (statement) described them. For example, for the item “I am very interested in the content area of this course”, a rating of one is to be selected if the statement is *not at all true of the student* and a rating of seven is selected if the *statement is very true of the student*. High scores indicate a greater level of the construct being measured, whereas low scores indicate a lower level of the construct being measured. The questionnaire was designed to be administered to a group and took approximately 20 – 30 minutes to complete (Pintrich et al., 1991). The questionnaire was modular, and the scales could be used together or individually. Table 2 presents a summary of the MSLQ scales, subscales, behaviours subsumed within the constructs, and sample items. This study used two of the MSLQ scales, that is, metacognition (12 items), and resource management (19 items) for a Total MSLQ score. The metacognition and resource management scales are typically used to measure students’ use of learning strategies and self-regulated learning.

Pintrich et al. (1991) determined the MSLQ instrument’s validity using predictive, criterion, construct, and discrimination validity. That is, the MSLQ sub-scales significantly correlated with student final course grades, which demonstrates predictive validity. Additionally, correlations were in the expected direction, which adds to the validity of the scale. Further, validity was also noted by addressing criterion validity, that is, the acceptance of the instrument by numerous researchers as a measure of student motivation and self-regulated learning. Construct validity of the MSLQ was demonstrated as indicators of the same construct were highly correlated. Additionally, confirmatory and exploratory factor analyse of the Motivation and Self-Regulated Learning scales were conducted on both scales, which indicated good construct validity (Cazan, 2017; Feiz et al., 2013; Saks et al., 2015) and that each subscale measured a specific latent trait, referred to as *unidimensionality* (Cavanagh & Waugh, 2011).

Lastly, Pintrich et al. (1991) explained that discriminate validity is identified, as the two scales (motivation and self-regulated learning) measure different constructs and do not correlate; additionally, the acceptance of the MSLQ is further demonstrated as many researchers used the MSLQ to validate their own instruments. These include Artino and McCoach’s (2008) 28-item Online Learning Value and

Self-Efficacy Scale (OLVSES), which consisted of the four subscales of the MSLQ. Magno's (2010) Academic Self-Regulated Learning Scale (A-SRL-S) justified validity by the instrument's correlation to the scales of the MSLQ. Additionally, validity of the A-SRL-S was determined through data-to-model fit with the MSLQ and showed that the instrument is a 'strong model'.

Table 2

Motivated Strategies for Learning Questionnaire Scales and Subscales

	Scale	Subscale	Measures	Sample Item
Motivation (31 items)	Expectancy (12 items)	1. Self-Efficacy (8 items) 2. Control beliefs (4 items)	Belief in one's own capabilities; use of specific learning strategies	I am very interested in the content of this course.
	Value (14 items)	1. Intrinsic goal orientation (4 items) 2. Extrinsic goal orientation (4 items)	Reasons for engaging with an academic task	Understanding the subject matter of this course is very important to me.
	Affect (5 items)	1. Anxiety (5 items)	Level of test anxiety	I feel my heart beating fast when I take an exam.
Learning Strategies (50 items)	Cognitive (19 items)	1. Rehearsal (4 items) 2. Elaboration (6 items) 3. Organisation (4 items) 4. Critical Thinking (5 items)	Use of planning and evaluation strategies	When I study the readings for this course, I outline the material to help me organise my thoughts.
	Metacognitive (12 items)	1. Self-Regulation (12 items)	Use of elaboration and organisation strategies	When reading for this course, I make up questions to help focus my reading.
	Resource Management (19 items)	1. Time and Study (8 items) 2. Effort Regulation (4 items) 3. Peer Learning (3 items) 4. Help Seeking (4 items)	Measures planning, attention, collaboration, assistance seeking strategies	I try to work with other students from this class to complete the course assignments.

4.2.2 Learning and Studies Strategies Inventory (LASSI)

Another important and widely-used instrument to measure self-regulated learning, especially with college students, is the Learning and Studies Strategies Inventory (LASSI) (Abulela & Davenport, 2020; Khalil et al., 2020). The LASSI was developed by Weinstein et al. (1987) and was based on Simon's (1979) model of learning and cognition. The LASSI 1st edition was designed to assess university and college students' learning and study strategies. It is comprised of the three scales Will, Skill and Self-Regulated Learning, and 10 subscales. According to Weinstein et al. (1987; 2016) and Weinstein and Palmer (2002), the LASSI is a self-report instrument administered in either a pencil-and-paper or online format. The LASSI requires students to indicate, on a rating scale, how well a statement describes them. For example, for the item "I find it hard to stick to a schedule", a rating of one indicates that statement is *not at all typical* of the student and a rating of 5 is selected if the statement is *very typical* of the student. High scores indicate a greater level of the construct being measured, whereas low scores indicate a lower level of the construct being measured. Responses to the statements typically range from *not at all typical* to *very much typical*. As a diagnostic tool, the LASSI measurement produces 10 individual scores (one for each scale). These scores are converted to percentiles and are used to identify a student's strengths and / or weaknesses (compared with a national or institutional standard) in the scale being measured. Compared to the MSLQ, the original version of the LASSI did not examine student self-regulated learning in as much detail; however, this was rectified in the second version of the LASSI, and this edition incorporated Weinstein's (1994) model of strategic learning (Weinstein & Palmer, 2002). According to Weinstein et al. (2016), items were revised in the LASSI 2nd Edition (2002) due to a greater understanding of metacognitive concepts of awareness, reflection, and self-regulation.

The LASSI 3rd edition was developed by Weinstein et al. (2016) with a focus on covert and overt thoughts (behaviours, attitudes, and motivations) and beliefs that relate to successful learning in postsecondary educational and training settings. Weinstein et al. (2016) noted five significant differences between the third and second editions, namely: (1) reduction in time taken to complete the instrument, (2) improvements in psychometric qualities, (3) incorporation of current research findings in the areas of educational psychology, developmental education, higher education and instructional psychology, (4) changes to minor wording issues, and (5) national norms that were based on a broader sample.

4.2.3 Academic Self-Regulation Scale (A-SRL-S)

The Academic Self-Regulated Learning Scale (A-SRL-S) is a popular self-report instrument for measuring self-regulated learning in college and higher education contexts (Magno, 2010; Malaga & Oducado, 2021). The A-SRL-S was developed by Magno (2010) and is based on Zimmerman's (2000) conceptualisation of self-regulated learning (i.e., self-generated thoughts, feelings and behaviours that are oriented to attaining goals) and social cognitive frameworks that relate student grades as an outcome of self-regulated learning (Dignath & Buttner, 2008; Kitsantas et al., 2008; Magno, 2011). The A-SRL-S instrument is administered in a pencil-and-paper format and consists of 54 items that are classified into seven academic self-regulated learning factors: (1) memory strategy, (2) goal setting, (3) self-evaluation, (4) seeking assistance, (5) environmental structuring, (6) learning responsibility and (7) organising (Magno, 2011). The internal consistencies for the seven factors ranged from .73 to .87 (Johny et al., 2012). Magno (2010) suggested that the A-SRL-S instrument provides a useful assessment of college students' self-regulated learning ability, the results of which can be used to guide the development of specific teaching approaches to enhance self-regulated learning in students. Additionally, the results of the A-SRL-S measure can then be used as a guide by instructors for the development of specific teaching approaches to enhance academic self-regulated learning factors (e.g., memory strategies) in students. The 54 items of the A-SRL-S are rated on a 4-point Likert scale that requires students to indicate whether they *strongly agree*, *agree*, *disagree* or *strongly disagree* with a statement concerning their self-regulated learning behaviour. Further, a study by Magno (2011) investigating the construct validity of the A-SRL-S with the MSLQ and LASSI by correlating the factors of the three scales in a zero-order correlation, showed that all subscales of the A-SRL-S, MSLQ, and LASSI were significantly related. Specifically, a slightly higher correlation among the A-SRL-S subscales with the LASSI subscales was observed, as compared to the MSLQ subscales. This shows that there is a closer similarity between A-SRL-S factors and LASSI factors. The A-SRL-S is an appropriate measure for self-regulated learning; however, compared to the MSLQ and the LASSI, the A-SRL-S requires greater administration time. The questionnaire is designed to be administered to a group and takes approximately 30 – 40 minutes to complete (Magno, 2011).

4.2.4 Online Self-Regulated Learning Questionnaire (OSLQ)

The last instrument taken into consideration for comparison purposes is the Online Self-Regulated Learning Questionnaire (OLSQ), a self-report instrument developed by Barnard et al. (2009) to measure self-regulated learning levels of college and university students enrolled in a wholly or partially online learning environment. The OSLQ is based on a social cognitive framework that views self-regulated learning as a cyclical process (Bandura, 1997; Pintrich, 2000; Zimmerman, 2008). The OSLQ instrument is administered online and consists of 24 items categorised into six subscale constructs: (1) environment structuring, (2) goal setting, (3) time management, (4) help seeking, (5) task strategies, and (6) self-evaluation (Barnard-Bark et al., 2011). All 24 items of the OSLQ are rated on a 5-point Likert scale that requires students to indicate their response to a statement concerning self-regulated learning (ranging from *strongly agree* to *strongly disagree*). High scores indicate a greater level of the construct being measured, whereas low scores indicate a lower level of the construct being measured. The questionnaire is designed to be administered online and some items are reverse scored. The internal consistency indexes of the subscales, obtained using Cronbach's alpha, range from .67 to .90 (Barnard et al., 2009), which indicates a high instrument reliability.

The OSLQ is considered an appropriate instrument for measuring the capacity of student self-regulated learning in an online or distributed learning environment (Barnard-Bark et al., 2011). The results obtained from the OSLQ provide useful profiles of student self-regulated learning behaviours, which can be used to identify self-regulated learning concerns. For example, Barnard-Bark et al. (2011) identified distinct self-regulated learning profiles in students (i.e., super, high, competent, or minimal / non-self-regulated learners). The study revealed that competent self-regulated learners exhibited learning characteristics that enable them to do well in their learning; however, unlike those with the super or high profiles these students may not strive to achieve their full potential. Additionally, their study established that students with a certain self-regulated learning profile tended to exhibit particular behavioural aspects as indicated in the in the scales and or subscales of the self-regulated learning instrument. For example, students with a *performance control* self-regulated learning profile seemed to place less emphasis on the *goal setting* and *environment structuring factors* of self-regulated learning. Goal setting refers to the setting of short and long terms goals and establishing standards for assessment completion (Handoko et al., 2019). Environmental structuring refers to the arrangement of the physical environment to enhance learning and avoid distraction (Whipp & Chiarelli, 2004). Instead, performance control profile students tended to exhibit skills and strategies such as attention regulation; self-monitoring; time management; task-strategy formation; and help-seeking during the learning process (Barnard-Brak et al., 2010). Barnard-Bark et al. (2010) suggest that these performance control profile students were more concerned with self-regulation in a post-hoc or reactive sense and are not necessarily concerned with behaving proactively by goal setting or structuring their environment proactively.

All of the five self-regulated learning instruments examined are appropriate for measuring college student self-regulated learning; however, the MSLQ was selected for this study due to its wide acceptance (i.e., translated in over 50 languages) and its modularity, which suited the selection of the most salient subscales for the purposes of this study; that is, the Metacognition scale, Resource Management scale, and Total Self-Regulated Learning score. At the time of the first round of data collection, the original version of the LASSI, which was later rectified in edition 2 and edition 3, lacked comprehensiveness compared to the MSLQ. The A-SRL-S was detailed but did not meet the time requirements for the current study. Lastly, the OSLQ would have been equally appropriate for this study; however, the teaching environment at the college was mainly face-to-face at the time of the first data collection (2012), and although it shifted to online in 2020 as a result the COVID-19 pandemic, the OSLQ was specifically designed for a distance learning environment (Bruso & Stefaniak, 2016), which was not the case in 2012.

4.3 SUMMARY

This chapter examines various instruments used to measure self-regulation from a neurological perspective and self-regulated learning from an educational perspective. In regard to self-regulation, these included (1) the Cognitive Assessment System, (2) Tower of Hanoi, (3), Tower of London, (4) Wisconsin Card Sorting Task, and (5) the Weschler's Scales. A few researchers, including Strauss (2006), Das (2004) and Callan et al. (2021), suggested that cognitive measures used to measure self-regulation could be used to measure self-regulated learning. In regard to self-regulated learning measures, these include (1) the Motivated Strategies for Learning Questionnaire, (2) Learning and Study Strategies Inventory scale, (3) Academic Self-Regulated Learning Scale. As researchers have reported mixed findings with using these instruments to measure student self-regulated learning in digital learning environments, the Online Self-Regulated Learning Questionnaire was created specifically for digital learning environments. However, even with these adaptations, the OSLQ continued to present mixed capacity to predict academic performance.

Researchers such as Winne and Perry (2000), De Backer et al. (2012), and van Halema et al. (2020) have suggested that measuring self-regulated learning in real time as a series of events has the advantages of better aligning self-regulated learning theory and affording more accurate data regarding learners (e.g., decisions to monitor and control their cognition, motivation, behaviour, and academic performance). Additionally, Araka et al. (2020) added that specific instruments designed to measure self-regulated learning in online environments do not seem to have reached traction due to a limited understanding of the digital learning environment. Underlying this approach is a move away from assessing self-regulation as an intrinsic aptitude and instead assessing it as a dynamic and adaptive event occurrence (Aleven et al., 2006; Hadwin et al., 2007; Rovers et al., 2019; van Halema et al., 2020; Zimmerman, 2008). As such, from this perspective, it could be proposed that self-regulated learning behaviour could be measured as a neurological construct: that is, using cognitive measures that are typically used to assess complex behavioural sequences.

The literature review in this thesis was divided into three chapters, and Chapter 5 reviews student characteristics and teacher pedagogical practices in relation to self-regulation and self-regulated learning.

Chapter 5 Literature Review: An Environmental View of Self-Regulated Learning

The previous chapters provided a greater understanding of the influences of digital technologies (Chapter 2), self-regulation and self-regulated learning practices (Chapter 3) in education, particularly in pedagogy and in changing learning settings. Variations to pedagogies included a shift from a teacher-centred to a student-centred approach. The evolving learning setting resulted in a shift from traditional face-to face learning towards blended / hybrid and online learning settings, especially due to the Coronavirus pandemic, which began in 2019 (Maqsood et al., 2021). Chapter 4 examined measures of self-regulation from a neurological perspective and measures of self-regulated learning from an educational perspective.

The Internet and various collaboration software (e.g., Zoom, Webex, Google Classroom, and Microsoft Teams), as discussed in Chapter 2, are significant digital technologies that have contributed to the advancement and acceptance of fully online and blended learning settings. Such changes to the learning setting are not new; *alternative learning* or *distance education* provided students with the opportunity to participate in learning through correspondence with teachers, while not being physically in a classroom (Clarke, 2019). The use of digital technologies has made alternative learning settings more practical and accessible and has allowed for instant synchronous and asynchronous communication between students and teachers. The governmental travel restrictions imposed to contain the spread of the COVID-19 virus caused most educational institutions to seek alternative learning settings, such as online and blended learning, which are now becoming a standard practice at all levels of education rather an alternative to traditional face-to-face learning settings.

Digital technologies play an important role in the learning process, and student self-regulation and self-regulated learning. As a direct relationship exists between the level of self-regulation and self-regulated learning exhibited by students and their academic performance (Al-Abdullatif, 2020; Broadbent & Poon, 2015), an understanding of this relationship is important. This chapter seeks to examine the relationship between digital technologies, self-regulation, and self-regulated learning from the student's personal environment: student characteristics including goal orientation (Section 5.1), age and experience (Section 5.2), home environment (Section 5.3), and student agency (5.4).

Students have various abilities, interests, attitudes, personalities, emotions, and prior experiences that influence their approach to self-regulated learning (Desai et al., 2016). For example, a study by Ben-Eliyahu and Linnenbrink-Garcia (2015) examined the self-regulated learning behaviour of 178 high school and 280 college students in South-Eastern United States in order to compare student self-regulated learning behaviour in their favourite and least favourite subjects. An analysis of the survey data showed that students' interests in the subjects that they were taking significantly influenced their self-regulated learning levels; that is, students exhibited higher levels of self-regulated learning behaviour in their reported favourite subject compared to the subject they had reported to be their least favourite. This study showed that, although the students had self-regulation skills, the activation and application of their self-regulatory strategies were dependent on the subject matter. As no further explanation from the researchers was provided to clarify a favourite or least favourite subject, it could be a assumed that a range of factors such as personal interests or orientations, knowledge of or experience with the subject matter, or the teacher's enthusiasm, all of which are important factors of the students personal environment and eductational providers learning environment, may have influenced the students' interest in their subjects.

Additionally, a study by Maga et al. (2014) to measure student self-regulated learning, emotions, and motivations in an academic setting recruited 5805 undergraduate participants from a range of disciplines at a university in Padua, Italy. Results of the study showed that students' emotions influenced motivation and self-regulated learning, and in turn affected academic performance. Additionally, it was concluded that motivation and self-regulated learning mediated the effects of emotion on academic performance; that is, positive emotions appeared to *increase* motivation, self-regulated learning, and academic performance. Student motivation can be influenced by a variety of internal and external factors such as personal interests, stage of cognitive development, performance needs, and a need for recognition or accomplishment (Aoyagi et al., 2020; Sverdlik et al., 2018).

According to Lazarides et al. (2018), motivation has a powerful effect on a student's goal orientation and is a driving force of student agency. Further, Nodoushan (2012) suggested that student agency is the source of student internal motivation and, in turn, is the impetus for the application of self-regulated learning behaviour in an academic context.

As student characteristics influence their use of self-regulation and self-regulated learning behaviours, the following sections of the literature review discuss the student characteristics: (1), goal orientation (Section 5.1), (2) age and experience (Section 5.2), (3) family and the physical environment (Section 5.3), (4) and student agency (Section 5.4) in relation to self-regulation, self-regulated learning, and digital technology usage.

5.1 GOAL ORIENTATION

Student goal orientation has been classified into two broad categories, *mastery* and *performance* (Matos et al., 2017). Mastery goal-orientated students are described as individuals who strive to enhance their competencies, skills, or knowledge (Elliot, 1999; Grant & Dweck, 2003). Performance goal-orientated students are individuals who strive to demonstrate superior competencies or abilities (Janke et al., 2016). Muis and Edwards (2009) suggested that a student's goal orientation varies depending on the reasons they are pursuing a learning objective; that is, their academic ambitions. It is therefore a significant attribute influencing a student's self-regulated learning behaviour and the amount of effort or self-regulation the student is willing to apply to a particular task. As discussed in Chapter 3, self-regulated learning requires students to construct their own goals and develop strategies to achieve these goals (Moos & Azevedo, 2006). As such, both mastery and performance goal-oriented students utilise cognitive self-regulated learning strategies (i.e., planning and resource management) while working towards their goal (Duda, 2005; Kaplan & Maehr, 2007).

An investigation of 61 high school biology students' self-regulated learning by Sungur and Tekkaya (2006) used the Motivated Strategies for Learning Questionnaire (MSLQ) to assess students' self-reported motivation and usage of learning strategies. An analysis of the data showed that students with high scores on the MSLQ's mastery and / or performance goal orientations subscales were compared to students with low scores on the same goal orientation, demonstrated greater use of self-regulated learning strategies such as planning, metacognition, and peer learning. Additionally, students with higher mastery and performance goal orientations were found to be more motivated than students with lower mastery and performance goal orientations. As motivation has a powerful effect on students' goal orientation levels, the *general expectancy* models of motivation by Pintrich (1989; 2000) and Schunk and Zimmerman (2012) provide a useful insight into factors affecting student motivation. These researchers proposed three motivational components that are key factors influencing self-regulated learning behaviour: (1) self-efficacy, (2) intrinsic task-value, and (3) anxiety.

5.1.1 Self-Efficacy

Self-efficacy refers to an individual's perception or belief in their ability to perform a specific task (Krok & Zarzycka, 2020). Self-efficacy and task-value, a perception of the importance or usefulness of a task, exert a strong influence on the level of student engagement with a task (Artino, 2009; Bandura, 1989; Pintrich & De Groot, 1990; Schunk et al., 2008; Zimmerman & Kitsantas, 2007). For example, a study by Geddes (2009) of an American university's business school students found that students with high levels of self-efficacy, compared to students with low levels of self-efficacy, showed more engagement with tasks and tended to use more self-regulated learning strategies such as planning. Similarly, research by Sungur and Tekkaya (2006) found that learners with high self-efficacy demonstrated higher levels of self-regulated learning, specifically for information searching, compared to learners with low self-efficacy. Results from these studies, and others including Fernandez-Rio et al. (2017), Ho et al. (2021), and Klassen (2010) have shown that students with lower self-efficacy tended to exhibit less self-regulated learning behaviours and were less engaged with academic activities compared to students with higher self-efficacy.

Du et al. (2020) suggested that students with low self-efficacy may exhibit an alternative goal orientation, namely *performance avoidance*. Performance-avoidance behaviour occurs when a student avoids or withdraws from a particular task to prevent the possibility of failing the task (Alhadabi & Karpinski, 2020). Further, studies have shown that self-efficacy can be raised in students through providing positive experiences or lowered through negative experiences (see, for example, Kauppinen et al., 2018; Usher et al., 2019). Research by Chiou and Wan (2007) with 136 college students in Taiwan sought to determine the relationship between student self-efficacy and positive and negative task experiences while using the Internet for information searching. Positive and negative experiences were manipulated through controlling the level of difficulty of Internet information search tasks; difficult tasks (ones taking longer to complete) were assumed to provide negative experiences, while easier tasks (ones taking less time to complete) were assumed to provide positive experiences. The study found that students who were provided with positive task experiences showed an increase in self-efficacy compared to students who were provided with negative task experiences. Additionally, results of the study showed that both positive and negative experiences impacted students with low self-efficacy more than students with high self-efficacy. This relationship between self-efficacy and self-regulated learning is consistent with findings from Loo and Choy (2013), Zimmerman and Kulikowich (2016), and Yasin et al. (2020) for both traditional face-to-face and online and blended learning settings.

Research by Choiu and Wan (2007), Munshi et al. (2018), and Perez-Sanagustin et al. (2020) showed the importance of scaffolding pedagogy to developing students' abilities and confidence with using digital technologies such as the Internet. Various digital technologies have been implemented in face-to-face, online, and blended learning settings to support student self-efficacy and enhance self-regulated learning. Shyr and Chen (2018) examined the use of digital technologies to support a flipped classroom approach with students of a second-year Taiwanese English university course. A flipped classroom approach is a form of blended learning that uses digital technologies to provide instructions and materials, including video recordings, as the preparation for a face-to-face class (Willey & Gardner, 2014). The difficulty many educators encounter with a flipped classroom approach is the reluctance of students to view the related class material prior to class, particularly for students with low mastery or performance goal orientations. However, Willey and Gardner (2014) suggested that evidence from their studies supports the notion that a student's goal orientation can be changed temporarily; that is, a student's mastery and performance orientation levels can be raised by the quality of the learning opportunity provided.

Shyr and Chen's (2018) flipped classroom study further supports Willey and Gardner's (2014) view that the quality of the learning opportunity provided can change students' goal orientations. Shyr and Chen's (2018) study, which involved the use of the *Flip2Learn* software with 81 students, used a quasi-experimental study aimed at determining whether the use of the software application contributed to student learning performance and self-regulation. The changes in students' pre- and post-test results were statistically significant between the students who used the software and students who did not, suggesting that student usage of the software increased students' academic performance. The researchers suggested that functions associated with the *Flip2Learn* software application supported cognitive activities required for self-regulated learning, and the software application supported students who were less verbally articulate, increasing their self-efficacy. Zarinfard et al. (2021) investigated the *Flip2Learn* software application with 50 students enrolled in a general English class at a university in Iran. Similar to the methods used by Shry and Chen (2018), Zarinfard et al. (2021) used pre- and post-test results which confirmed that the use of the software application improved academic performance in reading comprehension, and they also noted that the software application supported higher cognitive skills (important in self-regulated learning).

Similarly, Chen and Su's (2019) study involved the use of the *BookRoll* e-book software to support university students in central Taiwan. The software application was used to provide students with tools for self-evaluation and scaffolded guidance with goal-setting processes. The aim of the study was to investigate self-regulated learning, self-efficacy, and academic performance of the 109 participants. The experimental group, which used the software, consisted of 53 students, while the control group that did not use the software consisted of 56 students. Results of the study indicated that the use of the software application improved student self-efficacy by encouraging students to activate self-regulated learning strategies such as *rehearsal*. Additionally, students who the used the software application found it helpful in assisting with the development of their learning strategies.

Lastly, studies by Balbay and Kilis (2017) and Wang et al. (2021) examined the use of YouTube for improving student self-efficacy. The results of Balby and Kilis' (2017) study showed that student self-efficacy was increased due to the variety of materials available on YouTube to support student learning. The researchers' self-developed survey was used for the study to collect data from students regarding their selection of easy-to-understand YouTube videos. Wang et al's. (2021) study, with 258 participants from a university in Taiwan, used a questionnaire that examined their YouTube self-efficacy, learning interest, and learning satisfaction. The analysis of the data collected from the questionnaire showed that student YouTube self-efficacy was positively related to learning interest, and that learning interest was positively related to learning satisfaction. According to Chen and Hu (2020), Fryer et al. (2020), and Wang et al. (2021), student interest is positively related to and a significant predictor of student self-efficacy, and as such, these researchers recommended the need to increase student interests in order to improve their self-efficacy.

5.1.2 Task-Value

Task-value, similar to self-efficacy, influences a student's level of academic engagement, goal orientation, and self-regulated learning. Dietrich et al. (2021) stressed the importance of teachers and course designers in addressing student task-value perceptions when developing activities and assessments. Findings from studies by Artino and Stephen (2009) and Eden (2008) provided support for addressing student task-value perceptions. Artino and Stephen's (2009) research, involving 194 online students from a large public northern United States university, explored the differences between the levels of academic motivation and self-regulated learning of undergraduate and graduate students. The researchers' findings indicated that when an academic task contributed to the final grade of a course, undergraduate and graduate students alike showed an increase in performance, as they perceived the value of the task worthy of additional effort. Similarly, Eden's (2008) study demonstrated the association between task-value and students' usage of the *Student Response System* software application for class preparation with 120 students at a large south-eastern university in the United States. Results of the study found that when a grade value was associated with the use of a software application, students tended to use the software, compared to when a grade value was not associated to the use of the software. Both of these studies identified the importance of task-value in the pedagogical design of learning material.

Pentaraki and Burkholder's (2017) research identified that the usage of digital technologies in teaching can address student task-value perceptions by increasing their interests and engagement in the learning. Findings from studies that have investigated the capacity of digital technology usage, in various academic environments, to support task-value, increase student interest and engagement with learning objectives include those by Banyard et al. (2006) and Uebe Mansur et al. (2019). The study by Banyard et al. (2006), which involved 37 schools in England, examined the relationship between student interests and their perception of a task's value. Results of their study showed that the use of the Internet in class, by primary school students (5 to 11 years old) and secondary school students (11 to 18 years old), increased their enthusiasm as they perceived the benefits of using the digital technologies for information searching as being high, and that the incorporation of the Internet in the pedagogical design of the learning experience increased the task-value of learning. Similarly, Uebe Mansur et al.'s (2019) study determined that the teacher's ability to incorporate the software application *Trello* into their pedagogical practices provided students with a customised learning experience and increased the students' task-value perception. Trello is collaboration software that allows users to organise tasks into categories, shows the status of each task, and identifies who is currently working on a particular task. In the study, the researchers examined the perceived value of the *Trello* software in supporting group project work involving Brazilian post-graduate students enrolled in a multidisciplinary course. Teachers' feedback to the researchers, based on the students' use of the software application during the semester, was that it was well-received by the students, and that *Trello* assisted students in the management of their project tasks. The researchers noted that the use of *Trello* improved student task-value as the students were able to use the software application to customise and organise project tasks in accordance with their individual learning styles and thought processes.

Both of these studies support Bond and Bedenlier's (2019) conclusion that students are more engaged with tasks that are relatable and in which they have control. The researchers suggested that the use of digital technologies, such as collaboration and planning software applications, provide students with a level of control, but emphasise the importance of the teachers in providing students with support and guidance during the learning process.

5.1.3 Student Anxiety

The level of anxiety experienced by a student influences their goal orientation and self-regulated learning behaviour. *Academic anxiety* refers to distresses experienced as a result of academic pressures, which may lead to poor academic performance. The four components of academic anxiety are *worry*, *emotionality*, *task-generated interferences*, and *study-skills deficits* (Hooda & Saini, 2017). An investigation conducted by Fabrizio et al. (2021) into the impacts of motivational behaviour on the academic success of 40 clinical anatomy students at an Argentinian university, found that anxiety was strongly linked to goal orientation and a predictor of academic success. The researchers concluded that a student was more likely to succeed academically if their level of goal orientation exceeds their level of anxiety; that is, students with higher self-efficacy and higher self-confidence would most likely have reduced anxiety. These findings were similar to earlier research by Rosen et al. (2018), the results of which showed that students with low anxiety levels performed better academically compared to students who had higher anxiety levels. This finding is consistent with current understandings of brain-based learning theory (discussed in Subsection 5.2.3), which explains that stress, a common trigger for anxiety, is related to high-order, complex thinking. The aim of Rosen et al.'s (2018) study, which recruited university students in the United States, was to examine the relationship between students' smartphone usage, academic performance, and level of anxiety. The study affirmed that the frequency of smartphone usage influenced student test anxiety levels, and also showed that students who used their smartphones less frequently had lower levels of test anxiety. The results of the study, however, should not solely be used to link the frequency of smartphone usage to test anxiety as other factors may have contributed to test anxiety and were not discussed in the research findings. These include the purpose of the smartphone usage and time period and duration of the smartphone usage before an upcoming test, which may have resulted in insufficient test preparation. This supports other research that concluded that a negative aspect of digital technology usage is distraction (for example, Brady et al., 2021; Chen et al., 2020; Dontre, 2020), and the importance of self-regulated learning strategies to minimise distractions and maintain focus (Naglieri & Otero, 2018).

While digital technologies can be a disruption, Brady et al.'s (2021) research showed that they can also help *reduce* student test anxiety. In research involving 245 private university psychology students in the United States, the study investigated the impacts of a cognitive reappraisal interventions strategy had on students' experience and performance in the course. The cognitive reappraisal intervention strategy involved teachers sending students an email the night before an exam that either did or did not include a paragraph discussing a feeling of test anxiety as being beneficial or neutral. Results of collected questionnaires showed that students who received an email that contained a paragraph discussing test anxiety reported less *worry* about the upcoming test.

The following studies examine the use of digital technologies by teachers, as part of their pedagogical practice, in an attempt to help reduce student anxiety. Qi et al. (2020) studied the effects of digital technology usage for facilitating an online yoga and meditation session to help reduce anxiety in undergraduate students at a Chinese university. Their findings indicated that the online yoga session, which concentrated on breathing techniques, helped reduce student anxiety, while increasing mindfulness and motivation. However, the online meditation, while helping to reduce student anxiety, also reduced student motivation levels, and therefore, led to a reduction in academic productivity. In contrast, a study by Wang and Zhang (2021) investigating student anxiety in an online learning setting compared to a face-to-face learning setting of 160 English language students in a university in China, found that students in an online setting experienced greater anxiety compared to students in the face-to-face setting. Data collected through questionnaires and interviews with teachers and students identified three reasons for anxiety in the online settings. Firstly, online students believed they lacked the extrinsic motivation provided in face-to-face learning environments; secondly, language learning was more difficult in an online learning setting; and lastly, the online learning environment was not equipped for testing student knowledge of content - students felt they could not properly express or communicate their knowledge. The researchers concluded that the autonomous learning demands required from students in online learning settings resulted in an increase in student anxiety. In light of this, they suggested the need to: (1) provide a variety of learning resources, such as audio and video, (2) encourage group learning and collaboration, (3) enhance learning content, (4) include engaging activities, and (5) facilitate monitoring. These areas specified by Wang and Zhang (2021) are important strategies that are outlined in self-regulated learning theories, models, and frameworks (discussed in Chapter 4), which can be supported by digital technologies. However, different types of digital technology usage, including the frequency and duration of usage, affect students in different ways, and therefore needs to be examined in relation to the student's personal environment and the learning environment.

Student's self-efficacy, task-value beliefs, and anxiety levels significantly influence their motivation, and therefore, affect goal orientation. As such, it is important to consider the capacity of digital technologies (i.e., software applications) to support goal orientation. Additionally, an investigation by Robinson and Song (2019) examined the effectiveness of the *Student Academic Performance System* (SAPS) software application in improving student performance and goal orientations. Using the SAPS analytical tool results, the study showed that the software was able to evaluate the factors that contributed to student performance. This included the student's skill level, attendance, and time management. Additionally, the SAPS software facilitated collaboration between students and teachers, which allowed the teachers to work with students in revising learning strategies. These findings further support the self-regulated learning theories of Schunk (1985), Winne (2005), Zhao and Johnson (2012), and Zimmerman (2002), as discussed in Chapter 3. Results from both case studies showed that students with high mastery and or high-performance goal orientations used digital technologies such as online monitoring, evaluation, and collaboration tools to assess their performance, and if necessary, make changes to their learning strategies. These two case studies demonstrated that the use of digital technologies was effective in supporting students with high mastery and performance goal orientations.

5.2 AGE AND EXPERIENCE

Age and experience are important characteristics that contribute to a person's behaviour as they influence the brain's processing of information. Spranger (2010) suggested that during the developmental stages of life "our brain goes through periods of blooming and pruning" (p. 20), which supports Begley's (2007) research that, up to a certain stage, as we age, our brain's neural networks become more efficient. Therefore, our brain processes information differently depending on age and experience. For example, Meares (2016) explained that during early adolescence (11 to 14 years), the brain's frontal lobe experiences a growth spurt with the proliferation of new neurological connections. The notion that the changes in brain development through age and experience impact self-regulated learning and usage of digital technologies can be identified in the findings from studies by Lee and Tsai (2011) and Artino and Stephens (2009). Lee and Tsai (2011) surveyed 157 business school students at a university in Taiwan to determine their perceptions of Internet-based learning (online learning) and traditional face-to-face learning. Findings of the research indicated that older and more experienced graduate students were more self-regulated, interested in collaboration, and demonstrated greater information searching capabilities compared to younger and less experienced undergraduate students. Additionally, the study showed that the level of student academic experience influenced important self-regulated learning processes, such as collaboration and peer learning. That is, masters and doctorate level students with greater academic experience showed a higher level of interest in collaboration and exhibited greater self-regulated learning capabilities compared to undergraduate students with less academic experience. Similarly, Artino and Stephens (2009), as discussed in the task-value section of this chapter, found that graduate students, who had a greater level of university experience, reported significantly higher levels of academic motivation, online technology experience, and self-regulation compared to undergraduate students.

A study by Zeynep (2021) investigated the experiences of 454 pre-service teachers, from a public university in Turkey, while teaching in a flipped learning environment. The pre-service teachers reflected on both positive and negative aspects of the flipped learning experience, and approximately 75% of the reflections identified that the flipped learning approach resulted in better classroom management, improvements in student self-regulation, and an increase in peer collaboration. Among the negative reflections, the lack of student experience with digital technologies was one aspect that hindered student learning and the teachers felt that these skills needed to be purposefully developed in students. This was evident in Aguilera-Hermida's (2020) study in which the experiences, attitudes, and emotions of 270 college students who transitioned from a face-to-face class to an online class were collected via survey. Results of the study showed that students had a stronger preference for face-to-face learning compared to online learning, noting that a lack of digital technologies experience was a contributing factor to greater stress levels.

In current learning environments, many school, college, and university students are coined as *digital natives* (Prensky, 2009). A digital native is a person who has grown up in the digital age and due to their familiarity with digital technologies, can often easily learn how to use different technologies quickly and efficiently, and are not afraid to try unfamiliar digital technologies (Aziz et al., 2020). This is evident Lazakidou and Retalis' (2010) research, which introduced the collaboration software *Synergo* for problem solving to primary students in Greece. The study showed that as these young students became familiar with the software application, they were able to proceed with tasks faster compared to when they were unfamiliar with the software. In this regard, students who are digital natives may not have an issue with *how* to use digital technologies but may have an issue of *when* to use them. As discussed in Chapter 2, the frequency and duration of time people spend on their computers and mobile phones has been increasing, which can be a significant distractor and hence adversely affect student learning and self-regulated learning.

5.3 HOME ENVIRONMENT

Student self-regulation and self-regulated learning are influenced by family factors such as the behaviour of parents or care-givers, including their use of language, literacy levels, general attitudes towards society, and involvement in their children's learning (Cakiroglu & Ozturk, 2017; Kadhiravan, 2011; Talosa et al., 2021; Zadworna-Cieslack & Kossakowska, 2018). Additionally, home environmental factors, such as the family's socio-economic status and physical location, contribute to student self-regulation, self-regulated learning, and usage of digital technologies (Ciftci & Cin, 2017; Johnson et al., 2011; Shala & Grajcevci, 2018). Zadworna-Cieslak and Kossakowska (2018) reviewed the relationship between family factors, quality of peer relationships, school environment, and individual resources on the well-being of primary and secondary school students. The researchers suggested that family factors (i.e., nurturing or disruptive family relationships) influenced student psychological well-being, school adjustment, personal values, and behaviours. As the influences of the student's family environment are ongoing throughout students' schooling, in order to support student self-regulation and self-regulated learning, the impact of a student's personal environment must be considered in order to provide a holistic view of the factors influencing student self-regulated learning.

Studies by Kadhiravan (2011) and Cakiroglu and Ozturk (2017) identified that aspects of the home environment influenced student self-regulation and self-regulated learning. Kadhiravan's (2011) study, using student surveys, investigated various family factors of high school students in India, and determined that almost all dimensions of the home environment influenced student self-regulated learning. The researchers concluded that a positive family environment (one that had a nurturing environment) led to higher student self-regulation and self-regulated learning behaviour, while a negative family environment (one that was disruptive or disengaged) led to lower self-regulation and self-regulated learning behaviour. Cakiroglu and Ozturk (2017) investigated the self-regulated learning behaviour 30 undergraduate mechatronic students enrolled in a flipped classroom learning setting at a university in Turkey. Through interviewing with students, observing their learning behaviour, and examining the exchange of online messages between the students. The researchers concluded that the flipped classroom approach required students to prepare for class by viewing videos that were related to the course. Students who did not watch the videos reported that their disruptive and noisy family environment reduced their motivation. Similarly, student interviews conducted in Talosa et al.'s (2021) study showed that students in loud and distracting family environments found it difficult to stay engaged with their online studies, and they reported that their parents lacked the understanding of online learning and they felt pressured to do household chores while in their online class. These findings, that the family environment is an important influence on student self-regulated learning behaviour, support earlier research by Shek (2002) that family factors significantly relate to adolescent psychological well-being, academic performance, and behaviour.

In relation to the overuse of digital technologies, Islam (2021) suggested that Internet addiction and digital dependency have contributed to students being less communicative, having poor time management skills, lacking interest in academic learning, and self-regulated learning. Chen et al. (2020) concluded that Internet addiction and digital technologies dependency is related to impulsiveness in university students. Results of the study, which involved 426 university students in the United States, indicated the attentional impulsiveness of students positively related to digital technologies distraction. That is, students who demonstrated stronger impulsive behaviours were more easily distracted by digital technologies, and that habitual digital technology usage was strongly related to the level of distraction. Studies by Dontre (2020) and Brady et al. (2021) have shown that the abundance and ease of accessibility of digital technologies has led to an increase in students' multitasking, and they suggested that this often leads to students being distracted and having a lower attention span. Further, the family environment was found to be correlated with adolescent Internet usage behaviours (see for example, Li et al., 2014; Wang et al., 2018). Yen et al. (2016) and Park et al. (2008) explained that supportive parental monitoring and positive parent relationships helped protect students from Internet addiction; however, over-protective parents and negative relationships with parents contributed to student Internet addiction and problematic usage of the Internet.

In regard to family socio-economic status and physical location, studies by Johnson et al. (2011) and Ciftci and Cin (2017) found that these factors affected student self-regulation and self-regulated learning. Johnson et al.'s (2011) study of 474 psychology students at an elite university in the United States showed that students in lower socio-economic groups scored lower on the self-regulated learning measure Self-Efficacy for Self-Regulated Learning (SESRL, scale of the Children's Self-Efficacy Scale CSES; Bandura, 2005) compared to students in higher socio-economic groups. Ciftci and Cin's (2017) study of Turkish university students yielded similar results, and the researchers concluded that socio-economic status greatly affected student learning and resulted in inequitable opportunities for students in low socio-economic groups. Socio-economic factors may affect student self-regulation and self-regulated learning even more in online and blended learning settings. A study by Shala and Grajcevci (2018), using self-report measures developed for the study due to a lack of existing instruments, examined the impacts of the family's socio-economic status, ethnicity, location, and parental education on usage of digital technologies of 303 university students in Kosovo. The measure of student demographics and computer skills found that students living in rural areas had lower levels of digital technologies competence compared to students living in urban areas. Next, the family socio-economic measure, adapted from Aggarwal et al.'s (2005) Socio-economic Standing Scale (SES) included items related to students' social background, parents' employment, and family income, found that families classified as *low* in socio-economic standing had lower levels of digital competencies compared to students from families with a higher socio-economic standing. Lastly, a Likert scale survey adapted from Titzmann et al.'s (2011) Discrimination Hassles instrument and Visser-Wijnveen et al.'s (2016) Student Perception of Research Integration Questionnaire, revealed that students who felt that they were excluded by the university, peers and / or teachers due to factors such as ethnicity or socio-economic status, reported lower digital competency levels compared to students who did not feel excluded.

The level of parents' postsecondary education, even if they did not complete their studies, has been found to influence students' perceptions about and preparedness for college (Ishitani, 2006). Studies by Williams and Hellman (2004) and Antonelli et al. (2020) explored the relationship between first-generation and non first-generation university students; the 14-year gap between these two studies shows the importance of the ongoing research into this area. Both studies concluded that the level of parental or guardian academic experience influences student self-regulated learning. William and Hellman's (2004) study involved 829 rural university students enrolled in various online learning courses in the United States and revealed that first-generation university students compared to second-generation university students scored significantly lower in the use of self-regulated learning strategies and digital technology usage. Using Bandura's (1989) multi-dimensional self-efficacy scales, results of the study showed that students scored lower on their self-regulation for online learning and were less comfortable with online technologies. In regard to online technologies, similar results were obtained in Tran et al.'s (2020) study, which analysed a publicly available dataset of 1061 Vietnamese secondary students' backgrounds and their digital abilities. Using Bayesian statistics, the study showed that students' digital technologies literacy levels positively correlated with their parents' education level and socio-economic status. Additionally, students from urban schools scored slightly higher on levels of digital literacy compared to students from rural schools.

Antonelli et al.'s (2020) study recruited 914 undergraduate students enrolled in an education course in an attempt to understand the influence of parents' education levels on college students' development of self-regulated learning skills. Self-regulated learning behaviour was measured using the Learning and Study Strategies Inventory second edition (LASSI; Weinstein & Palmer, 2002) and information about parents' education level was derived from a survey of student characteristics. Results of their study confirmed that differences in students' self-regulated learning were linked to differences in parents' education levels rather than their choice of college. The findings showed distinct strengths and weaknesses in student self-regulated learning skills between students whose parents had postsecondary education (second-generation college students) and without postsecondary education (first-generation college students). First-generation college students scored above the 50th percentile on only one scale of the LASSI (*motivation*), whereas second-generation college students scored above the 50th percentile on three scales of the LASSI (*information processing, motivation,* and *test-taking strategies*). These studies identify the complexities in understanding the factors involved in supporting and enhancing student self-regulation skills, and Antonelli et al. (2020) conceded that there needs to be more investigation into these complexities. To better understand these complexities, it is important to identify the interrelationships between each; we cannot look at each factor individually but must analyse how they contribute to student self-regulated learning as a whole, hence a holistic approach taken in this current research.

5.4 STUDENT AGENCY

Student agency as described in Bandura's (1986; 2001) social cognitive theory, which encompasses the notion of *will* and *power*, is defined by Klemencic (2015) as a process of student actions and interactions during studentship. *Will* is shaped by students' past experiences and habits, present considerations of alternatives, and projections of the future in relation to the decisions they choose (Biesta et al., 2008). *Power* refers to a students' perceived capability in achieving a desired goal through their actions (Rucker et al., 2018). Individuals are responsible for their own actions and therefore are fundamental to the initiation, development, and contribution of their self-regulation and self-regulated learning processes and behaviours (McCombs & Marzano, 1990). Nodoushan (2012) concluded that this *agentive* view of self is the source of internal motivation, which in turn stimulates self-regulated learning. As such, a key element of student agency is the control that students have in initiating or not initiating self-regulated learning. Digital technologies can support the *will* aspect of student agency by providing greater control for the student. For example, a study by Marcelo and Yot-Dominguez (2019) into self-regulated learning and digital technology usage in university students identified that communication platforms such as *WhatsApp* and *Google Talk* were widely used by students in informal learning settings for assessment collaboration. While these technologies were not designed specifically for learning or self-regulated learning, they provided a means to do so. It is therefore not the reliance on a specific digital technology that should be the focus; instead, the focus should be on pedagogies to enhance self-regulated learning with the use of appropriate technology. Henderson et al. (2015) suggested that digital technologies alone would not transform education, but rather, they should be utilised as a supplement to learning, and that students need guidance to identify how best to use digital technologies for their own learning needs.

From the literature reviewed, the importance of understanding student self-regulation and self-regulated learning from two perspectives have been identified: that is, from the student perspective (*personal environment)* and that of the educational provider (*learning environment*). Researchers such as Wu and Xie (2018), Dontre (2020), and Throuvala et al. (2020) have highlighted the importance of pedagogical approaches to promote student self-regulated learning behaviour so that students may be able to manage distractions, particularly from digital technologies.

5.5 SUMMARY

This chapter reviewed the student's personal environment, specifically looking at the student characteristics of goal orientation, age and experience, home environment, and student agency; and examined the influence of these characteristics on digital technology usage and self-regulated learning. Self-regulated learning involves managing complex learning environments with cognitive strategies, meta-cognitive processing, and motivation (Kauffman, 2004). As discussed in the literature review (Chapters 2 to 5), self-regulated learning is a key component of the student learning process, and therefore contributes to academic performance. Through the course of the literature review, a variety of interrelated factors from the domain of the student's personal environment, including individual student characteristics (Chapter 5), digital technology usage (Chapter 2), and self-regulation (Chapter 4) have been shown to influence student-self-regulated learning. Additionally, as discussed in Chapter 2, the learning environment domain of an educational provider, which includes pedagogical practices, digital technology usage, and the learning setting, need to be considered in relation to supporting student self-regulated learning. As it has been firmly established, self-regulation and self-regulated learning are crucial to the learning process and academic performance (Ningrum et al., 2018) a study of the impacts of digital technologies on college student self-regulated learning through considering both the domains of the student and the educational provider is needed to be able to fully support student self-regulated learning.

This comprehensive review of the literature could allow educational providers to determine whether their current learning environment is able to accommodate the learning needs of the student, including self-regulated learning and digital technology usage.

Chapter 6: Research Methodology

The previous chapter concluded the literature review, and this chapter describes the research methodology used in this current study, including the research philosophy (6.1), design and methodology (Section 6.2), participants (Section 6.3), instruments (Section 6.5), data collection (Section 6.6), data analysis methods (Section 6.7), and ethical considerations (Section 6.8).

6.1 RESEARCH PHILOSOPHY

Research is a process of inquiry and is guided by the researcher's philosophy (Hassan et al., 2018; Zukauskas et al., 2018), which, in turn, influences the way in which the research is conducted (Bhatta, 2018). A research philosophy, which includes the researcher's ontology and epistemology, shapes the researcher's perspective about knowledge and truth (Berryman, 2019) and how they perceive the world (Mertens, 2014). Ontological perspectives include objectivist and subjectivist views. From an objectivist view, knowledge exists without influence and is not dependant on a person's beliefs or opinions (Choudhary et al., 2020; El-Den & Sriratanaviriyankul, 2019; Stroghminger & Yli-Vakkuri, 2019). By contrast, from a subjectivist view, knowledge exists only through experience, and is dependent on a person's beliefs and opinions (Han, 2019). In this regard, as there is no universal method for ascertaining complete truthfulness, a researcher's philosophy is fundamental to understanding their research approach (Denzin & Lincoln, 2018). In this current study, the researcher holds an objectivist ontological stance as he believes that knowledge can be measured using an appropriate methodology.

The methods adopted in a study are dependent on a researcher's epistemology, which is influenced by their ontological view, and can also be either objectivist or subjectivist (Maarouf, 2019). An epistemology is the study of knowledge and a researcher's epistemological view is important as it provides an understanding of how the researcher assessed the reliability of the knowledge obtained. Epistemological views include empiricism and rationalism, falsification and critical realism, and constructivism, and conventionalism (McNeill & Nicholas, 2019). Empiricist theory states that knowledge can only be uncovered through experience, while rationalist theory suggests that knowledge cannot be gained by experience; rather, knowledge is derived through the application of accepted logical mathematical analysis (Astafieva et al., 2019). Falsificationism theory states that true knowledge is unattainable; however, scientific approaches can be used to falsify what is believed to be true (Sardar, 2020). Unlike falsificationism, critical realist theory views knowledge as influenced by language, culture, experience, and expectations (Hoddy, 2018). Epistemology from a constructivist standpoint considers that there is no appropriate methodology to uncover knowledge, and as such knowledge is constructed from a researcher's perspective and not through scientific methods (Fedyk & Xu, 2018). Lastly, from a conventionalist standpoint, prior knowledge and scientific principles have no absolute validity and, as such, suggest that the methods used to obtain the knowledge are more relevant than the knowledge itself (Pogorelov & Ivchenko, 2017). This researcher's epistemological view is one of rationalism and, as such, the researcher believes that knowledge can be uncovered, and for this study knowledge should be uncovered using an unbiased analytical process.

The research philosophy of the current study incorporated an ontological objectivist approach and epistemological rationalism. From this paradigm, knowledge can be measured using appropriate methodologies and scientific instruments, and while the researcher's perspectives and experience can assist in the research, they should not take precedence over the statistics obtained. As such, a quantitative methodology was used for the current study.

6.2 RESEARCH DESIGN AND METHODOLOGY

Research design refers to the approach taken in obtaining evidence for answering research objectives and questions (Tobi & Kampen, 2018). The current research consisted of a quantitative repetitive survey approach to gather data from participating pathway college students in 2012 and 2020. During both the 2012 and 2020 data collections, self-report instruments, and numeracy, literacy, and neurological tests, discussed in more detail in Section 6.6, were used to collect information on student background, self-regulation, self-regulated learning, academic performance, and digital technology usage.

Quantitative methodologies involve the statistical treatment of collected data to answer the research questions (Rahi, 2017), which includes making predictions based on the analysed data in addition to describing and explaining the data (Murdoch et al., 2019). The overarching research objective of the current study was to determine the impacts of advancements in digital technology usage on student self-regulated learning. For this purpose, a holistic approach was taken; that is, to identify the factors affecting self-regulated learning and digital technology usage from a student perspective (i.e., student personal environment), and the capacity of an educational provider to support self-regulated learning (i.e., learning environment). Quantitative research methods are considered when: (1) objectivity is required in the interpretation of research findings, (2) the research instruments used for data collection are reliable, and (3) the research involves a large group of participants (Queiros et al., 2017; Schunemann et al., 2019). The objectivity of the analysed data is important as it allows for the results to be generalised to a larger population (Ong & Puteh, 2017). Additionally, as quantitative data is statistical, it can easily be compared to provide a clear interpretation of the research findings (Basias & Pollalis, 2018). As such, a quantitative methodology was suitable for the current research as the four research questions sought to describe, explain, and make predictions in regard to the relationships and variation in participating student self-regulated learning, academic performance, digital technology usage, and characteristics between two groups of participants (2012 and 2020 groups). Also, the current research had a large number of participants (total = 214, n = 105, 2012 group; n = 109, 2020 group), and used reliable instruments which included the Motivated Strategies for Learning Questionnaire (MSLQ), Cognitive Assessment System Matchings Numbers Planning subtest (CAS, MN), and the 2012 Year 9 National Assessment Plan - Literacy and Numeracy (NAPLAN) assessment for data collection. Lastly, objectivity in the research was important, and was maintained by using statistical analysis software, SPSS version 20, for analysing the results.

The limitations of a quantitative methodology are that it does not offer participants a chance to clarify their responses (Harari & Chioun, 2021), nor does it allow participants to clarify any questions they may not fully comprehend (Queiros et al., 2017). These limitations could lead to mistakes being made in the responses and thus could affect the reliability of the data collected (Butler et al., 2019; Surucu & Maslaci, 2020). To reduce the likelihood of this occurring, the researcher piloted the instruments to refine them and chose instruments that used language at a literacy level expected of the college student participants (i.e., minimum International English Language Testing Score band of 5.5), and language that was not culturally specific.

6.2.1 Research period

The research participants were recruited in 2012 and 2020 from a Western Australian pathway college. 2012 was when the study commences and also reflected the impact of digital technologies on society, measured using the Network Readiness Index (NRI), which was greater this year compared to previous years, as discussed in more detail in Chapter 8. Coincidentally, in 2012, there was an increase in digitisation (see Chapter 8, Subsection 8.1.1), and that year had the highest revenue of information technology-related sales between 2012 and 2020 (Mlitz, 2021). 2020 was selected as the second period for data collection as this was roughly one year on from the impacts of the responses to the COVID-19 pandemic, as experienced in Western Australia, and students were returning to their first trimester of studies through a mixture of online, blended, and face-to-face classes at the pathways college at which this research was conducted. During this 8-year period (2012 to 2020), the pathway college went through some significant changes in regard to Australian regulations governing pathway institutions and the delivery of its programs. However, these changes should not have affected the college recruitment of students at each period; therefore, the sample of research participants in 2012 and 2020 can be assumed to be at the same academic level.

6.2.2 Research location

A pathway college offers preparatory courses that are designed to enhance local and international students' skills, knowledge, and qualifications in order to enter a Bachelor's or Master's degree program (Aktar & Strong, 2019; De Wit & Jones, 2018). At the period of data collection in 2012, the college was a Registered Training Organisation, with its curricula registered with the Tertiary Education Quality Standards Agency of Australia (TEQSA) and the Australian Skills Quality Authority (ASQA). The college offered two main study programs: Diploma Programs and Tertiary Preparation Programs. While both programs provided courses in business, design, engineering, health science, and information technology, the course curricula content delivered in each program were at different levels of academic rigor. The curricula of the college Diploma Programs were registered with TEQSA and consistent with Level 5 of the Australian Qualifications Framework (AQF) learning outcomes. The curricula of the college Tertiary Preparation Programs were registered with ASQA and consistent with Level 4 of the AQF learning outcomes. As such, the course curricula of the Diploma Programs were more demanding academically and also had a higher entry requirement (i.e., entry required the completion of an Australian Year 12 or equivalent, while entry into the Tertiary Preparation Program required the completion of an Australian Year 11 or equivalent). In addition, entry into each program was dependent on a student's level of English language proficiency. The college Diploma Program required enrolling students to provide evidence that they had obtained an IELTS of 6 or more with no band (i.e., listening, reading, writing, or speaking) below 5.5, entry into the college Tertiary Preparation Program required an IELTS score of 5.5, with no band below 5.0. At the time of the 2012 data collection, apart from students who qualified for recognition of prior learning, each program consisted of eight 25-credit units that required a minimum of two trimesters to complete (i.e., 26 weeks). Upon successful completion of the Tertiary Preparation Program, students are able to advance to the Diploma. Enrolling students who failed to meet the college's English language proficiency requirements, for either program, were required to complete full-time English language support classes before commencing in the either program.

As an RTO in 2020, the college's curricula were registered with TEQSA, and the college continued to offer two main study programs; however, the names of these programs had been changed to Stage Two Diploma (formally Diploma Program) and Stage One (formally Tertiary Preparation Program). Both programs continued to provide courses in business, design, engineering, health science, and information technology. Similarly, the course curricula content delivered in each program were at different levels of academic rigor. That is, the Stage Two Diploma was consistent with Level 5 of the Australian Qualifications Framework (AQF) learning outcomes. The Stage One Diploma, technically, was registered at Level 5 of the AQF; however, the program curricula content was consistent with the 2012 Level 4 AQF learning outcomes. That is, students commencing the Stage One program enter at an AQF level 4, which transitions to an AQF level 5 as they progress into the Stage Two program. As such, it as was academically less demanding and had a lower entry requirement (i.e., entry into the college Stage One Diploma Program required the completion of an Australian Year 11 or equivalent; entry into the Stage Two Diploma Program required the completion of an Australian Year 12 or equivalent). Entry into the college Stage Two Diploma Program required enrolling students to provide evidence that they had obtained an IELTS of 6 or more with no band (i.e., listening, reading, writing, or speaking) below 5.5. Entry into the college Stage One Diploma Program required enrolling students to provide evidence that they had obtained an IELTS score of 5.5, with no band below 5.0. In addition, similar to 2012, with the exception of students who qualified for recognition of prior learning, each program consisted of eight 25-credit units that required a minimum of two trimesters to complete (i.e., 26 weeks). Also, upon successful completion of the Stage One Diploma Program students may advance to the Stage Two Diploma Program. Further, as per 2012, enrolling students for 2020 who failed to meet the college's English language proficiency requirements, for either program, were required to complete full-time English language support classes before commencing in the Stage One Diploma or Stage Two Diploma.

6.3 RESEARCH PARTICIPANTS

At the time of data collection in 2012 and 2020, the college student record system showed that there were 168 and 211 students respectively enrolled in the classes from which data were collected. In 2012, enrolments included students who varied in age from late adolescence through to late adulthood (i.e., 16 to 62), but most (i.e., 80%) were under 21 years of age. Further, the majority of enrolments were from overseas regions including Asia, Africa, Europe, and the Middle East. Similar to 2012, at the period of data collection in 2020, enrolments included male and female students who varied in age from late adolescence through to adulthood (i.e., 16 to 42); however, the percentage of enrolled students under 21 years of age was 79% and the majority of enrolments in 2020 were from Australia due to the lack of international students able to travel to Perth.

The commerce course formed the largest student cohort at the college, and due to convenience sampling (i.e., commerce class timetable and availability of the researcher), the commerce students were recruited for the study in both 2012 and 2020. In 2012 there were 168 commerce students, and in 2020, there were 211 commerce students, resulting in a total of 379 participants (i.e., population size). Of this population, due to the provision of informed consent, student absences on the day of data collection, technical issues, and data omitted due to incomplete responses, 105 participant responses were used from the 2012 group and 109 responses from the 2020 group (n = 105, 2012; n = 109, 2020).

In 2012, participants were recruited from eight separate classes (N = 168) at the college. These classes included compulsory units in the Commerce Diploma Program (DP) and the Commerce Tertiary Preparation Program (TPP). Due to technical issues with the data collection software, participant responses from two classes (n = 42) were omitted from the data analysis. Additionally, 21 participant responses were incomplete and therefore omitted from the data analysis. The final number of usable participant data for analysis (n = 105) were responses from 64 male and 41 female students ranging in age from 16 years to 42 years, with 80% of the participants under 20 years of age (mean 19.9 years). Of these participants, 78 (74.3%) were enrolled in the Diploma Program and 27 (25.7%) were enrolled in the Tertiary Preparation Program.

In 2020, participants were recruited from 12 separate classes (N = 211) at the college. These classes included compulsory units in the Commerce Stage Two Program and the Commerce Stage One Program. From the 211 students, 79 students were absent or did not wish to participate in the study. Three of the 79 students informed the researcher that they were not able to access the survey (presumably due to Internet restrictions in their home country). For the students who participated in the survey (n = 132), 23 responses were not included in the study as they were incomplete. The final number of usable participant data for analysis (n = 109) included responses from 63 male and 46 female students ranging in age from 16 years to 62 years (mean 19.7 years). Of these college students, 70 (64.2%) were enrolled in the Stage Two Program and 39 (35.8%) were enrolled in the Stage One Program.

6.3.1 Sample Size

Takai et al. (2020) stated that three criteria are required to determine appropriate sample size: (1) level of precision, (2) confidence level, and (3) degree of variability. The level of precision, expressed as a percentage, increases as the sample size increases; confidence level is the probability that the value of the parameters is within a specified range; and the degree of variability is the extent to which the scores are spread or clustered together in a normal distribution (Yang et al., 2019). There are several methods that can be used for determining an appropriate research sample size, such as: (1) using a census for small populations, (2) using a sample size of a similar study, (3) using published tables, and (4) using sample size calculation formulas (Taherdoost, 2018). The researcher determined the appropriate sample size for this current study by using Israel’s (1992) published sample sized tables as shown in Figure 10.

Figure 10 Israel's (1992 p.3) Sampling Size Table

Israel's (1992 p.3) Sampling Size Table

Size of Population	Sample Size (n) for Precision (e) of: ±5%	±7%	±10%
100	81	67	51
125	96	78	56
150	110	86	61
175	122	94	64
200	134	101	67
225	144	107	70
250	154	112	72
275	163	117	74
300	172	121	76
325	180	125	77
350	187	129	78
375	194	132	80
400	201	135	81
425	207	138	82
450	212	140	82

Size of Population	Sample Size (n) for Precision (e) of: ±3%	±5%	±7%	±10%
500	a	222	145	83
600	a	240	152	86
700	a	255	158	88
800	a	267	163	89
900	a	277	166	90
1,000	a	286	169	91
2,000	714	333	185	95
3,000	811	353	191	97
4,000	870	364	194	98
5,000	909	370	196	98
6,000	938	375	197	98
7,000	959	378	198	99
8,000	976	381	199	99
9,000	989	383	200	99
10,000	1,000	385	200	99
15,000	1,034	390	201	99
20,000	1,053	392	204	100
25,000	1,064	394	204	100
50,000	1,087	397	204	100
100,000	1,099	398	204	100
>100,000	1,111	400	204	100

a = Assumption of normal population is poor (Yamane, 1967). The entire population should be sampled.

According to Israel's (1992) Sampling Size Table, for a population of 379 a minimum sample size of 204 is required for a +/-5% precision (Figure 10). Due to technical issues, non-attendance and non-participation, the entire population of the commerce program at the college could not be captured. However, the current study collected complete data sets from 214 students and for a population of 379, this exceeds the minimum sample number required (i.e., 201) for a +-5% precision.

6.4 INSTRUMENTS

The following instruments were selected for use in this study: (1) 20 items from the 2012 Year 9 NAPLAN Literacy and Numeracy assessment sample items, (2) 36 items from the adapted version of Johnson's (2008) digital technology usage instrument to measure student duration and frequency of software application usage on a computer and mobile phone, (3) 16 items adapted from the Cogitative Assessment System (CAS) Matching Numbers (MN) planning subtest, and (4) an abbreviated Motivated Strategies for Learning Questionnaire (MSLQ), which consisted of 31 items from the instruments' Metacognition and Resource Management scales. Table 3 provides a summary of the items and measures of each instrument.

Table 3

Research Instruments - Items and Measures

Instrument	Items	Measure
NAPLAN 2012, Year 9 (Sample items)	20	• Literacy (10 items) o Reading comprehension o Language Conventions • Numeracy (10 items)
Digital Technology Usage	36	• Frequency of computer software application usage (12 items) • Frequency of mobile phone software application usage (12 items) • Duration of software application usage (12 items)
CAS Matching Numbers	16	• Self-regulation – planning (16 items)
Adapted MSLQ	31	• Metacognition (12 items) • Resource management (19 items) • Time and study • Effort regulation • Peer learning • Help-seeking

The NAPLAN assessment sample consisted of 20 items that measured student skills in Reading Comprehension, Language Conventions, and Numeracy. The digital technology usage instrument was comprised of 36 items that measured the frequency of computer software application use, frequency of mobile phone software application use, and the duration of software application. The adapted CAS MN planning subtest consisted of 16 items of the CAS MN planning subtest. The abbreviated MSLQ consisted of 31 items used to measure self-regulated learning. A time limit was imposed for the NAPLAN Literacy and Numeracy items as well as the CAS MN planning subtest items, as students were not expected to complete all items within the time limit; instead, the aim was to compare students with each other in terms of the number of correct responses provided.

6.4.1 National Assessment Plan – Literacy and Numeracy (NAPLAN)

As discussed in the literature review (Chapter 2), there are numerous methods for measuring student academic performance, including reviewing grades and assessment results, interviewing teachers, analysing student self-reports, and administering standardised tests (Allen, 2005; Begeny et al., 2011; Li et al., 2018). The NAPLAN assessments consisted of two scales, *literacy* and *numeracy.* The literacy scale consisted of two subscales, *reading comprehension,* which assessed student's understanding of a written text, and *language conventions*, which assessed student's grammar and punctuation skills. Both the *reading comprehension* and *language convention* items consisted of five multiple choice items (see Appendix A and Appendix B), and were limited to six minutes (deemed appropriate through pilot testing) and students were not expected to finish all of the questions. Each correct response received a score of one, and as such both subtests had a maximum score of five and a minimum score of zero. The *numeracy* scale required students to answer 10 items (see Appendix C) and had a time limit of two minutes (deemed appropriate through pilot testing). The numeracy items were in multiple-choice format, and each correct response received a score of one, so that the maximum score for numeracy was 10 and the minimum score was zero. The students were permitted to use a calculator as the numeracy items were taken from the Numeracy Calculator Allowed test paper.

The NAPLAN assessment was selected as the measure of student academic performance for this study as the participating students were expected to have basic Australian secondary school literacy and numeracy skills. The NAPLAN items used to measure college student academic performance were taken from the 2012 NAPLAN Year 9 sample items. The subtest items provided in the sample were arranged in difficulty level, with the most difficult items (the last five from each sample) were selected. Additionally, these sample items were deemed to be culturally neutral (i.e., not referring to distinct Australian culture or values). Lastly, the selected items were able to be administered online (i.e., selected response) and automatic scoring was used. It was considered to be extremely unlikely, as demonstrated in the instrument pilot testing, that the participating college students would have accessed and practised the Year 9 NAPLAN sample items of their own accord.

6.4.2 Frequency and duration of digital technology usage

Participant digital technology usage was measured using self-report items adapted from digital technology usage measures in previous research (i.e., Johnson, 2012). The current study investigated students' frequency and duration of usage for the purposes of recreation, commerce, information searching, and education on two types of devices (i.e., computers and mobile phones). Thirty-six items were used to measure three categories of digital technology usage: (1) frequency of computer software application usage (see Appendix D), (2) frequency of mobile phone software application usage (see Appendix E), and (3) duration of software application usage on any device (i.e., computer or mobile phone) (see Appendix F). Each category of digital technology usage consisted of 12 items relating to specific types of software applications (i.e., gaming, video chatting, text messaging, emailing, Facebook, image viewing, music listening, movie viewing, schoolwork, YouTube, shopping, and banking).

Each item in the frequency of computer software application usage and frequency of mobile phone software application consisted of a statement such as *I use a COMPUTER, including a laptop, notebook or tablet, for accessing the Internet to: play games*. Response options ranged from *never or hardly ever* (i.e., a score of 1) to *several times a day* (i.e., a score of 5). High scores indicated a greater level of the type of usage, whereas low scores indicated a lower level of the type of usage. The maximum score for the frequency of computer application usage was 60 (a rating of 5 on all 12 items) and the minimum was 12 (a rating of 1 on all 12 items).

6.4.3 Cognitive Assessment System Matching Numbers Planning Subtest

From the numerous methods for assessing self-regulation, as discussed in Chapter 4, the Cognitive Assessment System Matching Numbers planning subtest, which measures the construct of metacognitive planning from a neurological perspective (Naglieri & Das, 1997), was selected to measure self-regulation in this study. For the current investigation, the CAS Matching Numbers planning subtest was converted from a pen-and-paper format to a digital format for online administration and electronic scoring. Appendix G presents the last 16 items of the CAS Matching Numbers planning subtest (i.e., most difficult), which were deemed as a sufficient number of items for the timeframe provided to participants. Each item consisted of a group of six multi-digit numbers that were displayed in a row. The multi-digit numbers within each group of numbers looked very similar; however, two multi-digit numbers were the same. The objective for the student was to identify the two multi-digit numbers that were the same from a group of six multi-digit numbers, as illustrated in Figure 11. The items became progressively more difficult as the series of numbers in each group increased. Participants received a full score for selecting the two correct responses for each item; that is, the two multi-digit numbers that were the same (i.e., Figure 11; full score if B and D were selected). A score was not awarded if only one or no correct responses were selected (e.g., Figure 11; if A and B were selected). The maximum score a participant could receive in this subtest was 16 and the minimum was zero. The higher the score, the higher the level of planning attributed by the participant, and the lower the score, the lower the level of planning attributed by the participant.

Figure 11

Sample Item in the Adapted Cognitive Assessment System Planning Subtest to Measure Self-regulated Learning

9682	6982	6928	6982	9628	6962
A	B	C	D	E	F

6.4.4 Abbreviated Motivated Strategies for Learning Questionnaire (MSLQ)

From the numerous methods for assessing self-regulated learning, as discussed in Chapter 4, the MSLQ was selected as one of the measures of self-regulated learning. As of 2012, the MSLQ was the most commonly used self-report instrument for measuring self-regulated learning with university and college students (Rotgans & Schmidt, 2010). Additionally, the MSLQ still appears to be the most verified instrument in self-regulated learning research and provides a good balance between differentiated assessment and economical implementation (Roth et al., 2016). The MSLQ has frequently been converted from a pen-and-paper format to digital formats for online administration (e.g., Cho & Heron, 2015; Cho & Summers, 2012; Keskin & Yurdugul, 2020). Specifically, the abbreviated MSLQ is comprised of 31 items designed to measure the metacognitive (12 items; refer to Appendix H) and resource management (19 items; refer to Appendix I) components of self-regulated learning (Chen, 2002).

The metacognitive scale items measured the extent of participant planning, monitoring, evaluation, and elaboration of self-regulation strategies (12 items). The resource management scale is composed of four subscales, namely, time and study (8 items), effort regulation (4 items), peer learning (3 items), and help-seeking (4 items). Participants responded to each of the 31 items in the abbreviated MSLQ by selecting a response from a five-point rating scale, which most accurately reflected personal perception of their own behaviour. As such, a student would select *5* on the rating scale if the statement was true of the student's perception of their own behaviour. If the statement was not at all true of the student, they would select 1 on the rating scale (i.e., like me). If the statement was more or less true of the student, a response between 1 and 5 (i.e., sometimes like me, neither, not usually like me) would be selected. A five-point rating scale, as opposed to the seven-point rating scale proposed in the original abbreviated MSLQ (Pintrich et al., 1991) was adopted due to increasing criticism regarding the validity of rating scales with more than five response options (Johnson & Cavanagh, 2012). Several items, as indicated in Appendix H and Appendix I were reverse scored to allow for a summation of student ratings so as to provide metrics of the measured constructs. High scores for each self-regulated learning item indicated a greater level of the construct measured, whereas low scores indicated a lower level of the construct measured. When the appropriate items were reverse scored and all 31 MSLQ item ratings summed, the maximum possible score was 155 (31 items x 5 on each item) and the minimum possible score was 31 (31 items x 1 on each item).

6.5 PILOTING AND REFINING INSTRUMENTS

The instruments discussed in the previous section were adapted for online administration using Moodle (Modular Object-Oriented Dynamic Learning Environment), a popular Learning Management System, and the one used by the pathway college. In 2012, during testing of the online instruments by the researcher, it was discovered that the instruments in Moodle (version 2.0; however, this was resolved in version 3.10+) appeared differently when opened with the web browsers Internet Explorer and Mozilla Firefox. For example, the layout of the webpage window appeared differently in each browser (i.e., spacing of the tables). As a result, the instructions were modified to direct participants to use Mozilla Firefox when accessing the instruments from Moodle.

Two groups of college students volunteered to pilot the online questionnaires and assessments. Similar to the college students who would subsequently be invited to complete the online questionnaire, the pilot group consisted of students from both programs. The pilot group, like the participant group, had experience with Moodle's questionnaire and quiz features. The first group (n = 8) completed all items and provided feedback in relation to the clarity of instructions provided (refer to Appendix J for the participant feedback sheet). As a result of the feedback received, online, oral, and visual information presented to students was modified to include detailed step-by-step instructions for completing the online questionnaires and assessments.

The scores for the Reading Comprehension, Language Conventions, and Numeracy assessments of the volunteering students suggested that the allocated time limits provided for each of the subtests needed to be adjusted to ensure variability in the scores. As such, the working time for the Reading Comprehension instrument was reduced from 10 minutes to 6 minutes, the Language Conventions instrument from 10 minutes to 4 minutes and the Numeracy instrument from 10 minutes to 6 minutes. The instruments were then administered to a second group of volunteering students (n = 14), and a review of student responses to and feedback on the adjusted instruments suggested that the instructions were clear and the timings appropriate. All student responses were downloaded into a spreadsheet to ensure the automatic calculations were correct, and all responses were recorded.

For the 2020 participant group, no additional student testing was required as the instruments and data collection methods remained unchanged from 2012 However, the researcher and several colleagues tested the accessibility of the software using various browsers and at various locations (e.g., college campus and private homes) with no issues being reported. The only change in the 2020 data collection for the fully online and blended class settings was that the instructions were provided via the video conferencing software Zoom.

6.6 DATA COLLECTION

The adjusted instruments were administered to student participants during normally allocated class times in 2012 and 2020 at the college. Additionally, a Participation Information Statement was developed in 2012, in accordance with Curtin University ethics procedures, to obtain informed consent. Due to the classes being in an online format in 2020, this information was provided online via Moodle.

Instructors of each of the eight classes in 2012 and twelve classes in 2020 nominated a *student-free time* to ensure that the data collection process did not disrupt planned classroom lessons. *Student-free time* is class time allocated for students to continue with individual activities (i.e., homework). The completion of the online assessments and questionnaires required students to have access to a computer, the Internet, and Moodle.

Moodle was chosen as the software platform for data administration as it was familiar to the researcher and participants, and additionally Moodle provided features that were necessary for the online administration of the instruments (e.g., time limits, number of allowable attempts, and automatic scoring). Further, Moodle allowed for individual usernames and passwords to be assigned, which was essential for controlling access and providing anonymity. As required by research ethics, data could only be provided by college students who agreed to participate following an explanation of the research aims and requirements. As such, each potential college student received a unique username and password to access Moodle, and students selected a username and its corresponding password from a list, which had no connection to their college student details (i.e., they were able to remain anonymous). This Moodle security access setting ensured that each username was only permitted one attempt at the online assessments.

6.5.1 Data Collection Sites and Online Administration

In 2012, data collection occurred in eight classes that were delivered in two of the college's computer labs. The researcher was in the room and provided details about the research and instructions, which were projected onto a screen. Visual materials (i.e., PowerPoint), corresponding verbal instructions, and an information sheet containing login details for Moodle were provided to all students. These verbal instructions and the information sheet provided details of the project and described the types of data to be collected. Students were informed that their participation was voluntary and their responses to items in the online questionnaire would remain anonymous. As such, their choice to participate in the research was unrelated to their classwork and would have no bearing on their class progress. Students choosing not to participate in the research could ignore the instructions and continue with their own individual activities (e.g., homework). Students volunteering to participate in the research followed the instructions provided by the researcher.

In 2012, data were collected from 105 participating students, using two computer labs at the college. Each computer lab had 40 workstations, which had access to the online software that was used for data administration and collection (i.e., Moodle). The computer labs each consisted of 40 computers. In 2020, due to the impact of coronavirus (COVID-19) pandemic restrictions, the college delivered most of its classes remotely but also offered a limited number of face-to-face and hybrid (i.e., a mixture of face-to-face and online) classes. The online classes were delivered through an online collaboration software that had video and audio capabilities (i.e., Zoom), while the face-to-face classes were delivered in either the college computer labs or tutorial rooms. Students attending the face-to-face classes in the computer labs had access to the college computers, whereas students attending face-to-face classes in the tutorial rooms were required to have their own laptops or tablets for accessing class content. Lastly, the hybrid classes were delivered in either a college computer lab or tutorial room; however, the instructor utilised Zoom to engage with students attending the class online (i.e., not physically in class). The majority of the students were in Western Australia during the time of data collection; however, a few students joined the classes from their home countries (some requiring a VPN, for example students in China) to access the content. The face-to-face, hybrid, and online classes had a smaller number of students per class compared to when the data was collected in 2012. The data administration in the face-to-face classes was conducted in one college computer lab and in one college tutorial room.

In 2020, the administration and data collection occurred in twelve separate classes at the college (nine online classes, two face-to-face classes. and one hybrid class). For the online classes, data administration occurred through Moodle with the researcher facilitating via Zoom. The updated Moodle version (i.e., 3.10+) used for the 2020 data collection supported multiple browsers so students were instructed to use a browser that was familiar to them. Additionally, for the online classes, students accessed Moodle from various locations, using either their own computer, laptop, a public computer (e.g., at a library) or a college computer. For the online classes, the instructor provided students with the research details and instructions via Zoom. Administration and data collection for the face-to-face classes were conducted in a computer lab and tutorial classroom in a similar manner to the administration and data collection approach used in 2012. Students in the computer labs had access to two browsers (i.e., Google Chrome and Safari); however, students could also use their own laptops or tablets. The data collection in the tutorial classroom was conducted in the same manner as the face-to-face classes in the computer lab. Lastly, data collected in the hybrid class involved a combination of methods used in the face-to-face and online classes.

Data collected in the online classes was conducted using Zoom. Students enrolled in an online class could attend the class remotely from any location with an Internet connection using either they computers, laptops, tablets, or mobile phones. Students in the online Zoom class were able to hear, speak, and text message the instructor and other students. Additionally, students were able to see their instructor via the live streaming video function in Zoom, and student who activated the share video function of Zoom were able to show themselves using a webcam; however, very few opted to do this (the college only required students to share their video during a test or examination). The researcher used Zoom to facilitate data collection in the online classes. The data collected in the hybrid class was conducted in the tutorial room while using Zoom to engage with the students attending online.

In both data collection years, once participants accessed Moodle, they were directed to a navigation menu that included all of the instruments (i.e., 4 assessments and 3 questionnaires) as well as an instructor-led demonstration for student practice. Once students completed a subtest or questionnaire, they would be directed back to the main window in Moodle to select another assessment or questionnaire. The Moodle navigation menu interface, assessment, and questionnaire items were explained to the participating college students. All assessments (i.e., adapted CAS MN planning subtest and NAPLAN) had a time limit, identified by a symbol containing a *large red tick* next to the instrument's name.

The participants were instructed to attempt the adapted Cognitive Assessment System (CAS) Matching Numbers (MN) planning subtest first. Prior to that, participants were asked to follow a demonstration by the researcher on how to access and complete the items. The Matching Numbers Demonstration link was used by the researcher to explain the purpose of the adapted CAS MN planning subtest, time restrictions, and method of submission of the assessment or questionnaire. Once the participant clicked the Matching Numbers Demonstration link, a window appeared which stated the item name, description, and time allowed. Once participants clicked the "Attempt quiz now" button, a popup message appeared, which reminded students that these online assessment items were time-limited and required user confirmation to proceed. Students could then choose which items to proceed to next.

6.7 DATA ANALYSIS METHODS

After the participants submitted their completed online questionnaires, their responses were stored in Moodle. Following data collection from the last of the eight classes (2012) and the last of the twelve classes (2020), all Moodle data were downloaded into an Excel spreadsheet and then imported into SPSS version 20. First, a convergent validity analysis of MSLQ and NAPLAN was carried out for both 2012 and 2020 through the analysis of subscales' correlations. Descriptive statistics (i.e., mean, standard deviation, minimum, maximum, and frequency) provided information regarding the sample of participating college students and their completion of the three general categories of measured variables (i.e., self-regulated learning, academic performance, and digital technology usage). The data collected was analysed through parametric testing. Parametric tests are suitable when the data is normally distributed, independent, and free of outliers (Abdel-Salem & Verma, 2019). As each student participated in the questionnaire once, this satisfied the criteria for parametric testing.

Correlational analysis of the Motivated Strategies for Learning Questionnaire (MSLQ) and the NAPLAN assessments were conducted to determine the instruments' reliability and validity through internal consistencies (i.e., internal correlations). The Cognitive Assessment System Matching Numbers planning subtest did not include scales or subscales, but rather, all 16 items measured a single construct, *planning*, and therefore would not be expected to correlate. Similarly, the survey of student characteristics and the frequency and duration of software application usage would not be expected to correlate. Descriptive statistics were used to describe the five clusters of information including college students' academic performance, digital technology usage, self-regulation and self-regulated learning levels, and student characteristics.

For RQ1 and RQ2, independent sample t-tests, commonly used to test statistical differences between the means of two groups, compared student frequency and duration of computer and mobile phone software application usage in 2012 and 2020 (RQ1), and student self-regulation and self-regulated learning (RQ2). For RQ3, partial correlation analysis was used to determine the factors related to student digital technology usage. Lastly, for RQ4, regression analysis was used to determine the capacity of measures of self-regulated learning to explain variation in college student academic performance and digital technology usage patterns together with the capacity of digital technology usage to explain variations in measures of self-regulated learning**.**

6.7.1 Independent sample t-tests

Independent sample t-tests were conducted to answer Research Question 1 (*How has digital technology usage changed from 2012 to 2020?*), and Research Question 2 (*How has the use of digital technologies changed self-regulation and self-regulated learning from 2012 to 2020?*). For Research Question 1, an independent sample t-test analysis was conducted to establish the significant changes in digital technology usage between 2012 and 2020. This involved examining the changes in students' frequency and duration of computer and mobile phone software application usage. Similarly, for Research Question 2, an independent sample t-test analysis was conducted to establish the significant changes in student self-regulation and self-regulated learning between 2012 and 2020, as well as to determine the significance of the change in self-regulation and self-regulated learning.

6.7.2 Partial correlation

A partial correlation analysis was conducted to answer Research Question 3 (*What factors are related to college student digital technology usage?)*. Partial correlations are a measure of the strength and direction of a linear relationship between variables whilst controlling for the effect of one or more control variables (Dalecki & Willits, 1991). In this instance, the control variable was the year. That is, by keeping the year constant, the study was able to eliminate the effect of the difference in year as a factor related to college student digital technology usage. As the data collection for the study occurred at separate points (2012 and 2020), controlling the year provided the ability to determine the relationship between student digital technology usage and self-regulation, self-regulated learning, academic performance, and student characteristics.

6.7.3 Regression analysis

While the results of the partial correlation analysis established the factors related to digital technology usage, a linear regression analysis of these results was used to determine the effect of digital technology usage in predicting self-regulation, self-regulated learning, and academic performance. Additionally, regression analysis allowed for the inclusion of more dependent variables that the correlation did not capture, as well as capturing the inter-relationship of the dependent variables (Klees, 2016).

6.8 ETHICAL CONSIDERATIONS

Ethical considerations in research refer to the ethical responsibilities that need to be followed during the processes of a research study (Creswell et al., 2007). According to the National Health and Medical Research Council of Australia (2007), the National Statement on Ethical Conduct in Human Research (NSECHR), ethical conduct in human research is to protect participants from harm, discomfort or inconvenience while ensuring the research is beneficial to society. The current research adhered to the values and principles of ethical research conduct as outlined by followed the ethical principles described by the NSECHR: (1) respect, (2) merit and integrity, (3) justice, and (4) beneficence. Respect for the participants was ensured as the research followed the guiding principles including maintaining participant anonymity (Section 6.8.2). Respect was maintained during the research by following all Curtin University research guidelines, with participants being provided informed consent, not being subject to coercion, and being briefed on the aims and objectives of the research. Additionally, works not belonging to the researcher have been acknowledged, and collected data stored according to Curtin University's Data Management Plan. The merit of the research was justified as the potential benefits of better understanding the link between student digital technology usage, self-regulation, self-regulated learning, academic performance, and student demographic characteristics have the potential to better inform the development of pedagogical approaches for promoting and enhancing student self-regulated learning.

Research integrity has been maintained by the justification of research philosophy, design, methodology, and comprehensive review of the literature. Justice was adhered to by ensuring the scope and objectives were appropriate, the participant recruitment process was fair, no unfair burden or exploitation of participants occurred, and that there is equitable access to the benefits of the research. According to the National Health and Medical Research Council (2007), "ethical conduct is more than simply doing the right thing. It involves acting in the right spirit, out of an abiding respect and concern for one's fellow creatures" (p. 3). The statement includes four guiding ethical principles: (1) research merit and integrity, (2) justice, (3) beneficence, and (4) respect. The current study adheres to these guiding principles. The research has merit without posing a risk to participants. Justice occurs because all students were equally invited to participate and the burden of participating in the research was not excessive (e.g., 30 minutes of free time). The study was designed to minimise student discomfort, and the participants were informed of the purpose, data required, and data collection methods so that they could make an informed decision to participate. Data was collected respectfully, ensuring that students understood their rights and that the data would remain confidential (i.e., anonymous). Ethics Approval was obtained from Curtin

University, and all specified Curtin University research guidelines, at the time the research was conducted, were followed. Appendix K presents a copy of the ethics approval letter.

Apart from myself, individual responses were only available to Curtin University doctoral supervisors, Associate Professor Susan Blackley, and Doctor Audrey Cooke. Additionally, the Western Australian pathway college was provided with a summarised version of the response rate for documentation purposes. All collected data will be retained for seven years, as per Curtin University policy. In keeping with the nature of the study and the disruption in the time-period of data collection, this study adhered to ethics guidelines on data storage and data will be retained for a minimum of seven years from the last data collection year (2020). Given that the researcher works at the college where the research was conducted, he is well-versed in the culturally sensitive treatment of research participants. Additionally, the researcher was aware that as a teaching staff member of the college, his position could possibly influence the recruitment of students and staff. To mitigate any undue influence, the researcher explicitly made students and staff aware that participation in the study was voluntary, anonymous, and their participation or non-participation would not impact their course outcomes (e.g., grades). Teaching staff were made aware of the time requirements of the data collection and were asked to volunteer their class for the study if it did not negatively disrupt classroom learning.

6.9 SUMMARY

Research methodology is an important aspect of conducting research. This chapter provided a rationale of the author's ontological and epistemological views, which underpinned the quantitative research design and methodology. Additionally, the research participants were identified (Section 6.3) and the research sample size justified (Subsection 6.3.1). A description of the instruments used in the study to collect data on student self-regulation, self-regulated learning, digital technology usage, and demographic characteristics was provided in Subsection 6.4.3. Next, the testing and refinement process of the instruments to ensure that the limitations of a quantitative approach were minimised was discussed in Section 6.5. The method of data collection using the Learning Management System Moodle, for 2012 and 2020, were outlined in Section 6.6 and data analysis methods were explained in Section 6.7. Lastly, ethical considerations necessary for research with human participants were identified in Section 6.8. The next chapter, Chapter 7, presents a statistical analysis of the data gathered in order to answer the research questions presented in this chapter.

Chapter 7: Data Analysis and Results

In Chapter 6, a discussion of the research methods used for the study and the rationale for the selected quantitative analysis were presented. As discussed, a quantitative approach was used for the quantitative repetitive study, which included collecting data via established instruments that were adapted for the study and administered online. These instruments were the Motivated Strategies for Learning Questionnaire (MSLQ), the National Assessment Plan – Literacy and Numeracy (NAPLAN), and the Cognitive Assessment System (CAS) planning subtest. Additionally, student characteristics, frequency and duration of digital technology usage were collected to address the four research questions.

This chapter presents the results of the statistical analysis applied to the data collected in 2012 (n = 105) and 2020 (n = 109). First, the convergent validity of the MSLQ and the NAPLAN assessments were established by analysing the internal correlations of the instruments. As explained in the previous chapter, the CAS Planning Subtest did not include scales or subscales; rather all 16 items measured a single construct, *planning*, and therefore were not expected to correlate. Similarly, the survey of student characteristics, frequency and duration of software application usage was not expected to correlate. Next, descriptive statistics resulted in five clusters of information describing each of the 214 college students' results in terms of: (1) academic performance, (2) digital technology usage, (3) student self-regulation levels, (4) student self-regulated learning levels, and (5) student characteristics. These five types of data were analysed to provide: (1) descriptive statistics of the scores of participants, (2) differences between the two groups (i.e., 2012 and 2020) in terms of digital technology usage, self-regulation, and self-regulated learning levels, (3) relationship between digital technology usage and self-regulation, self-regulated learning, academic performance, and student characteristics, and (4) the capacity of digital technology usage to predict self-regulated learning and academic performance.

The results of the data analysis in this chapter are organised according to the correlational analysis to establish reliability and validity of the MSLQ and NAPLAN instruments (Section 7.1), descriptive statistics of student scores (Section 7.2), independent sample-tests (Section 7.3), partial correlational analysis (Section 7.4), and linear regression analysis (Section 7.5).

7.1 CORRELATIONAL ANALYSIS – INTERNAL CONSISTENCY

Mishra et al. (2019) used parametric tests in an assessment of the normality of data. Parametric statistics that are equally distributed and in a numerical scale can also be used for an assessment of normality and distribution (Uchechi, 2019). Parametric tests were used in this research as the data collected were quantified and normally distributed. The MSLQ included two scales (i.e., metacognition and resource management), the resource management subscale consisted of four subscales (i.e., time and study, effort-regulation, peer learning, and help-seeking).

Table 4 reports significant correlations between the MSLQ scales and subscales for the 2012 and 2020 participants. In 2012, an analysis of the relationship between scales of self-regulated learning showed that *metacognition* and *resource management* scale scores correlated highly with the MSLQ total score (i.e., metacognition; $r = .86$, $p < 0.01$ and resource management; $r = .90$, $p < 0.01$). Similarly, for the 2020 group, correlations between measures of self-regulated learning, that is, the *metacognition* and *resource managemen*t scale scores correlated highly with the MSLQ total score (i.e., metacognition; $r = .78$, $p < 0.01$ and resource management; $r = .88$, $p < 0.01$). These high and significant correlations support the convergent validity among subscales measuring similar, though distinct, constructs related to self-regulated learning.

Table 4

Significant Correlations between MSLQ Scales and Subscales

2012 Participants

MSLQ Scales and Subscales	Metacognition	Resource management	Resource Management Subscales			
			Time and study	Effort - regulation	Peer learning	Help - seeking
Total SRL	.863**	.897**	.712**	.563**	.470**	.557**
Metacognition		.550**	.409**	.383**	.354**	.322**
Resource Management			.818**	.595**	.466**	.638**
Time and study				.253**		.243*
Effort - regulation					.265**	.308**
Peer learning						.208*

** $p < 0.01$; * $p < 0.05$

2020 Participants

MSLQ Scales and Subscales	Metacognition	Resource management	Resource Management Subscales			
			Time and study	Effort - regulation	Peer learning	Help - seeking
Total SRL	.787**	.876**	.664**	.456**	.373**	.558**
Metacognition		.392**	.322**			.331**
Resource Management			.738**	.598**	.481**	.573**
Time and study				.218*		
Effort - regulation					.271**	.219*
Peer learning						.296**

** $p < 0.01$; * $p < 0.05$

The National Assessment Program – Literacy and Numeracy instrument, which consisted of 20 literacy and numeracy items adapted from the Year 9 NAPLAN sample items (ACARA, 2012), was used as a measure of academic performance. Table 5 reports significant correlations between the MSLQ scales and subscales for the 2012 and 2020 participants. For the 2012 group of participants, significant correlations emerged between total academic performance scores and each of the composite scales. That is, as total performance scores increased, numeracy scale scores ($r = .774$, $p < 0.01$) and literacy scale scores ($r = .659$, $p < 0.01$) tended to increase. Additionally, literacy scores significantly correlated with each of the two subscale scores for Reading ($r = .731$, < 0.01) and Language Conventions ($r = .710$, < 0.01). Similarly, for the 2020 group, significant correlations emerged between total academic performance scores and each of the composite scales. That is, as total performance scores increased, numeracy scale scores ($r = .770$, $p < 0.01$) and literacy scale scores ($r = .767$, $p < 0.01$) tended to increase. Additionally, literacy scores correlated significantly with each of the two subscale scores for Reading Comprehension ($r = .807$, < 0.01) and Language Conventions ($r = .761$, < 0.01), suggesting good internal convergent validity among the NAPLAN instrument's subscales.

Table 5

Significant Correlations between Academic Performance Scales and Subscales

2012 Participants

	Numeracy	Literacy	Literacy Subscales	
			Reading	Language conventions
Total Performance	.774**	.659**	.519**	.429**
Numeracy				
Literacy			.731**	.710**
Reading				

** p < 0.01

2020 Participants

	Numeracy	Literacy	Literacy Subscales	
			Reading	Language conventions
Total Performance	.770**	.767**	.585**	.620**
Numeracy		.194*		.194*
Literacy			.807**	.761**
Reading				.231**

** p < 0.01, * p < 0.05

7.2 DESCRIPTIVE STATISTICS

In the following subsections, a description of student scores for the 2012 and 2020 participating groups is presented in terms of student demographics (7.2.1), self-regulation (7.2.2), self-regulated learning (7.2.3), academic performance (7.2.4) and frequency and duration of digital technology usage (7.2.5).

7.2.1 Student demographic characteristics

Student demographic characteristics are presented in terms of (1) age, (2) program enrolled, (3) number of trimesters at the pathway college, (4) academic English language support requirements, (5) duration of English language support required, (6) duration of time in Australia, (7) employment status, and (8) education of family members. Participants ranged from 16 to 42 years (2012), and 16 to 62 years (2020); however, most participants were between 18 and 21 years of age (80%, 2012; 73%; 2020). Of the two programs at the college, 25.7% of students in 2012 were enrolled in the Tertiary Preparation Program and 74.3% of the students were enrolled in the Diploma Program. By 2020, the Tertiary Preparation Program was renamed Stage One, in which 64.2% of the participants were enrolled. The Diploma program, now known as Stage Two, consisted of 35.8% of the participant enrolments. Participants in both groups reported that they had been enrolled at the college from between one to 10 trimesters (study periods), the majority, in 2012 being in with their first trimester (18.1%) or second trimester (50.5%,). In 2020, 23.9% of students reported that they were enrolled in their first trimester, and 34.9% reported that they were enrolled in their third trimester. As presented in Table 6, the majority of participants in both groups (2012 and 2020) were not required to enrol in the support classes. However, of the participants required to enrol in academic English support classes, the majority in 2012 were enrolled for less than 10 weeks of support classes, and in 2020, the majority were enrolled for between 10 to 15 weeks of support classes; see Table 6 and Table 7.

Table 6

Participants by Academic English Support Requirements

Academic English Course Requirements	(2012) %	(2020) %
I was not required to do an academic English course	55.2	74.3
I was required to do an academic English course	44.8	25.7

Table 7

Participants by Duration of English Support Requirements

Duration of English Support Requirement	(2012) %	(2020) %
Less than 10 weeks	18.1	3.7
10 to 15 weeks	14.3	12.8
15 to 20 weeks	8.6	4.6
More than 20 weeks	8.6	6.4

The duration of time participants had resided in Australia for both 2012 and 2020 groups, ranged from less than six months to "All my life" (Table 8). The 2020 participants who were students at the college but had not yet arrived in Australia (due to COVID-19 travel restrictions) identified their duration of time in Australia as less than six months.

Table 8

Participants by Duration of Time in Australia

Duration of Time in Australia	(2012) %	(2020) %
Less than 6 months	11.4	23.9
Between 6 months and 1 year	13.3	16.5
Between 1 year and 2 years	21.9	16.5
Between 2 years and 3 years	17.1	6.4
Between 3 years and 5 years	17.6	3.7
More than 5 years	7.6	12.8
Most of my life	1.0	6.4
All my life	10.5	13.8

Participant paid employment status, (see Table 9) ranged from *less than 5 hours per week* to *more than 20 hours per week*, and of the 2012 group, the majority did not have currently have any paid employment (32.4%), and for the 2020 group, the majority had never had paid employment (29.4%).

Table 9

Participants by Employment Status

Employment Status	(2012) %	(2020) %
Less than 5 hours a week	5.7	1.8
Between 5 to 10 hours a week	12.4	8.3
Between 10 to 15 hours a week	10.5	11.9
Between 15 to 20 hours a week	15.2	14.7
More than 20 hours a week	4.8	8.3
I currently do not have any paid employment	32.4	25.7
I have never had paid employment	19.0	29.4

Next, Table 10 presents the education level of the participants' immediate family members, and the majority of participants indicated that they have or had immediate family members who had completed university studies (60%, 2012;

65.1%, 2020). Lastly, Table 11 presents a summary of student demographic characteristics.

Table 10

Participants' Immediate Family Members' Education Level

University completion by family members	**(2012) %**	**(2020) %**
I do not have immediate family who have completed university studies	40.0	34.9
I have / had immediate family members who have completed university studies	60.0	65.1

Table 11

Summary of Student Responses

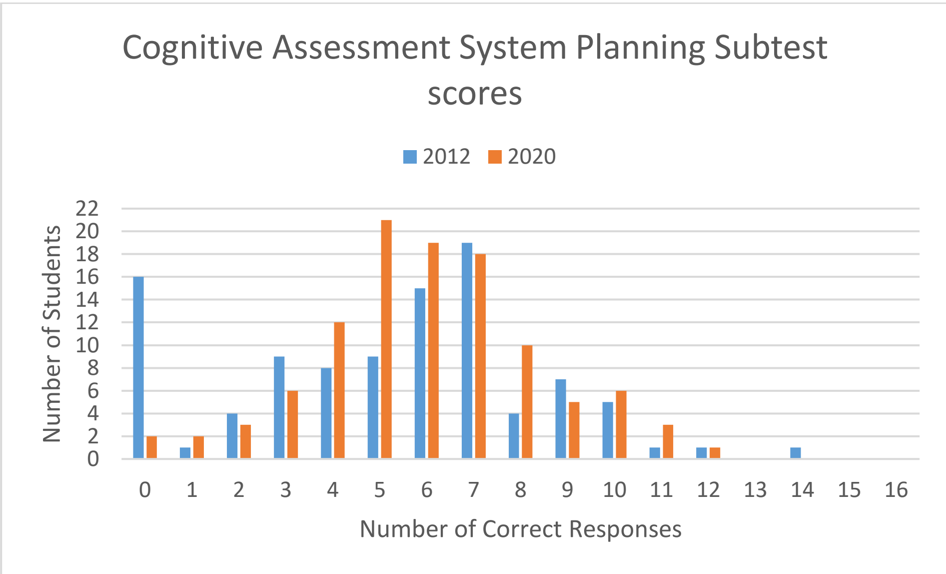
		2012	**2020**
Age	16 - 42	86% ≤ 21 years	88% ≤ 21 years old
Program	TPP / Stage 1	25.7%	74.3%
	DP / Stage 2	35.7%	64.3%
Number of study periods	Range between 1 – 10 trimesters	Majority in 2nd Trimester (50.5%)	Majority in 3rd Trimester (34.9%)
Academic English support course	Required	44.8%	25.7%
	Not Required	55.2%	74.3%
	Less than 15 weeks	32.4%	16.5%
Duration of time in Australia	Range between < 6 months to All my life	Majority was 1 – 2 years (21.9%)	Majority was 0 < 6 months (23.9%)
Employment status	No current paid employment	32.4%	29.4%
Education of family members	University Qualification	60%	65.1%

7.2.2 Self-regulation

Self-regulation was measured using the Cognitive Assessment System (CAS) Planning subtest. This theoretically brain-based measure of self-regulation included 16 items adapted from the CAS Planning Subtest. Figure 12 presents a summary of the number of participating college students who achieved each possible score; that is, 0 to 16. For the 2012 students, the mean CAS Planning Subtest score was 5.19; the lowest was 0 and the highest was 14 (SD 3.15). Nineteen participants responded correctly to eight (i.e., half of the items) or more of the items, and 19 participants responded incorrectly to all items. For the 2020 students, the mean CAS Planning Subtest score was 6.04; the lowest was 0 and the highest was 12 (SD 2.38). Twenty-seven participants responded correctly to eight or more items and two students responded incorrectly to all items.

Figure 12

Number of Students Achieving each Adapted CAS Planning Subtest Score



7.2.3 Self-regulated learning

Self-Regulated Learning was measured using an abbreviated Metacognitive Strategies for Learning Questionnaire (MSLQ). Table 12 presents a descriptive summary of the MSLQ scores for the 2012 and 2020 participants, and it is noted that considerable variability existed within the sample of 105 college students in 2012 and the sample of 109 college students in 2020. Out of a possible total MSLQ score of 155, in 2012, student scores ranged from 59 to 120, and in 2020, student scores ranged from 50 to 100. A score of 100 in the MSLQ is 65% of the total achievable score; in 2012, 10 students scored 100 or more, and in 2020, four students scored 100 or more. The 2012 participants had a greater standard deviation compared to the 2012 group, indicating that there was a greater variation in scores from the mean for the 2012 group compared to the 2020 group.

Table 12

College Students' Scores on the Motivated Strategies for Learning Questionnaire (MSLQ)

2012 Participants

Scales and Subscales	Lowest	Highest	Mean	SD
Total (maximum 155)	59	120	83.71	13.45
Metacognition (maximum 60)	15	51	32.09	7.13
Resource management (maximum 95)	36	74	51.62	8.14
Time and study environment (maximum 40)	10	34	22.38	5.1
Effort-regulation (maximum 20)	6	17	10.78	2.2
Peer learning (maximum 15)	3	14	8.4	1.72
Help-seeking (maximum 20)	4	17	10.06	2.91

2020 Participants

Scales and Subscales	Lowest	Highest	Mean	SD
Total (maximum 155)	50	100	75.44	10.31
Metacognition (maximum 60)	16	42	27.74	5.40
Resource management (maximum 95)	33	66	47.70	6.91
Time and study environment (maximum 40)	9	30	19.47	4.41
Effort-regulation (maximum 20)	5	15	10.14	2.10
Peer learning (maximum 15)	3	12	8.50	1.75
Help-seeking (maximum 20)	4	16	9.59	2.73

7.2.4 Academic performance

The measure of academic performance consisted of 20 literacy and numeracy items adapted from the Year 9 National Assessment Plan – Literacy and Numeracy (NAPLAN) practice items. Table 13 provides a descriptive summary of the NAPLAN scores for the participants. From a total Academic Performance score of 20, the 2012 group scored between 1 and 17 (mean = 7.8), and the 2020 group scored between 1 and 18 (mean = 8.76). This suggests that, overall, students in the 2020 scored higher on total academic performance scores compared to the 2012 group.

Table 13

College Students' Scores of the Academic Performance Measures

2012 Participants

Academic Performance Measures	Lowest	Highest	Mean	SD
Total academic performance (maximum 20)	1	17	7.8	2.58
Literacy (maximum 10)	1	10	4.1	1.63
Reading comprehension (maximum 5)	0	5	1.8	1.15
Language conventions (maximum 5)	0	5	2.3	1.11
Numeracy (maximum 10)	0	10	3.7	1.94

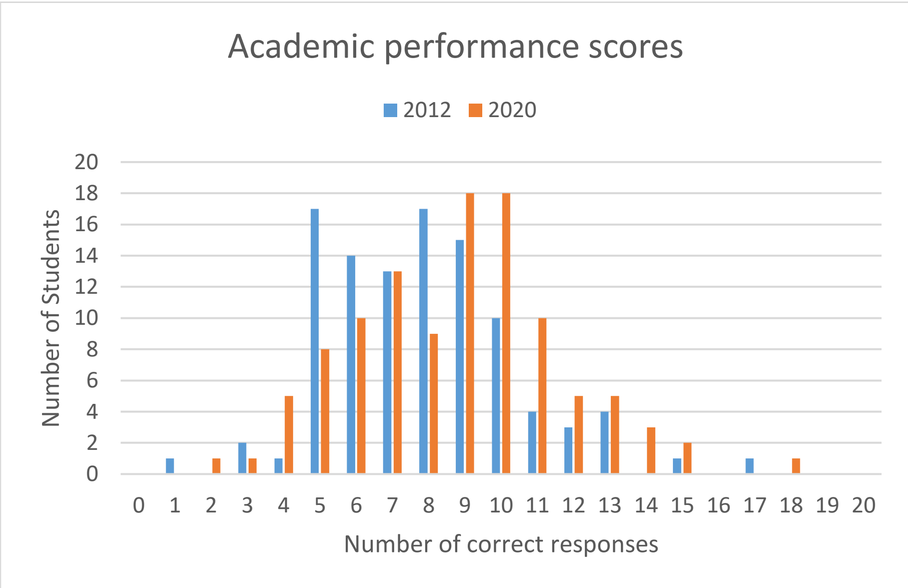
2020 Participants

Academic Performance Measures	Lowest	Highest	Mean	SD
Total academic performance (maximum 20)	1	18	8.76	2.88
Literacy (maximum 10)	1	9	4.90	1.87
Reading comprehension (maximum 5)	0	5	2.19	1.24
Language conventions (maximum 5)	0	5	2.71	1.13
Numeracy (maximum 10)	0	9	3.86	1.88

Figure 13 presents a graphical representation of the number of participants achieving each possible score on the total performance measures. Considerable variability on the measures of academic performance was apparent for the sample of 105 college students in 2012 and the sample of 109 college students in 2020. Out of the possible Total Academic Performance score of 20: in 2012, student scores ranged from one to 17, and in 2020, student scores ranged from one to 18. A score of 15 in Total Academic Performance is 75% of the total achievable score: in 2012, three students scored 15 or more on Total Academic Performance, and in 2020, two students scored 15 or more. In 2012, four students correctly answered four or less questions, and in 2020, seven students correctly answered four or less questions. This indicates that in 2012, there was a greater number of students who achieved in the "extremely high range", and in 2020 there was a greater number of students who achieve in the "extremely low range."

Figure 13

Number of Students Achieving each Score on the Academic Performance Measure



7.2.5 Digital technology usage

College student digital technology usage was analysed in relation to frequency (i.e., number of software applications accessed over a period) and duration (i.e., minutes of software application usage over period of time). Students accessed 12 specific software applications using a computer and / or mobile phone. The frequency of student computer software application usage for 2012 is presented in

Table 14 and Table 15. For the 2012 students, the frequency of all application software usage varied considerably (i.e., between *never or hardly ever* to *several time a day*); however, of the 12 specific software applications, music applications were used most frequently (i.e., 44.8% *every day or almost every day*). Similarly, for the 2020 students, the frequency of all application software usage varied considerably, however, of the 12 specific software applications, the frequency of schoolwork application usage had the highest rating (i.e., 45.0; *every day or almost every day*).

Table 14

College Students' Frequency of Computer Software Application Usage

2012 Participants (as % of the group)

Application Software	Frequency of Computer Software Application Usage				
	1	2	3	4	5
Games	25.7	13.3	33.3	16.2	11.4
Video chat	19.0	25.7	31.4	12.4	11.4
Text message	20.0	5.7	14.3	29.5	30.5
Email	5.7	14.3	33.3	31.4	15.2
Facebook	7.6	10.5	21.0	20.0	41.0
Images	5.7	10.5	30.5	25.7	27.6
Music	1.9	5.7	16.2	31.4	44.8
Movies	6.7	11.4	31.4	30.5	20.0
School work	2.9	2.9	41.9	41.9	10.5
YouTube	6.7	15.2	25.7	24.8	27.6
Shopping	16.2	34.3	36.2	8.6	4.8
Banking	10.5	37.1	37.1	10.5	4.8

1 = Never or hardly ever; 2 = A few times a month; 3 = A few times a week; 4 = Every day or almost every day; 5 = Several times a day

Table 15

College Students' Frequency of Computer Software Application Usage

2020 Participants (as % of the group)

Application Software	Frequency of Computer Software Application Usage				
	1	2	3	4	5
Games	37.6	15.6	22.0	17.4	7.3
Video chat	20.2	21.1	33.0	22.9	2.8
Text message	22.0	17.4	18.3	12.8	29.4
Email	1.8	8.3	34.9	37.6	17.4
Facebook	39.4	14.7	16.5	12.8	16.5
Images	13.8	21.1	25.7	22.9	16.5
Music	14.7	13.8	22.0	23.9	25.7
Movies	9.2	22.0	27.5	26.6	14.7
School work	.9	2.8	18.3	45.0	33.0
YouTube	6.4	10.1	18.3	34.9	30.3
Shopping	18.3	37.6	31.2	6.4	6.4
Banking	36.7	31.2	19.3	9.2	3.7

1 = Never or hardly ever; 2 = A few times a month; 3 = A few times a week; 4 = Every day or almost every day; 5 = Several times a day

Descriptive statistics of individual student ratings of frequency of mobile phone software application usage for 2012 and 2020 participants are presented in Table 16 and Table 17. Similarly, for both data collection periods, the frequency of student application software usage was diverse (i.e., between *never or hardly ever* to *several times a day*). However, in both periods, the frequency of text messaging usage received the highest (i.e., 57.1% (2012) and 65.1% (2020); *several times a day*).

Table 16

College Students' Frequency of Mobile Phone Application Software Usage

2012 Participants (as % of the group)

Application Software	Frequency of Mobile Phone Software Application Usage				
	1	2	3	4	5
Games	24.8	20.0	23.8	21.0	10.5
Video chat	39.0	20.0	21.0	9.5	10.5
Text message	1.9	3.8	7.6	29.5	57.1
Email	13.3	13.3	26.7	24.8	21.9
Facebook	13.3	5.7	16.2	19.0	45.7
Images	11.4	7.6	27.6	21.0	32.4
Music	9.5	2.9	20.0	24.8	42.9
Movies	42.9	17.1	17.1	7.6	15.2
School work	40.0	21.9	23.8	8.6	5.7
YouTube	21.0	19.0	28.6	17.1	14.3
Shopping	42.9	29.5	16.2	6.7	4.8
Banking	32.4	18.1	29.5	13.3	6.7

1 = Never or hardly ever; 2 = A few times a month; 3 = A few times a week; 4 = Every day or almost every day; 5 = Several times a day

Table 17

College Students' Frequency of Mobile Phone Application Software Usage

2020 Participants (as % of the group)

Application Software	Frequency of Mobile Phone Software Application Usage				
	1	2	3	4	5
Games	32.1	19.3	15.6	16.5	16.5
Video chat	11.9	18.3	27.5	26.6	15.6
Text message	2.8	2.8	5.5	23.9	65.1
Email	1.8	10.1	23.9	34.9	29.4
Facebook	22.9	7.3	17.4	22.0	30.3
Images	0.9	7.3	17.4	39.4	34.9
Music	0.9	0.9	9.2	30.3	58.7
Movies	11.0	22.0	27.5	15.6	23.9
School work	29.4	19.3	22.0	16.5	12.8
YouTube	10.1	5.5	16.5	30.3	37.6
Shopping	14.7	25.7	30.3	14.7	14.7
Banking	11.0	26.6	22.9	19.3	20.2

1 = Never or hardly ever; 2 = A few times a month; 3 = A few times a week; 4 = every day or almost every day; 5 = Several times a day

Table 18 and Table 19 provide descriptive information on individual student responses for the duration of application software usage on a computer and mobile phone. The duration of application software usage varied substantially (i.e., between *never* or *hardly ever* to *several times a day*). Of the 12 specific software applications, the majority of the 2012 participants reported that they spent the longest duration of time accessing movies, music, and gaming applications (i.e., 38.1%, 27.6%, and 27.6% respectively; more than 60 minutes per day), while the majority of the 2020 participants reported that they spent the longest duration of time accessing schoolwork, YouTube, and movie applications (i.e., 46.8%, 46.8%, and 43.1% respectively; more than 60 minutes per day). The least duration of time (2012) was accessing of shopping, banking, and email software applications (i.e., 40.0%, 39.0%, and 33.3% respectively; 0 to 5 minutes per day), whilst for the 2020 participants it was accessing Facebook, banking, and gaming software applications (i.e., 32.1%, 29.4%, and 25.7% respectively; 0 to 5 minutes per day).

Table 18

College Students' Scores on Duration of Computer and Mobile Phone Application Software Usage

2012 Participants (as % of the group)

Application Software	Duration of Computer and Mobile Phone Application Software Usage				
	1	2	3	4	5
Games	27.6	9.5	17.1	18.1	27.6
Video chat	29.5	13.3	23.8	17.1	16.2
Text message	12.4	20.0	26.7	17.1	23.8
Email	33.3	41.0	15.2	7.6	2.9
Facebook	19.0	21.0	22.9	15.2	21.9
Images	25.7	35.2	24.8	10.5	3.8
Music	7.6	10.5	25.7	28.6	27.6
Movies	22.9	5.7	17.1	16.2	38.1
School work	16.2	11.4	23.8	21.9	26.7
YouTube	14.3	21.9	26.7	18.1	19.0
Shopping	40.0	21.9	21.9	3.8	12.4
Banking and bill payment	39.0	36.2	19.0	2.9	2.9

1 = 0 to 5 minutes; 2 = 5 to 15 minutes; 3 = 15 to 30 minutes 4 = 30 to 60 minutes; 5 = greater than 60 minutes

Table 19

College Students' Scores on Duration of Computer and Mobile Phone Application Software Usage

2020 Participants (as % of the group)

Application Software	Duration of Computer and Mobile Phone Application Software Usage				
	1	2	3	4	5
Games	25.7	9.2	11.0	21.1	33.0
Video chat	19.3	14.7	13.8	14.7	37.6
Text message	8.3	9.2	27.5	27.5	27.5
Email	12.8	43.1	28.4	11.0	4.6
Facebook	32.1	12.8	14.7	21.1	19.3
Images	22.0	29.4	32.1	13.8	2.8
Music	4.6	6.4	21.1	27.5	40.4
Movies	11.9	15.6	11.0	18.3	43.1
School work	4.6	3.7	15.6	29.4	46.8
YouTube	8.3	8.3	17.4	19.3	46.8
Shopping	18.3	21.1	33.0	18.3	9.2
Banking and bill payment	29.4	36.7	23.9	5.5	4.6

1 = 0 to 5 minutes; 2 = 5 to 15 minutes; 3 = 15 to 30 minutes 4 = 30 to 60 minutes; 5 = greater than 60 minutes

7.3 INDEPENDENT SAMPLE T-TEST

An independent sample t-test analysis provided a comparison of the frequency and duration of student computer and mobile phone digital technology usage between 2012 and 2020, and identified the significance of these changes. Independent sample t-tests were also applied to compare the differences in student self-regulation and self-regulated learning levels between 2012 and 2020 as well as identifying the significance of these differences. An independent sample t-test is a parametric testing method that is used to analyse two different groups (Kent State University Libraries, 2021; Samuels & Gilchrist, 2014). Of the data collected in the study, the variables (frequency and duration of digital technology usage) had been compared between the years 2012 and 2020.

7.3.1 Comparison of digital technology usage in 2012 and 2020

Table 20 provides a comparison of the frequency of computer application software usage. The mean frequency of usage of Facebook, imaging, music, and banking are all significantly higher during 2012 compared to 2020, while the frequency of usage of computer software for schoolwork is higher in 2020 compared to 2012. This indicates a shift in the frequency of college student software application usage from 2012 and 2020, most likely due to the transition from traditional face-to-face learning settings to fully online and blended learning settings.

Table 20

Comparison of Frequency of Computer Software Application Usage by Year (2012 vs 2020)

Computer Software Application usage	**N**	**Mean**	**Mean difference**	**T**	**Significance**
Facebook					
2012	105	3.76	1.24	6.424	.000
2020	109	2.52			
Images					
2012	105	3.59	0.52	3.080	.002
2020	109	3.07			
Music					
2012	105	4.11	0.79	4.794	.000
2020	109	3.32			
Schoolwork					
2012	105	3.54	-0.52	-4.554	.000
2020	109	4.06			
Banking					
2012	105	2.62	0.50	3.477	.001
2020	109	2.12			

Table 21 shows that 10 out of 12 applications displayed a significant change in the frequency of mobile usage between 2012 and 2020. Games and text messaging were not significant, implying that there was no difference in the frequency of mobile phone usage for text messaging and games. For the significant applications, only the frequency of mobile phone usage for Facebook had a positive difference; the other nine software applications had a *negative* difference. This indicates that the use of mobile phones for Facebook was more frequent during 2012 compared to 2020, while other applications like YouTube were more frequently used in 2020 compared to 2012. The increase in frequency of mobile phone software application usage in 2020 could be attributed to the advances in mobile phone technology, including accessibility and convenience.

Table 21

Comparison of the Frequency of Mobile Phone Software Application Usage by Year (2012 vs 2020)

Mobile Phone Software Application usage	N	Mean	Mean difference	T	Significance
Video chat					
2012	105	2.32	-0.83	-4.687	.000
2020	109	3.16			
Email					
2012	105	3.29	-0.51	-3.163	.002
2020	109	3.80			
Facebook					
2012	105	3.78	0.49	2.408	.017
2020	109	3.29			
Images					
2012	105	3.55	-0.45	-2.832	.005
2020	109	4.00			
Music					
2012	105	3.89	-0.56	-3.911	.000
2020	109	4.45			
Movies					
2012	105	2.35	-0.84	-4.393	.000
2020	109	3.19			
Schoolwork					
2012	105	2.18	-0.46	-2.586	.010
2020	109	2.64			
YouTube					
2012	105	2.85	-0.95	-5.326	.000
2020	109	3.80			
Shopping					
2012	105	2.01	-0.88	-5.362	.000
2020	109	2.89			
Banking					
2012	105	2.44	-0.67	-3.833	.000
2020	109	3.11			

As shown in Table 22, the duration of computer and mobile phone application usage in 2020 significantly increased for video chat, text messaging, email, music, schoolwork, YouTube, and shopping. Similar to the frequency of mobile phone software application usage, the duration of mobile phone application usage could also be attributed to the advances in mobile phone technology, including accessibility and convenience.

Table 22

Comparison of Duration of Software Application Usage by Year (2012 vs 2020)

Duration of Software Application usage	**N**	**Mean**	**Mean difference**	**T**	**Significance**
Video chat					
2012	105	2.77	-0.60	-2.883	.004
2020	109	3.37			
Text messages					
2012	105	3.20	-0.37	-2.107	.036
2020	109	3.57			
Email					
2012	105	2.06	-0.46	-3.286	.001
2020	109	2.51			
Music					
2012	105	3.58	-0.35	-2.150	.033
2020	109	3.93			
Schoolwork					
2012	105	3.31	-0.79	-4.572	.000
2020	109	4.10			
YouTube					
2012	105	3.06	-0.82	-4.577	.000
2020	109	3.88			
Shopping					
2012	105	2.27	-0.52	-2.978	.003
2020	109	2.79			

7.3.2 Comparisons of self-regulation and self-regulated learning between 2012 and 2020

Student Cognitive Assessment System Matching Numbers planning subtest results showed that the 2020 group scored *higher* compared to the 2012 group, suggesting that the 2020 group had significantly higher self-regulation compared to students in 2012. As a comparison, Table 23 presents the Motivated Strategies for Learning Questionnaire (MSLQ) scores for the 2012 and 2020 participating students. While students' Peer learning and Help-seeking scores for 2012 and 2020 had no significant differences, mean scores for Total MSLQ, Metacognition, Resource Management, Time, Study Environment, and Effort Regulation were significantly higher for the 2012 student groups.

Table 23

Comparison of Self-Regulated Learning: Motivated Strategies for Learning Questionnaire (MSLQ) Scores by Year (2012 vs 2020)

MSLQ	N	Mean	Mean difference	T	Significance
Total MSLQ					
2012	105	83.71	8.27	5.037	.000
2020	109	75.44			
Metacognition					
2012	105	32.10	4.35	5.020	.000
2020	109	27.74			
Resource management					
2012	105	51.62	3.92	3.804	.000
2020	109	47.70			
Time and study environment					
2012	105	22.38	2.91	4.465	.000
2020	109	19.47			
Effort regulation					
2012	105	10.78	0.64	2.189	.030
2020	109	10.14			

7.4 PARTIAL CORRELATION: FACTORS RELATED TO STUDENT DIGITAL TECHNOLOGY USAGE

Partial correlation analysis is used when there is a direct interaction between the variables, and for comparing two continuous variables to each other (Allen et al., 2018; Kowalweski, 2018). Partial correlation was used in this study to measure the linear association between the factors related to digital technology usage. The use of partial correlation analysis, with the year as a control variable, allowed for the identification of factors that were related to college student digital technology usage. Partial correlational analysis showed that student characteristics (Section 7.4.1), student academic performance (Section 7.4.2), and self-regulated learning (Section 7.4.3) related to digital technology usage (Section 7.4.1). However, there was no relationship between self-regulation measures and digital technology usage.

7.4.1 Student characteristics and digital technology usage

In term of the frequency of computer software application usage, partial correlational analysis showed that nine of the 12 investigated student characteristics correlated with 10 of the 12 computer software applications. Student characteristics correlated negatively with the frequency of usage for six of the 10 computer software applications and correlated positively with the frequency of usage for five of the 10 computer software applications (Table 24). The use of Facebook and banking software applications had the most partial correlations with student characteristics (i.e., duration of English course and age).

As for the frequency of mobile phone software application usage, partial correlational analysis showed that six of the 12 investigated student characteristics correlated with six of the 12 mobile phone software applications. Table 24 shows that student characteristics correlated negatively with the frequency of usage for all six mobile phone software applications and correlated positively with the frequency of usage for three of the six mobile phone software applications. The use of Facebook, images, and banking software applications had the highest number of positive partial correlations with student characteristics (i.e., duration of English course, age, employment status, and family members' university qualifications).

For the duration of software application usage, partial correlational analysis showed that six of the 12 investigated student characteristics correlated with nine of the 12 software applications. As shown in Table 24 student characteristics correlated negatively with the duration of usage for eight of the nine software applications and correlated positively with the duration of usage for two of the nine software applications. The use of Facebook and schoolwork software applications had the highest number of positive partial correlations with student characteristics (i.e., duration of English course, age, and family members' university qualifications). This suggests that these software applications might be particularly relevant in college students' daily routine.

Table 24

Student Characteristics and Digital Technology Usage

Frequency of Computer Software Application Usage

	Games	Video Chat	Text Messages	Email	Facebook	Images	Music	Movies	School Work	YouTube	Banking
Number of trimesters at the college		-.250**									
Duration of English course					.263**	.173**				.188*	
Duration the respondent lived in Australia			-.176**								
Age					-.223**		-.197*	-.197*			.244**
Employment status											.178**
Have immediate family members who have completed uni									-.274**		

Frequency of Mobile Phone Software Application Usage

	Video Chat	Text Messages	Facebook	Images	Music	Banking
Type of program enrolled in	-.167*					
Duration of English course			.290**	.169*	.188**	
Age		-.262**	-.171**		-.218**	.195*
Employment status				.160*		.184*
Have immediate family members who have completed uni						-.238**

Duration of Software Application Usage

	Games	Video Chat	Text Messages	Email	Facebook	Movies	School Work	YouTube	Shopping
Number of trimesters at the college		-.163*							
Duration of English course					.221**				
Duration the respondent lived in Australia						-.187*	-.190*	-.179*	
Age					-.162*				
Have immediate family members who have completed uni				-.162*			-.183*		

*5% level of significance, **1% level of significance

7.4.2 Academic performance and digital technology usage

With regard to frequency of computer software application usage, partial correlational analysis showed that four of the five investigated academic performance measures correlated with six of the 12 computer software applications. As shown in Table 25, academic performance correlated *negatively* with the frequency of usage for all six of the computer software applications, and no positive partial correlations were found. The usage of banking software applications had the highest number of negative partial correlations with academic performance (i.e., Total Academic Performance, Literacy, and Language Conventions).

With regard to frequency of mobile phone software application usage, partial correlational analysis showed that four of the five investigated academic performance measures correlated with four of the 12 mobile phone software applications. As shown in Table 25, academic performance correlated negatively with the frequency of usage for all four of the mobile phone software applications; again, no positive partial correlations were found. The use of video chat software applications correlated with all four of the academic performance measures.

For the duration of software application usage, partial correlational analysis showed that four of the five investigated student characteristics correlated with three of the 12 software applications. As shown in Table 25, academic performance correlated negatively with the duration of usage for all three of the software applications; again, no positive partial correlations were found. The use of email and Facebook software applications had the most partial correlations with academic performance, and each correlated with two separate academic performance measures.

Table 25

Academic Performance and Digital Technology Usage

Frequency of Computer Software Application Usage

	Text Messages	Facebook	Movies	YouTube	Shopping	Banking
Total, Literacy, Language Conventions,	-.154*					-.173*
Total, Literacy	-.183*					-.177*
Total, Numeracy		-.189**	-.159*	-.163*		
Total Academic performance		-.166*	-.139*	-.188**	-.135*	-.163*

Frequency of Mobile Phone Software Application Usage

	Video Chat	Movies	School Work	Shopping
Total, Literacy, Reading Comprehension	-.196**	-.169*		
Total, Literacy, Language Conventions,	-.139*		-.148*	-.184**
Total, Literacy	-.223**	-.151*	-.141*	-.191**
Total Academic Performance	-.176*			

Duration of Software Application Usage

	Email	Facebook	YouTube
Total, Literacy, Language Conventions,	-.162*		
Total, Literacy	-.167*		
Total, Numeracy		-.164*	-.161*
Total Academic Performance		-.143*	

*5% level of significance, **1% level of significance

7.4.3 Self-regulated learning and digital technology usage

With respect to the frequency of computer software application usage, partial correlational analysis showed that all of the investigated self-regulated learning measures correlated with nine of the 12 computer software applications. As shown in Table 26, self-regulated learning correlated negatively with the frequency of usage for four of the nine computer software applications and correlated positively with the frequency of usage for five of the nine computer software applications. The usage of schoolwork software applications correlated negatively with all self-regulated learning measures.

Partial correlational analysis showed that four of the seven investigated student characteristics correlated with the frequency of usage for five of the 12 mobile phone software applications. As shown in Table 26, self-regulated learning correlated negatively with the frequency of usage for two of the five mobile phone software applications and correlated positively with the frequency of usage for four of the five mobile phone software applications. The use of schoolwork software applications had the most partial correlations with self-regulated learning (i.e., Total MSLQ scores and Metacognition score), and all partial correlations were negative; that is, the more frequently students used schoolwork software applications, the lower they scored on the self-regulated learning instrument.

Partial correlational analysis showed that six of the seven investigated student self-regulated learning measures correlated with the duration of usage for four of the 12 software applications. As shown in Table 26, self-regulated learning correlated negatively with the duration of usage for one of the four software applications and correlated positively with the duration of usage for three of the four software applications. The use of schoolwork software applications had the most partial correlations with self-regulated learning, which were all negative partial correlations. Only the Effort-Regulation subscale scores and Peer Learning subscale scores did not correlate with the duration of schoolwork software application usage.

These partial correlational results indicate that the frequency and / or duration of digital technology usage was associated with student self-regulated learning scores, either positively or negatively. For example, as shown in Table 26, the frequency of gaming software application usage and student self-regulated learning scores are positively correlated; that is, as student frequency of gaming software application usage increases, MSLQ scores tend to increase. In contrast, the frequency of schoolwork application usage and student self-regulated learning scores are negatively correlated; that is, as student frequency of schoolwork application software usage increase, MSLQ scores tend to decrease.

Table 26

Self-Regulated Learning and Digital Technology Usage

Frequency of Computer Software Application Usage

	Games	Video Chat	Text Messages	Email	Images	Music	Movies	School Work	Shopping
Motivated Strategies for Learning Questionnaire	.213**	-.153*						-.377**	
Metacognition	.180**		-.156*	-.137*				-.240**	
Resource management	.188**	-.148*						-.397**	
Time and study environment	.138**				.138*	.145*	.171*	-.385**	.227**
Effort-regulation								-.143*	
Peer learning		-.140*						-.163*	
Help-seeking	.203**							-.202**	

Frequency of Mobile Phone Software Application Usage

	Games	Email	Images	Movies	School Work	Shopping
Motivated Strategies for Learning Questionnaire					-.145*	
Metacognition					-.149*	
Time and study environment			.170*	.138*		.144*
Help-seeking	.163*	-.146*				

Duration of Software Application Usage

	Games	Images	School Work	Shopping
Motivated Strategies for Learning Questionnaire	.210**		-.235**	
Metacognition	.178**		-.154*	
Resource management	.184**		-.244**	
Time and study environment			-.223**	.186**
Effort-regulation		.141*		
Help-seeking	.191**		-.141*	

*5% level of significance, **1% level of significance

7.5 LINEAR REGRESSION ANALYSIS

In Section 7.4, a partial correlational analysis determined the factors affecting student digital technology usage. These factors were student characteristics, academic performance, and self-regulated learning. Linear regression analysis was used to determine whether digital technology usage can predict some factors related to student's digital technology usage, namely self-regulated learning and academic performance.

7.5.1 Digital technology usage a predictor of self-regulated learning

Linear regression analysis identified that digital technology usage can predict student self-regulated learning metacognition. Presented in Table 27 the year (2012 or 2020), student frequency of computer schoolwork and text messaging application usage, frequency of YouTube mobile phone application usage, and duration of games application usage are accounted for. The year, duration of games application usage, and the frequency of YouTube mobile phone usage has a positive coefficient, whereas the frequency of computer schoolwork and text messaging usage has a negative coefficient. That is, for the year, there is a 4.48 increase in metacognition scores for participants in 2012. This suggests that a unit increase in the duration of gaming and frequency of mobile phone YouTube usage resulted in an increase in metacognition of .690 and .642 respectively.

Table 27

Self-Regulated Learning and Digital Technology Usage

	Metacognition	Time and Study Environment	Effort-Regulation	Peer Learning	Help-Seeking
R-squared	.196	.316	.046	.017	.070
(Constant)	31.989	27.663	11.574	9.560	11.154
Year (1=2012,0=2020)	4.480				
School Work (Computer)	-1.646	-2.401	-.485	-.291	-.609
Games (Duration)	.690				
Text Messages (Computer)	-.725				
YouTube (Mobile)	.642				
School Work (Duration)		-.733			
Shopping (Computer)		1.198			
Movies (Computer)		.644			
Images (Duration)			.304		
Games (Computer)					.382

7.5.2 Digital technology usage a predictor of academic performance

Linear regression analysis identified that digital technology usage can predict student academic performance. Table 28 shows that a change in student Reading Comprehension, Language, and Numeracy scores can be explained by the students' duration and / or frequency of usage of seven of the 36 software applications. For example, students' use of video chat and the year accounted for a 5.0% change in Reading Comprehension scores; that is, there was a -.505 decrease in Reading Comprehension scores for participants in 2020. Similarly, a unit increase in the frequency of mobile phone video chat software application usage resulted in a decrease in Reading Comprehension of .181.

Table 28

Academic Performance and Digital Technology Usage

	Reading	Language	Numeracy
R-squared	.050	.097	.064
(Constant)	2.765	2.517	4.309
Year (1=2012,0=2020)	-.505		
Video Chat (Mobile)	-.181		
Banking (Computer)		-.216	
YouTube (Duration)		.126	-.188
Text Messaging (Computer)		-.171	
Images (Computer)		.186	
Facebook (Computer)			-.247
Email (Mobile)			.250

7.6 CHAPTER SUMMARY

This chapter presented the statistical analysis applied to the collected data, including correlation, descriptive statistics, partial correlations, and linear regression analysis. Descriptive statistics clustered the data collected from the participants into academic performance, digital technology usage, levels of self-regulation and self-regulated learning, and student characteristics. From these clusters, the analysed data provided: (1) descriptive statistics of the scores for the sample of students, (2) differences between the two groups (i.e., 2012 and 2020) in terms of digital technology usage, self-regulation, and self-regulated learning levels, (3) relationship data for usage of digital technologies and self-regulation, self-regulated learning, academic performance, and student characteristics, and (4) data for usage of digital technologies in predicting self-regulated learning and academic performance. Additionally, the convergent validity of the MSLQ and the NAPLAN scales and subscales were determined by using internal correlations estimates. While this chapter presented the significant results of these analysis, results of additional correlational and independent t-tests, not specifically discussed in this chapter, are presented Appendix L and Appendix M. The next chapter, Chapter 8, presents an interpretation of the results and a discussion of how the results align with the literature, the research aims, and research questions.

Chapter 8: Discussion

In Chapter 7, the results of statistical analysis, including descriptive statistics of participants' characteristics, self-regulation and self-regulated learning levels, academic performance, and digital technology usage for 2012 and 2020 were presented. Additionally, a comparison of the changes in student digital technology usage, self-regulation, and self-regulated learning for the same period was presented. Next, the factors affecting student digital technology usage, that is student characteristics, academic performance, and self-regulated learning levels, were analysed, and lastly digital technology usage statistics for predicting student self-regulated learning and academic performance were given. The overall aim of the study was to examine the impact of advancements in digital technologies on student self-regulation and self-regulated learning, for students at a Western Australian pathway college. An understanding of the factors related to college students' usage of digital technologies has the potential to inform the development of a model for supporting student self-regulated learning by evaluating the learning environment from a college perspective, and the personal environment from student perspective. The collected data and ensuing analyses aimed to answer the research questions:

RQ 1: How has digital technology usage changed from 2012 to 2020?

RQ 2: How has the use of digital technologies changed self-regulation and self-regulated learning from 2012 to 2020?

RQ 3: What factors are related to college students' digital technology usage?

RQ 4: In what ways can digital technology usage predict self-regulated learning and academic performance?

The analysis of the data relating to Research Question 1 supported previous studies by indicating that digital technology usage, that is the duration and frequency of student software application usage, increased from 2012 to 2020. The data pertaining to Research Question 2 contradicted the notion that levels of self-regulation equate to self-regulated learning. The 2020 students showed an increase in self-regulation levels compared to the 2012 group; however, over the same time period, results indicated that student self-regulated learning levels decreased. The findings associated with Research Question 3 identified that certain digital technology usage positively correlated with the factors of college students' characteristics, academic performance, and levels of self-regulated learning, while other digital technologies correlated negatively with these factors. Lastly, the findings aligned with Research Question 4 determined that students' digital technology usage can predict students' levels of self-regulated learning and academic performance.

Current practices for supporting student self-regulated learning seem to involve: gaining an understanding of student levels of self-regulated learning behaviour, as discussed in Chapter 4; incorporating established pedagogies, as discussed in Chapter 5; and identifying digital technologies capable of reinforcing student self-regulated learning processes and providing a delivery medium that supports pedagogical practices. Although there has been much discussion regarding the capacity of digital technologies to support each phase of the self-regulated learning process, and for teaching, it is still fair to say that promoting and enhancing student self-regulated learning in digital learning environments has been challenging, especially during the COVID-19 period.

As previously discussed in Chapter 2, the transition from classroom face-to-face learning to online learning has been challenging and often rushed. A factor that is often mentioned is the importance of the digital competence of students to actively participate, and teaching staff to facilitate this participation. Unfortunately, this area is often overlooked in practice, and the new proposed model for assessing student self-regulated learning aims to expand on current models by considering the student's personal environment (i.e., self-regulated learning behaviour, digital technology usage, and characteristics) and the learning environment provided by the educational institution (i.e., pedagogy, digital technologies, learning setting – face to-face / online / blended).

This chapter discusses the results of the study by comparing the data collected with established theories and frameworks, and the findings of previous studies.

Section 8.1 presents the implications concerning the changes in the duration and frequency of usage of digital technologies for college students in 2012 and 2020, and Section 8.2 outlines how the use of digital technologies has impacted self-regulation and self-regulated learning in 2012 and 2020. The impact of these changes is discussed and a dual model of assessing self-regulation is proposed. In Section 8.3 there is a discussion of the factors related to student usage of digital technologies, and Section 8.4 explores the capacity of student usage of digital technologies to predict self-regulated learning and academic performance. The limitations of the study are then addressed, and the chapter concludes with a brief summary.

8.1 RESEARCH QUESTION 1: HOW HAS DIGITAL TECHNOLOGY USAGE CHANGED FROM 2012 TO 2020?

The first research question of the study aimed to contribute to the literature on the advancements of digital technologies taking place in the last decade (2012 – 2020) by analysing whether these have been accompanied by a change in its usage. As discussed in Chapter 2, there have been significant changes in digital technologies within the last decade. These included changes to hardware for computers and mobile phones in terms of power, performance, and storage size (Alsop, 2021; Liu, 2021; Microsoft, 2021). The results, reported in Chapter 7, were obtained by using independent sample t-tests to compare the frequency and duration of computer and mobile phone software application usage reported by students in 2012 and 2020. This section discusses how the usage of digital technologies has changed in 2012 and 2020 for the college students in terms of (1) duration of software application usage (Subsection 8.1.1), and (2) frequency of software application usage (Subsection 8.1.2).

8.1.1 Frequency of software application usage (2012 vs 2020)

The descriptive statistics (Chapter 7, Subsection 7.25) show that the frequency of mobile phone text messaging scored the highest usage scores compared to all other mobile phone software applications. This finding is not a surprise, as previous studies have identified the high level of mobile phone ownership and usage for text messaging in college students. For example, a survey of 235 college students by Pettijohn et al. (2015) found that 99.6% of the students owned mobile phones and 98% of them texted daily. The need to constantly check text messages has led to the development of the term *Textraphrenia*, which is an "addiction to text messaging" (Verma et al., 2014, p. 510), and can be used to describe a person's state of apprehension while waiting for a text message (Nehra et al., 2012). Additionally, from the independent sample t-test analysis, as shown in Table 21 (Chapter 7, Subsection 7.3.1), the mean scores of student frequency of mobile phone software application usage for video-chat, email, Facebook, image viewing, music, movies, schoolwork, YouTube, shopping, and banking showed a significant difference in frequency of use in 2020 compared to 2012.

Whilst the frequency of mobile phone music software applications usage had the highest mean in both 2012 (3.89) and in 2020 (4.45), all applications, *except* Facebook, were used more frequently in 2020. This data is in line with Anderson and Jiang's (2008) report for the Pew Research Center, which outlined the popularity of different online platforms among adolescents. Their findings showed that only roughly half (51%) of the adolescents interviewed said they used Facebook, notably lower than YouTube, Instagram, or Snapchat. Additionally, Zhang et al. (2017) suggested that due to the social interactions on online shopping platforms, this might negatively correlate with social media platforms such as Facebook. Results of this current study support Zhang et al.'s (2017) findings, as mobile phone shopping application usage increased, while mobile phone Facebook software application usage decreased.

Further, all computer software applications, *except* schoolwork, were more frequently accessed in 2012 than in 2020. This decrease in frequency for the majority of computer software applications seems to be attributed to the increase in the software application usage on mobile phones (Rashid & Ashgar, 2016). Again, accessing Facebook on computers had the largest decrease (32.89%) in the mean frequency of usage among all software applications in 2020. In contrast, the frequency of computer schoolwork software application usage in 2020 increased 14.69% from 2012. The increase in the frequency of computer schoolwork application usage is not surprising given that, as explained in Section 8.1.1, in view of the COVID-19 restrictions many students were forced to study online (Adedoyin & Soykan, 2020). In summary, of the software applications explored, only the frequency of schoolwork application usage and music software application usage *increased* in duration and frequency for both computer *and* mobile phone application usage. While the rationale behind the increase in schoolwork application in both duration and frequency has been described in Section 8.1.1 and could coincide with the occurrence of the COVID-19 pandemic, according to Rahimi and Park (2020), the increase in both duration and frequency of music software applications' usage can be attributed to the growth of on-demand music streaming as opposed to downloading. The researchers pointed out that technology and innovation have resulted in great energy and investment in the Internet architecture and applications of audio-streaming services. They also stated that the rise in paid music streaming service companies, such as Apple Music, MelOn, YouTube Music, Spotify, and SoundCloud, was responsible for the increase in the on-demand music streaming services revenue. It is suggested that the increased usage of streaming services may have been a result of home isolation, as a way of connecting with the outside world, and of passing the time whilst in isolation (Marston et al., 2020).

While image viewing and banking software did not show any significant change in terms of the duration of usage, the frequency of the software application usage significantly *decreased* on computers but significantly *increased* on mobile phones. This may be due to a global increase in popularity of apps, due to their computing power comparable to desktop computers (Wai et al., 2018). Amongst the total software applications examined, only one (schoolwork) of the 12 showed an increase in computer software application usage, and nine of the 12 (images, music, schoolwork, banking, video-chat, email, movies, YouTube, and shopping) showed an increase in mobile phone software application usage. This supports the findings of Brohl et al. (2018) that showed significant differences in generational preferences of digital technologies; that is, it was identified that younger generations used smartphones more often than older generations, whose preferences were for laptops and desktop PCs.

The current study expands the existing literature by investigating both duration and frequency of software application usage by college students, and by showing that, with specific regards to the latter, college student frequency of mobile phone software application usage far exceeds the frequency of computer software application usage. The advancements in mobile phone hardware and software applications have afforded users greater convenience and mobility, for example, compared to desktop and laptop software applications (Punchoojit & Hongwarittorn, 2017), and increased accessibility (Hinton, 2020), and these changes are likely to have contributed to a greater frequency of usage.; for example, Learning Management Systems were accessible via a mobile phone in 2020, but not in 2012.

While convenience, mobility, and accessibility are major advantages of mobile phone software applications, including educational software applications, the disadvantage appears to be *usability*. The physical dimensions, such as screen size of mobile phones, may make it difficult for student-centred learning, particularly in regard to participation or demonstration. In fact, a student-centred learning approach requires that the student play an active role in the learning and often involves contributions to discussions or demonstrations. Although participation can be achieved using audio, it is often difficult to physically contribute to a shared piece of work using a mobile phone. The increasing trend for mobile phone application usage by students has significant implications for educational providers. As discussed at the beginning of this chapter, online learning is no longer considered an alternative or supporting mode to learning but an essential delivery method, especially in light of the ongoing COVID-19 restrictions (Adedoyin & Soykan, 2020). As such, educational providers will need to review delivery methods to address the trends in mobile phone usage. In early studies, for example, Ianos and Oproiu (2017) and Teo (2019), it was identified that the technology should not stipulate pedagogy, rather support pedagogy. This principle could be achieved in a face-to-face learning environment where students have access to the necessary resources; however, due to COVID-19, the technological resources and pedagogical practices of teachers changed significantly. Although technology should not dictate pedagogical approaches, for effective learning to occur the accessibility, practicality, and limitations of the technology must be considered. Additionally, digital technologies, as documented in the literature, may hinder student learning and self-regulated learning experiences. For example, the sheer volume of digital resources available to students, which have been made more convenient and accessible by mobile phones, contributes to learning distractions. Therefore, educational providers need to evaluate the suitability of learning software applications with regard to student self-regulated learning needs, discussed in the next section.

8.1.2 Duration of software application usage

The descriptive statistics (Chapter 7, Subsection 7.2.5, Table 18 and Table 19) show that out of the software applications examined, the duration of movie, music, and gaming software applications occupied most of the students' time in 2012. In contrast, the majority of 2020 students spent the most of their time accessing schoolwork, YouTube, and movie software applications. While for 2012, these findings are not surprising as watching movies, listening to music, and gaming are time-consuming activities, for 2020, it could be suggested that COVID-19 affected students' online habits. That is, students may have spent more time on schoolwork software applications because the college's main learning mode was fully online classes. Also, YouTube and watching movies may have helped students in coping with the isolation they experienced and as a way to reduce stress, anxiety, and depression (Kiraly et al., 2020).

In regard to the independent sample t-test analysis, as shown in Table 21 (Chapter 7, Subsection 7.3.1), the mean scores of the duration of student software application usage had increased significantly in 2020 for the majority of software applications considered, namely: (1) video-chat (MD = -0.60), (2) text messaging (MD = -0.37), (3) email (MD = -0.46), (4) music (MD = -0.35), (5) schoolwork (MD = -0.79), (6) YouTube (MD = -0.82), and (7) shopping (MD = -0.52). As digital technologies continue to advance, it is likely that students' software application usage will also continue to increase, and, as such, educational providers must consider the impacts these may have on student learning, in particular, the highest increases in software applications: YouTube, schoolwork, and shopping, email, and video-chat.

YouTube had the greatest increase in duration of usage (26.80%, from a mean of 3.06 to 3.88) from 2012 to 2020. This could be a consequence of the COVID-19 pandemic, which caused governments to implement travel restrictions and home-based online learning. These arrangements prevented students from attending face-to-face classes and, as such, universities and many other educational providers were forced to digitalise the delivery of teaching content (Adedoyin & Soykan, 2020), and many educational institutions were not prepared for the sudden transition from the traditional learning environment to an online learning environment (Adedoyin & Soykan, 2020; Hodges et al., 2020; Strielkowski, 2020). Furthermore, the considerable decrease in offline contact, as a result of the government's policy of physical distancing and minimisation of unnecessary contact with other people during the pandemic, might have led people to seek alternative ways of connecting with others through use of digital technologies (Galea et al., 2020; O'Connell et al., 2021). It could be reasoned that YouTube, due to its social networking features that make it an ideal place to create, connect, collaborate (Chau, 2010), might have constituted one of the means for students to virtually connect with peers. The increase in the duration of YouTube usage could also be linked to the increased accessibility of YouTube between 2012 and 2020 due to the reliability and speed of Internet connection, and increased accessibility of hardware such as computers and mobile phones (Caron, 2016; Chin et al., 2019). In fact, in the period 2012 to 2020, Australian home average Internet speeds increased from 15.4Mbps to 58.83Mbps (Hinton, 2020; James, 2013), while Australian mobile phone Internet speeds increased from 3Mbps to 67.85Mbps (Hinton, 2020; Ranner and Mustaniemi, 2019). It is therefore posited that these developments may have contributed to the increase in the duration of the time students spent watching videos on YouTube. Additionally, due to the sudden change in the learning setting from face-to-face to online, educators may have embedded learning YouTube links into Learning Management Systems in order to provide students with supporting audio-visual content (see, for example, Rueda et al., 2017). Further, students may have accessed YouTube of their own accord to seek clarification on new learnings (see, for example, Jackman, 2019).

The increase of student *schoolwork* software application usage had the second largest percentage change (23.87%, from a mean of 3.31 to 4.10). As discussed above in relation to YouTube, the COVID-19 pandemic resulted in many educational providers transitioning from face-to-face learning to an online learning environment. In Australia, the increase in Internet speeds could have assisted with the transition, which may have been more difficult to achieve in 2012 compared to 2020. Additionally, in 2020, Learning Management Systems (LMSs) were more accessible than in 2012. For example, in 2012, LMS such as Moodle were only accessible via a computer; however, by 2020, they were supported by mobile phones (Peramunugamage et al., 2019), which provided greater flexibility and convenience for students. Finally, during pre-pandemic times, online education was not considered a mission-critical delivery mode for educational providers but rather a good-to-have alternative (Ribeiro, 2020; as cited in Adedoyin & Soykan, 2020); however; due to the global pandemic, it has become a priority rather than an alternative (Adedoyin & Soykan, 2020).

The usage of applications for *shopping* had the third largest increase in 2020 from 2012, that is, 23.87%, from a mean of 2.27 to 2.79. The United Nations Conference on Trade and Development (2019) indicated that e-commerce platforms such as Amazon and Alibaba have become increasingly popular. The COVID-19 pandemic has undoubtedly impacted upon people's online shopping behaviour; for example, a study by Grashuis et al. (2020) highlighted the decrease in the willingness of consumers to physically shop inside grocery stores during high rates of COVID-19 transmission. Furthermore, in this emergency scenario, many people discovered the safety and benefits of home deliveries, store pick-ups, and cashless payment to a point where online shopping and home deliveries have been classified as 'essential services' by several governments (Pantano et al., 2020). Additionally, the popularity of online shopping has been facilitated by emerging developments in technology as well as the increase in digitalisation, which has helped e-commerce platforms increase their reach and convenience (dos Santos et al., 2017).

Email also displayed a significant growth in usage duration from 2012 to 2020, with a difference of 21.84% from a mean of 2.06 to 2.51. These results align with previous findings; for example, a study by Rashid and Ashgar (2016), investigating the impacts of digital technologies on student academic performance and engagement, concluded that student email usage was the most used medium by college students for general communication with peers and teachers. Additionally, the shift to primarily online communication forms during the pandemic may have contributed to the increase in usage duration of emails, even potentially resulting in phenomena such as "email overload" for both educators and students (Redinger et al., 2020, p. 403).

Finally, video-chat showed a major increase in usage duration from 2012 to 2020, (21.66% increase from a mean of 2.77 to 3.37). The COVID-19 pandemic changes to instruction modes had an impact on video-chat usage due to the rapid transition from face-to-face to virtual interactions across many contexts. A study by Pfund et al. (2021) investigated how the Big Five traits (i.e., extroversion, agreeableness, openness, conscientiousness, and neuroticism) were associated with video-chat usage prior to and following the beginning of the pandemic. Results of the study showed that a higher extraversion trait was associated with greater video-chat usage prior to and following the beginning of the pandemic, while neuroticism predicted more frequent video-chat usage when accounting for age and the other Big Five traits (agreeableness, openness, and conscientiousness).

8.2 RESEARCH QUESTION 2: HOW HAS THE USE OF DIGITAL TECHNOLOGIES CHANGED SELF-REGULATION AND SELF-REGULATED LEARNING FROM 2012 TO 2020?

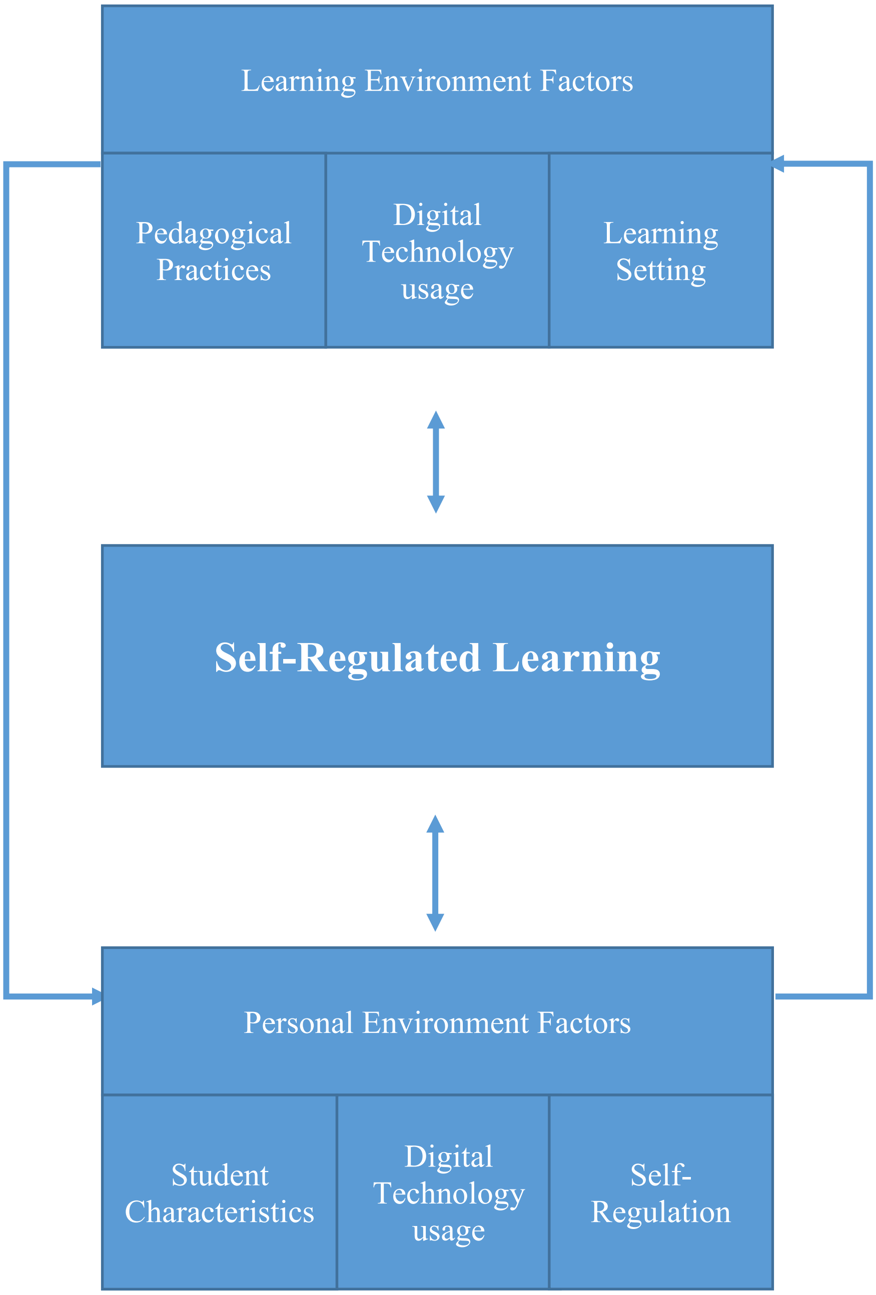
As discussed in Section 8.1, the period 2012 – 2020 has been characterised by significant changes in digital technologies and their usage by college students, particularly in terms of duration and frequency. The second research question of the study aimed to determine whether levels of self-regulation and self-regulated learning have also changed over the course of the same period. As illustrated by the literature review in Chapter 3, the current study conceptualised self-regulation in terms of student cognitive planning, while self-regulated learning was conceptualised as students' reported *application* of their cognitive planning. As such, specific instruments were selected for measuring the two constructs. Regarding self-regulation, the Matching Number Planning Subtest from the Cognitive Assessment System (Naglieri & Das, 1997) was used as a single score for student self-regulation (see Chapter 4, Subsection 4.1.1). Conversely, self-regulated learning was measured through a combination of selected scales included in the Motivated Strategies for Learning Questionnaire (see Pintrich et al., 1991), namely the metacognition scale, and the resource management scale, comprising time and study, effort regulation, peer learning, and help-seeking subscales, in addition to a total self-regulated score (see Chapter 4, Table 2).

The results of this current study have shown that student self-regulation *increased* from 2012 to 2020, while student self-regulated learning *decreased* during the same period. Although previous research identified a direct relationship between the level of student self-regulation and self-regulated learning (see Jivet et al., 2020; Schunk & Zimmerman, 2012; Zimmerman, 1986), the difficulty in encouraging students to apply their self-regulation to a learning task has also been noted. This was made even more difficult by the impact of COVID-19, and, as shown in studies by Strielkowski (2020) and Hodges et al. (2020), this transition was rushed and might have failed to take advantage of the affordances and possibilities of online formats, compounded by a potential lack of understanding of learning objectives and assessment requirements by students. This sudden change, along with the potential distractions associated with unregulated engagement with various digital technologies, makes it unsurprising that students struggled with self-regulated learning in 2020. Although the COVID-19 pandemic restrictions and restructuring of learning was a unique situation, it brings to light the disruption of sudden changes to educational processes and the importance of the learning process from a student perspective and the perspective of the educational provider. As discussed in Chapter 5, from a teaching perspective, various student-centred learning pedagogies such as brain-based learning, problem-based learning, and scaffolding have been developed through understanding student learning processes and student self-regulated learning (see Savery & Duffy, 1995; Shen & Tsai, 2008; Weiss, 2000). Additionally, as discussed in Chapters 3 and 4, various instruments have been developed to assess the level of student self-regulation, and self-regulated learning, such as the Cognitive Assessment System (CAS; Naglieri & Das, 1997) and the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1991), and this understanding allows teachers to focus on areas of weakness students may have. However, with all these models and theories, what seems to be lacking is the assessment of the technological resources and capabilities of the educational provider to support student learning in an online learning environment. As such, it is advisable that an assessment of the ability to support student self-regulated learning takes a holistic approach, in other words, it would include an assessment of the educational provider in supporting pedagogy and student self-regulated learning.

The impact of advancements in digital technologies on students' self-regulated learning is complex due to the interdependencies of factors affecting both. As indicated from the comprehensive review of the literature, digital technologies are one of several factors that contribute to student self-regulated learning. As stated previously, there are other factors that influence student self-regulated learning, and so a dual approach is proposed for assessing self-regulated learning, as illustrated in Figure 14, that assesses the student's personal environment and the educational learning environment of the educational institution.

Figure 14

Dual Model of Self-regulated Learning.



The Dual Model of Self-Regulated Learning consists of three interrelated layers, The self-regulated learning layer is central to the model, and it is affected by the surrounding layers, educational providers' learning environment and the student's personal environment. The educational providers' learning environment consists of: (1) pedagogical practices, (2) digital technology usage, and (3) learning setting. Pedagogical practices refer to the method of facilitation used to promote self-regulated learning strategies, including student-centred learning, scaffolded learning, provision of feedback, brain-based learning, or problem-based learning. Digital technology usage is the assessment of the hardware and software applications utilised in pedagogical practices in particular learning settings, as well as an assessment of the facilitators' or teachers' skills using the hardware and software applications. The learning setting refers the delivery method for the learning, for example, face-to-face learning utilising digital technologies, online learning, or blended / hybrid learning. The student's personal environment consists of (1) student characteristics, (2) digital technology usage, and (3) self-regulation. Student characteristics are individual student traits, digital technology usage refers to students' familiarity with hardware and software applications and usage habits, and self-regulation refers to the management of one's own behaviour. As illustrated in the model, the learning environment and the student's personal environment influence each other. For example, the pedagogical practices, utilisation of digital technologies, and type of learning setting adopted in the educational provider's learning environment influences all aspects of the student's learning behaviour. In turn, the student's personal environment including the student characteristics, developed through their experience; student's exposure to, and usage habits of digital technologies, and self-regulation traits influence their level of engagement with the learning environment. The areas stemming from the self-regulated learning layer show that the factors of both the learning environment and the personal environment influence the student's self-regulated learning behaviour. That is, student self-regulated learning can be enhanced when educators are aware of and can cater for the factors from both the student personal environment (i.e., student characteristics, digital technology usage, and self-regulation behaviour) and the educational providers' learning environment (i.e., pedagogical practices, digital technology usage, and learning setting). However, a lack of awareness of these factors can prevent the development of student self-regulated learning. Additionally, the self-regulated learning layer shows that a student's initial behaviour or attitudes towards self-regulated learning influences their level of engagement with the learning environment and their willingness to make changes to their *personal environment*.

The rationale behind an alternative method of promoting self-regulated learning is that current measures of self-regulated learning tend to address behavioural aspects of regulation. It has been suggested that these self-regulated learning scores can then be used by teachers and educational institutions to address areas in which self-regulated learning is lacking. However, as discussed in Chapter 5, digital technology competence in students and teachers has been identified as a pedagogical requirement. As such, it is important to develop a pedagogical framework for assessing student self-regulated learning in learning environments that rely on digital technologies. In light of this, the Dual Model of Self-Regulated Learning provides a framework for assessing the capacity of educational providers to support student self-regulated learning by evaluating the critical aspects of the learning environment and the student's personal environment. An evaluation of the practices and behaviours from both an education provider's perspective and the students' perspective would provide a better understanding of whether the factors of each environment support one another and promote self-regulated learning. The implications are that educational providers can use this model to evaluate their own *learning environment* and have an understanding of the *student's personal environment*, in order to determine whether current *pedagogical practices*, *usage of digital technologies*, and *learning settings* are ideal for supporting self-regulated learning, and if not, what needs to be changed. To do this, educational providers could utilise the Dual Model of Self-Regulated Learning as a checklist for assessing both domains that affect student self-regulated learning. For example, an assessment of the student's digital technology usage could identify their level of digital technology competence, and an assessment of the educational provider's pedagogical practices could determine whether it caters for students who need assistance with digital technology usage. Additionally, an assessment of the educational provider's digital technology usage could identify whether the digital technology is suitable for supporting the pedagogical practices. It is important for educational providers to undertake these assessment as they have the potential to provide a better understanding of the self-regulated learning support needed by the student and whether the educational institution is providing this support.

8.3 RESEARCH QUESTION 3: WHAT FACTORS ARE RELATED TO COLLEGE STUDENTS' DIGITAL TECHNOLOGY USAGE?

The third research question of the study aimed to investigate the factors that influenced college students' usage of digital technologies. As illustrated in Chapter 7, Section 7.4, the factors explored can be grouped into: (1) student and learning environment characteristics, (2) academic performance, and (3) self-regulated learning. The analysis involved the use of partial correlations to understand the relationship between aforementioned factors and usage of digital technologies, specifically in relation to the usage duration of software applications and usage frequency of both computer and mobile phone software applications.

As for the student and personal environment characteristics, the current study took into consideration the following student and learning environment characteristics: (1) number of trimesters attended at college, (2) length of English course, that is, the duration of English language course a student was required to enrol in prior to their commencement at the college, (3) type of program enrolled, that is, Stage One (formally Tertiary Preparation Program) or Stage Two (formally Diploma Program), (4) length of student's residence in Australia, (5) age, and (6) employment status and (7) having immediate family members who have completed university.

The duration of Facebook application usage positively correlated with the duration of the English language course but negatively correlated with age. These results are similar to the results found from a study by AbuSa'aleek (2015) into student use of social networking sites such as Facebook at a university in Saudi Arabia. The study surveyed 65 English as a Foreign Language (EFL) students to determine their perception of Facebook in EFL learning. The student self-reports showed that they believed that Facebook, as an online learning tool, facilitated, supported, and encouraged their English language learning. Additionally, the majority of students *agreed* or *strongly agreed* with the statement that their motivation and confidence improved as a result of using the Facebook application usage in their class. Negative relationships were found between student Facebook software application usage and age, which aligns with the literature indicating a decrease in Facebook usage, specifically in the teenage population (Anderson & Jiang, 2018).

The same negative trend was found between age and music software application usage, and age and movie software application usage. It is therefore suggested that these results are due to the popularity, in younger generations, of mobile phones as opposed to computers for carrying out most online activities. This was indeed supported by the following findings related to the frequency of mobile phone software applications, where a *negative* correlation between the frequency of music mobile phone applications and age was found. The remaining correlations of the study showed that software applications and the student characteristics all displayed a negative trend. Among these, a negative relationship was noted between students without family members having university qualifications and a low duration of schoolwork software usage. Indeed, as previously addressed in Subsection 8.2 of this chapter, a lower socio-economic status (which *might* in this case be implied by the absence of immediate relatives with a university degree), can negatively affect the student's online-learning experience for reasons such as having a poor Internet connection and/or low-quality or outdated devices (Adedoyin & Soykan, 2020).

A negative correlation was found between family university qualifications and the frequency of banking software applications usage, which seemed to be supported by the literature on the topic. That is, consumers who lack the technologies to use mobile and online banking, such as a smartphone and home Internet access (issues that are more frequently related to lower socio-economic status), are less likely to benefit from faster services delivery made available by mobile-phone banking apps (Hayashi & Toh, 2020). Overall, these findings have added to the existing literature by adding layers of analysis to the study of the relationship between software applications usage and specific student characteristics; for example, by taking into consideration the division between duration and frequency of usage, computer, and mobile phone software applications, as well as a wide range of different software applications and student characteristics. However, due to the complexity of such a research design, it is suggested that further studies should aim at reducing the number of software applications to be investigated when taking into consideration postsecondary school students as well as the students' characteristics that are most likely to affect the use of the software applications.

The duration of email, Facebook, and YouTube software application usage correlated *negatively* with the total academic performance scores, numeracy and literacy scales scores, and language conventions subscale scores. Similarly, computer software applications frequency of usage for text messaging, banking, Facebook, movies, YouTube, and shopping correlated *negatively* with total academic performance scores, numeracy, and literacy scale scores and language conventions subscale scores. These results support the literature on the relationship between the use of social network sites and academic performance; in particular, they aligned with previous studies showing a negative relationship between the use of social network sites for non-academic purposes and students' academic performance (Marker et al., 2018; Van Der Schuur et al., 2015).

On the same note, the frequency of mobile phone video-chat, movies, schoolwork, shopping, and movie software application usage correlated *negatively* with total academic performance scores, numeracy and literacy scales scores and language conventions subscale scores. These findings support the proposition that a negative relationship exists particularly between smartphone dependency and student academic performance (Amez & Baert, 2020; Gupta et al., 2016; Lin & Chiang, 2017; Longnecker, 2017; Rashid & Asghar, 2016; Samaha & Hawi, 2016 as cited in Kates et al., 2018). Similar to the literature mentioned above regarding software application usage duration, the key aspect in the association between smartphone usage and academic performance seems to be linked to the different purposes of mobile phone use. For example, Lau (2017) found a non-significant relationship between mobile phone use for academic purposes and student performance, while a statistically significant negative relationship was found between mobile phone use for non-academic purposes and academic outcomes. Therefore, while the negative correlation between the majority of computer and mobile phone software applications with academic performance is not surprising, it is posited that the specific negative relationship between schoolwork mobile-phone software application frequency and academic performance highlights the need for further investigation.

This study revealed mixed findings, that is, both positive and negative correlations between digital technology usage and college student self-regulated learning. As reported in Table 18 in Chapter 7, the frequency and duration of computer games software use *positively* correlated with almost all MSLQ scales. Conversely, the frequency and duration of schoolwork software application usage *negatively* correlated with all self-regulated learning scores (except effort regulation and peer learning subscale scores, which were not significant). These findings suggest that games might have a key role in improving self-regulated learning in students. Although this field of research is still emerging, several studies have demonstrated that games have an impact on student self-regulated learning variables, such as self-efficacy (Bergey et al., 2015; Jackson & McNamara, 2013). Furthermore, games seem to provide a learning context that promotes situational interest that may eventually lead to sustained personal interest (Nietfield, 2017), which might explain the positive correlation between self-regulated learning and both frequency and duration of usage. Finally, the frequency of mobile phone schoolwork and email software application usage correlated *negatively* with total MSLQ scores, metacognition scale scores, and time and study subscale scores.

Regarding schoolwork software application usage, the negative association between the frequency and duration of schoolwork usage and self-regulated learning is an important finding as it seems to contradict Zhao and Johnson's (2012) Comprehensive Model of Self-Regulated Learning with Web-Based Technologies, as discussed in Chapter 3. According to Zhao and Johnson (2012), web-based technologies would help promote student self-regulated learning and peer collaboration, as can be seen from the findings: the negative correlations showed that increases in student duration and frequency of digital technology usage resulted in *decreases* in self-regulated learning. However, Zhao and Johnson (2012, p. 5), noted that "self-regulated learning is enhanced when instructional strategies and delivery methods are embedded into the design and use of the technology". While this statement may be true, their comprehensive model does not address how the instructional strategies and delivery methods could be embedded in the design of the use of technology. The proposed Dual Model of Self-Regulated learning (see Figure 14), can serve as a framework for addressing whether the design of instructional strategies and delivery methods of an educational provider (i.e., learning environment) meets the needs of the students' personal environment in order to support and enhance student self-regulated learning.

Furthermore, the findings do not align with previous studies (see for example, Adeyinka & Mutula, 2010; Pollard et al., 2010; Sahin Kizil & Savran, 2016) indicating that digital technologies have the capacity to support self-regulated learning, for example, by facilitating the comprehension of academic learning requirements, guiding planning activities, and forming strategies. Although digital technologies have the capacity to support self-regulated learning, as mentioned previously, digital technologies alone do not guarantee the promotion of self-regulated learning in students. In order to support self-regulated learning, a combination of multiple factors is necessary: namely, the best-aligned digital technologies for specific learning purposes, a prepared and knowledgeable instructor, and an educational context where the students understand the reasons for using digital technologies (Drijvers, 2015). As such, the reason why the results of this study do not support the studies of Adeyinka and Mutula (2010), Pollard et al. (2010), and Sahin Kizil and Savran (2016) could be a result of a multitude of factors within the student's personal environment and the educational provider's learning environment. Overall, these findings highlight that there are still many unanswered questions on how to ensure that the impact of digital technologies can benefit the students' learning process and self-regulated learning. These mixed findings seem to be aligned with the literature suggesting that university and college students, even though they are frequent users of digital technologies, tend not to use digital technologies to regulate their own learning processes, thus dispelling the myth that "digital natives" are skilled in the use of digital technologies because they were born in the last two decades (Yot-Dominguez & Marcelo, 2017). As such, it is important for educational providers to not assume that university and college students do not need support in digital technology usage. Further study, for example, could examine how the aforementioned conditions (e.g., teachers' online teaching skills, students' digital skills, device conditions) impact the relationship between digital technology usage and self-regulated learning levels (e.g., as moderating or mediating factors).

8.4 RESEARCH QUESTION 4: IN WHAT WAYS CAN DIGITAL TECHNOLOGY USAGE PREDICT SELF-REGULATED LEARNING AND ACADEMIC PERFORMANCE?

The last research question of the study aimed to examine whether college student usage of digital technologies can predict self-regulated learning and academic performance. The analysis involved the use of a multiple linear regression model with digital technologies as the independent variable and student self-regulated learning scores, and academic performance scores as the dependent variables. In regard to self-regulated learning, findings showed that digital technologies, such as schoolwork, games and YouTube software application usage accounted for 19.6% of the changes in the metacognition score. Similarly, the 31.6% of time and study subscale score was explained by schoolwork (computer frequency and duration), shopping and movie software application usage. Finally, schoolwork software application usage frequency negatively predicts all self-regulated learning scale and subscale scores: that is, as the frequency of student schoolwork software applications usage increased, their self-regulated learning level *decreased*.

These results do not align with findings of previous research. For example, a study by Chen and Su (2019) found that the use of a software called BookRoll E-book had improved students' self-efficacy by encouraging them to activate self-regulated learning strategies, such as rehearsal. Similarly, Lazakidou and Retalis (2010) showed that a computer-based instructional method was effective in boosting self-regulated problem-solving skills in primary school students. A possible reason for this mismatch may be that self-regulated learning is not an innate trait and can be developed through instruction and coaching (Sitzman et al., 2009; Zimmerman, 2002). Further, teachers' beliefs about and understanding of self-regulated learning principles play a key role in students' development and implementation of self-regulated learning strategies (Alvi & Gillies, 2021). Hence, further research could investigate the aforementioned aspects in order to develop a full picture of the negative relationship between schoolwork software application frequency of usage, particularly on mobiles phones, and self-regulated learning scores. Another relationship worth touching upon is the *positive* correlation between YouTube and metacognition (64.2%); that is, the more frequently students used YouTube, the higher their levels of metacognition. This finding aligns somewhat with a previous study by Lei et al. (2015) showing that metacognition affected YouTube video searching behaviours: that is, students with higher metacognition skills used fewer keywords, browsed fewer videos, and spent less time evaluating videos, but they achieved higher learning performance. In other words, the fewer keywords the students used, the more efficient they were at searching, resulting in higher learning performances. Furthermore, students with higher metacognition were more focused, for they were less likely to watch videos on the video recommendations list that were irrelevant to the task requirements.

Overall, although the relationship was weak, the findings in this study showed that digital technology usage could predict student self-regulated learning behaviour. The findings also indicate directions for further research in determining which software applications are relevant in order to predict self-regulated learning, as well as, whether additional factors can explain the relationship between digital technologies and self-regulated learning. As for academic performance, the findings showed that higher duration of YouTube software application usage and frequency of image viewing software usage were more likely to predict the *literacy* component of academic performance. Literacy was less likely to be predicted when banking and text messaging software applications were frequently used. Furthermore, the frequency of mobile phone email software application usage was a predictor of the *numeracy* component of academic performance. Lastly, an increase in the frequency of computer banking and mobile phone video-chat software application usage may negatively impact the reading component of academic performance. However, the relationship between YouTube software application usage and students' literacy scores of this study support previous research that suggested the use of YouTube positively correlated with student literacy, see for example Almurashi's (2016) study of YouTube as a resource for helping students with their English lessons.

The other findings in the study do not seem to have been examined in previous literature; this could be due to varying interpretations of academic performance and the complexity of measuring digital technology usage. Therefore, as in the case of the self-regulated learning results, it is suggested that further studies are needed to narrow down the software applications that can be most relevant to the prediction of academic performance from a digital technology usage perspective.

8.5 LIMITATIONS

It is acknowledged that there are several limitations to this research. Firstly, findings from this study may not be applicable to different time periods other than 2012 and 2020. As a matter of fact, several times throughout the study it was suggested that the findings, particularly the ones collected in 2020, may have been affected by the COVID-19 pandemic outbreak. Next, there were limitations in the measurements used for this study.

Students' software application usage was measured using self-reporting questionnaires, which may not have represented a real picture of students' digital technology usage. Furthermore, students may have not been able to accurately distinguish between frequency and duration of software application usage. In regard to measuring student self-regulation and self-regulated learning, a selection of specific scales and subscales from established neurological and educational instruments were used. That is for self-regulation, the Matching Number (MN) Planning Subtest from the Cognitive Assessment System (CAS; Naglieri & Das, 1997) was used as a single score for student SR (see Chapter 4, Subsection 4.1.1), as a combination of selected scales were included in the Motivated Strategies for Learning Questionnaire (MSLQ; see Pintrich et al., 1991), namely the Metacognition scale, and the Resource Management scale, comprising time and study (TS), effort regulation (ER), peer learning (PL), and help-seeking (HS) subscales, and a total self-regulated learning score (see Chapter 4, Table 2). These were used in order to measure self-regulated learning; however, it could be argued that selecting only certain scales (due to time requirements) might have unintentionally affected the results. As such, the use of the same measurements in 2012 and 2020, instead for example an using an updated version of Naglieri and Das' (1997) Cognitive Assessment System, that is the Cognitive Assessment System Second Edition (CAS2; Naglieri & Otero, 2018) might have had an impact on the mixed results obtained. However, the rationale for using the same instruments in both 2012 and

2020 was justified as a necessity for comparing the scores of both study periods. As such, the findings should be limited to the instruments used.

Additionally, the use of the Year 9 National Assessment Plan – Learning and Literacy (NAPLAN) sample items was designed to assess student literacy and numeracy in Australian Year 9 students and not, as participated in this study, pathway college students from a mix of educational backgrounds. However, the use of the NAPLAN items was justified due to its practicality as a comparison of literacy and numeracy scores amongst the college students. Also, given the mixed educational backgrounds of the college students, it was thought that the items were appropriate for the study as the questions in the NAPLAN did not require Australian culturally-specific knowledge. Lastly, the literacy and numeracy items should have been comprehensible to the participating college students, as acceptance into the college required an IELTS score of 5.

Next, for a quantitative analysis, the sample size of the participating college students could be considered small; however, this is the nature of educational research. Finally, it could be argued that when investigating digital technologies, findings should also be limited to the geographical area where data have been collected. In fact, the particularly high speed of Internet connection in Australia mentioned at the beginning of this chapter might have influenced the usage frequency and duration of software applications from the students. In other words, findings cannot be generalised to countries or specific geographical locations where an Internet connection is considerably slower.

A mixed-method approach, including interviews, may have been useful for a deeper understanding the relationship between digital technologies, self-regulation, self-regulated learning, and academic performance. However, due to the number of variables measured, the time constraints, and number of participants in the study, it would not have been feasible to use both methods. Despite the aforementioned limitations, it is important to recognise that the results are still valid for the purpose of answering the research questions and they make a valuable contribution to the self-regulated learning research of the last decade, especially in the college student population of Western Australia.

8.6 SUMMARY

This study used a quantitative methodology to address the research questions and placed the findings in the context of the wider literature surrounding self-regulation and self-regulated learning. It was shown that digital technology usage increased from 2012 to 2020. Furthermore, it was found that the levels of self-regulation and self-regulated learning in college students did not match, with the level of self-regulation increasing from 2012 to 2020 and self-regulated learning decreasing over the same time span. This study did not align with previous research showing a direct relationship between self-regulation and self-regulated learning. Therefore, the Dual Model of Self-Regulated Learning was proposed as a new way to evaluate and consider the practices and behaviours from both the student' perspective and the educational provider's perspective to identify whether the factors of each domain support one another towards the promotion and enhancement of self-regulated learning.

In addition, both positive and negative correlations were found between college students' digital technology usage and (1) student characteristics, (2) academic performance, and (3) self-regulated learning levels. Lastly, it was shown that students' digital technology usage could predict their levels of self-regulated learning and academic performance. Implications of these findings were discussed, with recommendations made to further narrow down the number of software applications worth being considered when studying self-regulated learning, as well as refining the measurement of digital technology usage. Finally, the limitations of the study were highlighted, in terms of measurement methodologies for digital technology usage, self-regulation and self-regulated learning, the number of software applications taken into consideration, and generalisation of the findings to the geographical area. These limitations provided the basis for the suggestions for further research.

Chapter 9: Conclusion and Recommendations

Educational learning environments across all phases of learning have changed dramatically over the past two years, especially due to the travel restrictions imposed in many countries in an attempt to contain the COVID-19 virus. These changes include a greater degree of fully online and blended / hybrid learning. Online learning was once considered an alternative learning mode that provided students with the flexibility of attending class while not physically being present; however, it is now considered essential by many educational providers. Instead of only using a traditional face-to-face learning mode, the fully online or blended hybrid learning mode has been embedded in educational learning environments. Whether it be online, blended, or face-to-face learning, the use of digital technologies, self-regulation, and self-regulated learning is essential in the learning process. Numerous studies discussed throughout this thesis have shown that digital technologies have the capacity to support the learning process and self-regulated learning (see, for example, Shyr & Chen, 2018; Wang et al., 2021; Willey & Gardner, 2014; Zarrinfard et al., 2020).

Additionally, with progress in our understanding of the cognitive functioning of the brain and the processes required for self-regulation and self-regulated learning to occur, it is not surprising to see this knowledge incorporated into pedagogical theory and practice. For example, the utilisation of brain-based learning theory in teaching strategies was a result of research into how the brain ‘learns’ (Jenson, 2008), and as an outcome, the incorporation of brain-based learning pedagogical practices has been able to support and develop students’ learning and self-regulated learning behaviours (see Kriegeskorte & Douglas, 2018; Mayer, 2017; Mendoza et al., 2019). Also, the transition from a *teacher-centred* to *student-centred* pedagogical approach was the result of research that recognised the need for greater student involvement in their learning (see Di Felice, 2018; Radzali et al., 2018; Torrisi-Steele, 2020). Next, the acknowledgement of the need for real-world, simulated, and contextualised problems to motivate, focus, and initiate student learning saw the inclusion of problem-based learning practices (see, Akcay, 2009; Bergman et al., 2013; Gerrits & Wirtz, 2018; Shen et al., 2008). Lastly, research into *scaffolding* and *feedback* strategies, as a way to introduce students to new concepts and provide support when needed, showed that these practices developed student learning and self-regulated learning, as they provided students with the tools and resources to identify errors or misconceptions in their learning (Cheng et al., 2004; Crowther, 2020; Czocher et al., 2018; Gidalevich & Kramarski, 2019; Munshi et al., 2018; Perez-Sanagustin et al., 2020; Uribe & Vaughan, 2017).

Given the advances in digital technologies and pedagogical practices to support student learning, it is thefore concerning to see a decline in college student self-regulated learning. This current study, therefore, approached digital technology usage and the need to support self-regulated learning from a holistic view; that is, through the research questions introduced in Chapter 1, the study identified two domains affecting student self-regulated learning: (1) the student's personal environment, and (2) the educational provider's learning environment. The student's personal environment included the aspects of student characteristics, digital technology usage, and self-regulation; whilst the educational provider's learning environment included the aspects of pedagogical practice, digital technology usage, and learning setting. An understanding of both domains was crucial in the development of the Dual Model of Self-Regulated learning (see Chapter 8, Figure 14). The four research questions of this study were used to collect data to specifically examine the domain of the student's personal environment. Although the educational provider's learning environment is equally as important, due to the time and scope constraints of this research, data were not collected for this domain, but perhaps this can be an area for further research.

Research Question 1 informed the study of changes in digital technologies from 2012 to 2020 (Chapter 2). The study established that while computer and mobile phone software application usage both increased from 2012 to 2020, the increases in student mobile phone software application usage were greater than computer software application usage. That is, the frequency and duration of mobile phone software applications, including those being used for schoolwork, increased more than computer usage. These findings support the literature that asserted that advances in mobile phones from 2012 to 2020 including reliability, speed, accessibility, and convenience (see, for example, Hinton, 2020; Punchoojit & Hongwarittorrn, 2017) have contributed to greater mobile phone usage. Additionally, the increased capabilities of mobile phones to support a greater variety of software applications in 2020 compared to 2012, such as commonly used Learning Management Systems software applications (Al-Sharhan et al., 2020; Finch et al., 2021; Ilyas et al., 2017; Sulun, 2018; Turnbull et al., 2019) may have contributed to more college students choosing to use mobile phones for schoolwork instead of a computer. This is an important finding as it identifies one of the many factors that may have contributed to the decline in student self-regulated learning. Although the capability for accessing the college's Learning Management System using a mobile phone provided students with the convenience to do so, the use of the mobile phone (e.g., smaller screen size) may have resulted in ineffectiveness in engaging with related learning materials and requirements. Research Question 2 examined other factors related to student digital technology usage and self-regulated learning.

Research Question 2 led the researcher to consider additional factors of the student's personal environment that affected self-regulated learning, namely *student characteristics* and *self-regulation behaviour*. A significant finding in regard to RQ2 was that, while college students' self-regulation had increased from 2012 to 2020, college students' self-regulated learning decreased during the same period. These findings contradict the direct relationship between self-regulation and self-regulated learning reported in another research (see, for example, Jivet et al., 2020; Schunk & Zimmerman, 2008; Zimmerman,1986). This led the researcher of this current study to concluded that these additional factors, namely the pedagogical practices, available digital technologies, and an educational provider's learning environment (beyond the control of the student) contribute to students' self-regulated learning behaviour. As such, the Dual Model of Self-Regulated Learning (see Figure 14) was proposed as a framework for assessing the factors of both the student's personal domain and the educational provider's learning domain, in order to determine: (1) the self-regulated learning requirements needed, and (2) the capacity to support these self-regulated learning requirements. Next, Research Question 3 examined the factors influencing student digital technology usage.

Research Question 3 focused on the factors affecting students' usage of digital technologies, specifically in relation to student characteristics, academic performance, and self-regulated learning. In relation to student characteristics, there was an overwhelming number of negative correlations between the software applications examined in the study and student characteristics. A particular negative correlation worth noting was between the student characteristic *university qualifications of family members* and the duration of schoolwork software application usage. The study found that students who did not have immediate family members with a university qualification did not use the schoolwork software application as much as students who had. This finding is important as it shows that not only do parents or parental figures influence student usage of digital technologies (see, for example, Li et al., 2014; Park et al., 2008; Wang et al., 2018; Yen et al., 2015), but the student's usage of digital technologies is influenced by all members of the immediate family unit. Unfortunately, in the study, the definition of 'immediate family members' was not provided to the student participants, and, as they were from a range of different cultures, their interpretation of members of the immediate family may have been different to that of a Western definition.

Of the academic performance and digital technology usage correlations, most of the software application usages (e.g., computer Facebook and YouTube; mobile phone video chat, movies, schoolwork, and shopping) correlated *negatively*. These findings support the literature that determined that prolonged usage of social media sites negatively impacts upon academic performance (see, for example, Marker et al., 2018; Van Der Schuur et al., 2015), and that smartphone dependency negatively impacts upon academic performance (Amez & Baert, 2020; Gupta et al., 2016; Lin & Chiang, 2017; Longnecker, 2017; Rashid & Asghar, 2016; Samaha & Hawi, 2016 as cited in Kates et al., 2018). The only positive correlation identified was between student self-regulation and gaming software application usage, which supports the literature suggesting that games can reinforce students' self-regulated learning (see, for example, White & Frederiksen, 2005; White et al., 2009). These findings are significant as they serve to remind educators about the interrelationship of the factors within the student's personal environment and how they affect each other, and their influence on academic performance and self-regulated learning.

The findings collected in regard to Research Question 4 confirmed that student digital technology usage could predict student self-regulated learning, but not necessarily academic performance. In the current study, it was shown that students' use of schoolwork, games, shopping, movie, and YouTube software application usage accounted for their change in the self-regulated learning metacognition scale, and resource management, time, and study subscale scores. However, the most significant finding in this context was the *negative* relationship between students' schoolwork software application usage and self-regulated learning scores. In contrast to previous studies (see, for example, Lazakidou & Retalis, 2010; Chen & Su, 2019) suggesting a direct relationship between the level of student self-regulated learning and schoolwork, this current study showed that the more students utilised schoolwork software applications, the lower were their self-regulated learning scores. This inconsistent finding may be a result of a combination of factors that need to be explored from both the student's personal environment and the educational provider's learning environment perspectives (discussed further in Section 9.2, recommendations for further research).

9.1 IMPLICATIONS FOR PRACTICE FOR EDUCATIONAL PROVIDERS

As identified in this study, the student's personal environment, including their digital technology usage, individual characteristics, and self-regulation levels, are factors that influence student self-regulated learning. The findings of the study have significant implications for educational providers; firstly, the trend of student mobile phone usage for accessing software applications, including schoolwork, seems likely to continue (RQ1). It is therefore important for educational providers to recognise the need for learning materials to not only be compatible with mobile phones / smartphones but also to ensure that the use of the hardware can provide comparable learning experiences to those accessed via a computer. Much like the direction educational providers took transitioning from a teacher-centred to a student-centred pedagogical approach, it may be time to transition the delivery of the learning materials from traditional personal computers to mobile platforms such as mobile phones / smart phones. That is, to accept and embrace the popularity of the use of these devices amongst college students, and to look at not only advancing the accessibility of educational software applications on these devices but also the usability of the software applications on these mobile devices Next, in regard to RQ2, it was identified that, to be able to support and enhance student self-regulated learning, educational providers need to assess the factors that may prohibit students from achieving the self-regulated learning requirements expected of them. In this regard, the proposed Dual Model of Self-Regulated Learning provides guidance on ways to identify the factors that need to be assessed in terms of the student's personal environment. While the proposed model is still in its infancy and will need to be developed with further research, it does give educational providers a starting point for assessing the factors and responsibilities in both domains.

The findings associated with RQ3 showed various positive and negative correlations between student digital technology usage and student characteristics, academic performance, and self-regulated learning. It would be best practice for educational providers to understand these relationships in order to embed necessary self-regulated learning *resource management* skills into the aspects of the *learning environment* domain to address the digital technology usage that may hinder or promote student self-regulated learning and / or academic performance. Lastly, in regard to RQ4, there was an indication that digital technology usage can predict student self-regulated learning behaviour and academic performance, and this finding strengthens the implications discussed in the previous research questions. This section addressed the need for educational providers to be cognisant of changes in student digital technology usage and provide a guideline of the factors influencing student digital technology usage. The next section discusses the future research needed on the Dual Model of Self-Regulated Learning in order for provide specific assessable items for each domain.

9.2 RECOMMENDATIONS FOR FUTURE RESEARCH

The current research identified the impacts of changing digital technologies on students' learning and self-regulated learning in 2012 and 2020. The study's findings also suggested the need for a holistic approach in examining the factors affecting student self-regulated learning; namely the two domains of the Dual Model of Self-Regulated Learning – students' personal environment and educational providers' learning environment. While this study investigated the factors of the students' personal environment that may hinder or support student self-regulated learning, it did not provide details of how each of these factors could be assessed. As such, future research of the students' personal environment domain could be used for the development of an instrument to assess the self-regulated learning inhibitors or promotors for each domain factor. Additionally, while this study reviewed the literature on an educational provider's learning environment domain that may impact student self-regulated learning, it did not investigate the influence of this domain on college students' self-regulated learning, and so this could be an area of future research. Such an investigation may contribute to the development of an instrument for assessing the capacity of an educational provider's learning environment to support self-regulated learning. This instrument has the potential to offer educational providers a holistic measurement tool that provides information regarding potential inhibitors or promoters of self-regulated learning from the student's perspective (personal environment domain), and from an educational provider's perspective (learning environment domain), and information regarding its capacity to support self-regulated learning.

9.3 SIGNIFICANCE

The current study added to the existing literature on self-regulated learning by investigating this construct in pathway college students in Western Australia. Specifically, its novelty resulted from comparing levels of self-regulation and self-regulated learning from 2012 and 2020. Notably, this latter period of time has been affected by the COVID-19 pandemic that resulted in significant changes in educational systems, such as the shift from face-to-face to online learning. Another contribution of the current research was the investigation of the association between digital technology usage with a wide range of student-related factors (student personal and learning environment characteristics, academic performance, and self-regulated learning). In light of this, the researcher proposed a new model to explain the relationship between these factors, the Dual Model of Self-Regulated Learning (see Figure 14), specifically designed for learning environments relying on digital technologies. Furthermore, as the existing measures of self-regulated learning tend to address behavioural aspects of regulation from the students' point-of-view, the proposed model also takes into consideration the education provider's perspective in order to provide a better understanding of whether the factors of both the education provider and the student's environment support one another and promote self-regulated learning.

9.4 SUMMARY

This current study showed that the duration and frequency of student software application usage increased from 2012 to 2020, which is in line with the existing literature on the advancement of digital technologies in the last decade. Secondly, the study found that student self-regulation *increased* from 2012 to 2020, while student self-regulated learning *decreased* over the same period. These findings led the researcher to develop a new model for evaluating and explaining the factors affecting student self-regulated learning, specifically from a student's personal environment, and the educational provider's learning environment. Thirdly, it was found that some digital technology usage positively correlated with college students' characteristics, academic performance, and levels of self-regulated learning, while other digital technologies correlated negatively with these factors. Lastly, it was determined that students' digital technology usage can predict students' levels of self-regulated learning and academic performance.

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Appendices

Appendix A Reading Comprehension items

Item 1 **Hudson's address was part of**

A. An ongoing discussion of ideas.
B. An emotional publicity campaign.
C. An announcement of official policy.
D. Debate between meteorological experts.

Item 2 **What is Hudson's opinion of the idea that people should alter their habits? (paragraph 2)**

A. It is just another way of expressing his scheme.
B. It could be objected to by any reasonable person.
C. It is good in theory but could not be put into practice.
D. It would work well but would be expensive to implement.

Item 3 **When Hudson says, I am not aware that any systematic attempt has been made to lengthen the hours in summer on this account (last paragraph), he is**

A. Overstating his case.
B. Appealing to emotions.
C. Qualifying an assertion.
D. Contradicting his own opinion.

Item 4 **Which statement about public opinion is consistent with the underlying assumption in the text?**

A. It is too powerful to fight against.
B. It contains a lot of traditional wisdom.
C. It is a result of long, intelligent thinking.
D. It can be changed by good, rational arguments.

Item 5 **What method does Hudson use to deal with his opponents?**

A. He refers to expert opinion.
B. He ignores their arguments.
C. He raises doubts about their motives.
D. He points out errors in their arguments.

Appendix B Language Conventions items

Item 1 **Plucking the strings of a guitar makes _____ vibrate, and each produces a different range of notes.**

Which word correctly completes the sentence?

A. it
B. them
C. that
D. those

Item 2 **Which sentence has the correct punctuation?**

A. “Sorry I’m late, he apologised, but my car wouldn’t start.”
B. “Sorry I’m late” he apologised “but my car wouldn’t start.”
C. “Sorry I'm late,” he apologised, “but my car wouldn’t start.”
D. “Sorry I’m late,” he apologised, “But my car wouldn’t start.”

Item 3 **_____ sustained, a rainforest requires a rainfall of at least 1500 millimetres a year.**

Which words correctly complete the sentence?

A. If they have
B. In order to be
C. So they can be
D. Therefore being

Item 4 **Council plans for the new pool were approved _____ on Monday.**

Which option correctly completes the sentence?

A. last Friday: work will begin
B. last Friday, work will begin
C. last Friday; work will begin
D. last Friday! Work will begin

Item 5 **The three sports _____ cricket, netball and tennis ___ were played enthusiastically by the family.**

Which punctuation mark should be used in “both” spaces in the sentence?

A. - (dash).
B. : (colon).
C. … (ellipsis).
D. ; (semicolon).

Appendix C Numeracy items

Question 1. What is the median height?

In a gym class, 29 students took turns jumping.

Pete recorded the height each student jumped.

Height (cm)

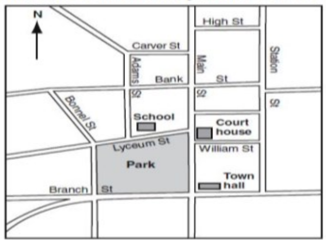
3	2 4
4	1 5 6
5	2 4 4 8 9
6	1 1 3 4 5 6 6 8 9
7	2 2 5 7 8
8	3 5 5
9	1 2

Key: 5|2 means 52

a. 63 cm b. 65cm
c. 64 cm d. 66cm

Question 2. Which street does Jill live in?

Jill lives in a street that runs directly north–south.
Her house is north of the park and west of the school.



a. Adam St b. Bonnel St
c. Station St d. Main St

Question 3. Which one of the following is equivalent to 2(5m + 1)?

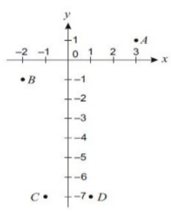
a. 7m + 1 b. 10m + 1
c. 10m + 2 d. 12m

Question 4. Jade buys a 500 gram bag of beads at a market. Each bead has a mass of 0.48 grams. Which of the following is the best estimate for the number of beads in the 500 gram bag?

a. 100 b. 250
c. 1000 d. 2500

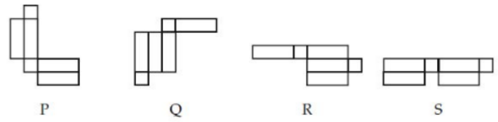
Question 5. Which two points will the straight line pass through?

The graph of $y = 2x - 5$ will be drawn on this grid.



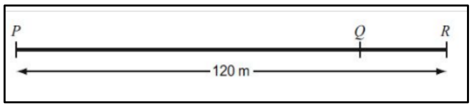
a. A and B b. B and C
c. B and D d. A and C

Question 6. Which two nets form a closed rectangular prism?



a. P and R b. P and Q
c. Q and R d. R and S

Question 7. The distance from P to Q is four times the distance from Q to R. What is the distance from Q to R?



a. 15 metres b. 20 metres
c. 24 metres d. 30 metres

Question 8. Sally has seen four movies. The ticket prices were \$13, \$8, \$10 and \$10. The next movie she plans to see is in 3D and the ticket price is \$34. Which of these will **not** change after Sally sees the movie?

a. The median of her ticket prices
b. The mean of her ticket prices
c. The range of her ticket prices
d. The total of her ticket prices

Question 9. A ticket costs \$75. A fee of 10% is added to the price. Which calculation will give the new price?

a. 75 + 10 b. 71 + 0.1
c 75 x 0.1 d. 75 x 1.1

Question 10. Which pair of values satisfies this inequality?

The height (h metres) and age (a years) of a tree are related by the following inequality:

$h < 4a - 3$ for values of a between 1 and 10

a. h = 2 and a = 1 b. h = 6 and a = 2
c h = 10 and a = 3 d. h = 20 and a = 6

Appendix D Frequency of computer software application usage items

Item 1	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to play *games*
Item 2	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to *video chat* (e.g., Skype, MSN)
Item 3	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to t*ext message*
Item 4	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to *email*
Item 5	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to *Facebook*
Item 6	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to access *images*
Item 7	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to access *music*
Item 8	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to access *movies*
Item 9	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to do *school work*
Item 10	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to access *YouTube*
Item 11	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet to s*hop*
Item 12	I use a COMPUTER, including a laptop, notebook or tablet for accessing the Internet do *banking*

Appendix E Frequency of mobile phone software application usage items

Item 1	I use a MOBILE PHONE to play *games*
Item 2	I use a MOBILE PHONE to access *video chat* (e.g., Skype, MSN)
Item 3	I use a MOBILE PHONE to access t*ext messages*
Item 4	I use a MOBILE PHONE to access my *email*
Item 5	I use a MOBILE PHONE to access *Facebook*
Item 6	I use a MOBILE PHONE to access *images*
Item 7	I use a MOBILE PHONE to access *music*
Item 8	I use a MOBILE PHONE to access *movies*
Item 9	I use a MOBILE PHONE to do *School Work*
Item 10	I use a MOBILE PHONE to access *YouTube*
Item 11	I use a MOBILE PHONE to *shop*
Item 12	I use a MOBILE PHONE to access *banking*

Appendix F Duration of software application usage items (on any device)

Item 1	On average, using your computer or mobile phone, how many minutes each day would you play *games?*
Item 2	On average, using your computer or mobile phone, how many minutes each day would you *video chat* (e.g., Skype, MSN)?
Item 3	On average, using your computer or mobile phone, how many minutes each day would you t*ext message?*
Item 4	On average, using your computer or mobile phone, how many minutes each day would you *email?*
Item 5	On average, using your computer or mobile phone, how many minutes each day would you use *Facebook?*
Item 6	On average, using your computer or mobile phone, how many minutes each day would you access *images?*
Item 7	On average, using your computer or mobile phone, how many minutes each day would you *spend accessing music?*
Item 8	On average, using your computer or mobile phone, how many minutes each day would you spend accessing *movies?*
Item 9	On average, using your computer or mobile phone, how many minutes each day would you spend doing *school work?*
Item 10	On average, using your computer or mobile phone, how many minutes each day would you spend accessing *YouTube?*
Item 11	On average, using your computer or mobile phone, how many minutes each day would you spend access *shopping?*
Item 12	On average, using your computer or mobile phone, how many minutes each day would you spend *banking?*

Appendix G Cognitive Assessment System Matching Numbers planning subtest items

Question 1

Match the following numbers

9682	6982	6928	6982	9628	6962
A	B	C	D	E	F

Question 2

Match the following numbers

7136	7613	7316	7163	7316	7631
A	B	C	D	E	F

Question 3

Match the following numbers

9513	9153	9135	9351	9531	9135
A	B	C	D	E	F

Question 4

Match the following numbers

4978	4979	4879	4897	4987	4979
A	B	C	D	E	F

Question 5

Match the following numbers

54639	54693	45639	54639	45936	54396
A	B	C	D	E	F

Question 6

Match the following numbers

38719	87139	38179	38197	38179	87319
A	B	C	D	E	F

Question 7

Match the following numbers

71234	72134	72143	74213	72134	71243
A	B	C	D	E	F

Question 8

Match the following numbers

83247	82347	83274	83247	83272	82374
A	B	C	D	E	F

Question 9

Match the following numbers

561837	516873	156783	516873	561793	651873
A	B	C	D	E	F

Question 10

Match the following numbers

173659	316795	137659	137659	136597	135679
A	B	C	D	E	F

Question 11

Match the following numbers

278943	278934	278943	278394	289743	278493
A	B	C	D	E	F

Question 12

Match the following numbers

941526	954261	951426	954126	951462	954126
A	B	C	D	E	F

Question 13

Match the following numbers

2713498	7124389	2731948	2713498	7213489	1273948
A	B	C	D	E	F

Question 14

Match the following numbers

8217459	8214795	8142975	2814579	8217954	8214795
A	B	C	D	E	F

Question 15

Match the following numbers

5286597	5863197	5865179	5869317	5863197	5682317
A	B	C	D	E	F

Question 16

Match the following numbers

7863159	7865319	7836519	7685319	7835619	7836519
A	B	C	D	E	F

Appendix H Abbreviated Motivated Strategies for Learning Questionnaire (MSLQ) Metacognition scale items

Item 1	During class time I often miss important points because I'm thinking of other things.
Item 2	When reading for this course, I make up questions to help focus my reading.
Item 3	When I become confused about something I'm reading for this class, I go back and try to figure it out.
Item 4	If course readings are difficult to understand, I change the way I read the material.
Item 5	Before I study new course material thoroughly, I often skim it to see how it is organised.
Item 6	I ask myself questions to make sure I understand the material I have been studying in class.
Item 7	I try to change the way I study in order to fit the course requirements and the instructors teaching style.
Item 8	I often find that I have been reading for this class but don't know what is was all about.
Item 9	I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying.
Item 10	When studying for this course I try to determine which concepts I don't understand well.
Item 11	When I study for this class, I set goals for myself in order to direct my activities in each study period.
Item 12	I usually study in a place where I can concentrate on my course work.

Appendix I Abbreviated Motivated Strategies for Learning Questionnaire (MSLQ) Resource Management scale items

Time and study	
Item 1	I usually study in a place where I can concentrate on my course work.
Item 2	I make good use of my study time for this course.
Item 3	I find it hard to stick to a study schedule (REVERSED).
Item 4	I have a regular place set aside for studying.
Item 5	I make sure that I keep up with the weekly readings and assignments for this course.
Item 6	I attend this class regularly.
Item 7	I often find that I don't spend very much time on this course because of other activities (REVERSED).
Item 8	I rarely find time to review my notes or readings before an exam (REVERSED).
Effort regulation	
Item 9	I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do.
Item 10	I work hard to do well in this class even if I don't like what we are doing.
Item 11	When course work is difficult, I either give up or only study the easy parts (REVERSED).
Item 12	I work hard to do well in this class even if I don't like what we are doing
Peer learning	
Item 13	When studying for this course, I often try to explain the material to a classmate or friend.
Item 14	I try to work with other students from this class to complete the course assignments.
Item 15	When studying for this course, I often set aside time to discuss course material with a group of students from the class (REVERSED).
Help seeking	
Item 16	Even if I have trouble learning the material in this class, I try to do the work on my own, without help from anyone.
Item 17	I ask the instructor to clarify concepts I don't understand well.
Item 18	When I can't understand the material in this course, I ask another student in this class for help.
Item 19	I try to identify students in this class whom I can ask for help if necessary.

Appendix J Feedback sheet provided to students in the pilot test

Where the instructions clear for:

1. Matching Numbers Question
   Yes/No
   Please comment
   ____
   ____

2. Reading Question
   Yes/No
   Please comment
   ____
   ____

3. Language convention Question
   Yes/No
   Please comment
   ____
   ____

4. Numeracy Question
   Yes/No
   Please Comment
   ____
   ____

Was there sufficient time for the:

5. Matching Numbers Question
   Yes/No
   Please comment
   ____
   ____

6. Reading Question
   Yes/No
   Please comment
   ____
   ____

7. Language convention Question
   Yes/No
   Please comment
   ____
   ____

8. Numeracy Question
   Yes/No
   Please Comment
   ____
   ____

Other Comments:

Appendix K Ethics Approval Letter (Curtin University)

Curtin University

Research Office at Curtin

GPO Box U1987
Perth Western Australia 6845

Telephone +61 8 9266 7863
Facsimile +61 8 9266 3793
Web research.curtin.edu.au

27-Nov-2020

Name: Susan Blackley
Department/School: Curtin University
Email: Susan.Blackley@curtin.edu.au

Dear Susan Blackley

RE: Ethics Office approval
Approval number: HRE2020-0713

Thank you for submitting your application to the Human Research Ethics Office for the project **College student self-regulated learning, academic achievement and use of digital technology: Implications for theory, research and practice**.

Your application was reviewed through the Curtin University Low risk review process.

The review outcome is: **Approved**.

Your proposal meets the requirements described in the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research (2007)*.

Approval is granted for a period of one year from **27-Nov-2020** to **26-Nov-2021**. Continuation of approval will be granted on an annual basis following submission of an annual report.

Personnel authorised to work on this project:

Name	Role
Zhao, Peter	Student
Blackley, Susan	Supervisor

Approved documents:

Document

Standard conditions of approval

1. Research must be conducted according to the approved proposal
2. Report in a timely manner anything that might warrant review of ethical approval of the project including:
   - proposed changes to the approved proposal or conduct of the study
   - unanticipated problems that might affect continued ethical acceptability of the project
   - major deviations from the approved proposal and/or regulatory guidelines
   - serious adverse events
3. Amendments to the proposal must be approved by the Human Research Ethics Office before they are implemented (except where an amendment is undertaken to eliminate an immediate risk to participants)
4. An annual progress report must be submitted to the Human Research Ethics Office on or before the anniversary of approval and a completion report submitted on completion of the project
5. Personnel working on this project must be adequately qualified by education, training and experience for their role, or supervised
6. Personnel must disclose any actual or potential conflicts of interest, including any financial or other interest or affiliation, that bears on this project
7. Changes to personnel working on this project must be reported to the Human Research Ethics Office
8. Data and primary materials must be retained and stored in accordance with the Western Australian University Sector Disposal Authority (WAUSDA) and the Curtin University Research Data and Primary Materials policy
9. Where practicable, results of the research should be made available to the research participants in a timely and clear manner
10. Unless prohibited by contractual obligations, results of the research should be disseminated in a manner that will allow public scrutiny; the Human Research Ethics Office must be informed of any constraints on publication
11. Approval is dependent upon ongoing compliance of the research with the Australian Code for the Responsible Conduct of Research, the National Statement on Ethical Conduct in Human Research, applicable legal requirements, and with Curtin University policies, procedures and governance requirements
12. The Human Research Ethics Office may conduct audits on a portion of approved projects.

Special Conditions of Approval

It is the responsibility of the Chief Investigator to ensure that any activity undertaken under this project adheres to the latest available advice from the Government or the University regarding COVID-19.

This letter constitutes low risk/negligible risk approval only. This project may not proceed until you have met all of the Curtin University research governance requirements.

Should you have any queries regarding consideration of your project, please contact the Ethics Support Officer for your faculty or the Ethics Office at hrec@curtin.edu.au or on 9266 2784.

Yours sincerely

Amy Bowater
Ethics, Team Lead

Appendix L Comparison of Digital Technology and Student Group Scores

Comparison of MSLQ Groups Total scores for Digital Technology usage means (2012)

Scores	N	Mean	Mean Difference	T	Significance
Facebook (computer)					
At or Above mean	14	4.07	0.55	2.148	.043
Below Mean	91	3.52			
Images (computer)					
At or Above mean	14	4.21	0.12	3.076	.004
Below Mean	91	4.10			
Movies (computer)					
At or Above mean	14	2.93	-0.71	4.444	.000
Below Mean	91	3.64			
Schoolwork (computer)					
At or Above mean	14	3.93	0.48	-3.085	.003
Below Mean	91	3.45			
Shopping (Mobile)					
At or Above mean	14	2.57	0.65	2.011	.047
Below Mean	91	1.92			
Shopping (Duration)					
At or Above mean	14	3.00	0.85	2.218	.029
Below Mean	91	2.15			

Comparison of MSLQ Group Total scores for Digital Technology usage means (2020)

Scores	N	Mean	Mean Difference	T	Significance
Email (computer)					
At or Above mean	55	3.36	-.049	-2.817	.006
Below Mean	54	3.85			
Schoolwork (computer)					
At or Above mean	55	3.89	-0.35	-2.208	.029
Below Mean	54	4.24			
Email (mobile)					
At or Above mean	55	3.58	-0.44	-2.245	.027
Below Mean	54	4.02			
Schoolwork (mobile)					
At or Above mean	55	2.31	-0.67	-2.588	.011
Below Mean	54	2.98			
Schoolwork (duration)					
At or Above mean	55	3.87	-0.46	-2.251	.026
Below Mean	54	4.33			
YouTube (duration)					
At or Above mean	55	4.16	0.57	2.351	.023
Below Mean	54	3.59			

Comparison of Metacognition Total scores for Digital Technology usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
Games (computer)					
At or Above mean	80	2.60	-0.60	-2.019	.046
Below mean	25	3.20			

Comparison of Metacognition Total scores for Digital Technology usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Games (computer)					
At or Above mean	56	2.66	0.51	2.010	.047
Below mean	53	2.15			
Images (computer)					
At or Above mean	56	2.79	-0.59	-2.450	.016
Below mean	53	3.38			
Games (mobile)					
At or Above mean	56	2.95	0.59	2.097	.038
Below mean	53	2.36			
Music (mobile)					
At or Above mean	56	4.30	-0.30	-2.071	.041
Below mean	53	4.60			
Schoolwork (mobile)					
At or Above mean	56	2.32	-0.66	-2.536	.013
Below mean	53	2.98			
Games (duration)					
At or Above mean	56	3.59	0.66	2.187	.032
Below mean	53	2.92			

Comparison of MSLQ Resource Management Total scores for Digital Technology usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
Images (computer)					
At or Above mean	19	4.21	0.76	2.633	.010
Below mean	86	3.45			
Music (computer)					
At or Above mean	19	4.53	0.50	2.007	.047
Below Mean	86	4.02			
Movies (computer)					
At or Above mean	19	4.11	0.79	2.841	.005
Below Mean	86	3.31			
Schoolwork (computer)					
At or Above mean	19	2.89	-0.79	-4.013	.000
Below Mean	86	3.69			
Text Messaging (mobile)					
At or Above mean	19	4.68	0.39	2.320	.025
Below SD	86	4.29			
Images (mobile)					
At or Above mean	19	4.21	0.80	2.454	.016
Below SD	86	3.41			
Schoolwork (duration)					
At or Above mean	19	2.42	-1.09	-3.200	.002
Below SD	86	3.51			

Comparison of MSLQ Resource Management Total scores for Digital Technology usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Schoolwork (computer)					
At or Above mean	54	3.85	-0.42	-2.674	.009
Below mean	55	4.27			
YouTube (duration)					
At or Above mean	54	4.20	0.64	2.624	.010
Below Mean	55	3.56			

Comparison of Time and Study Environment Total Scores for Digital Technology usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
Schoolwork (computer)					
At or Above mean	32	3.06	-0.69	-4.220	.000
Below mean	73	3.75			
Images (mobile)					
At or Above mean	32	3.94	0.55	2.004	.048
Below mean	73	3.38			
Schoolwork (duration)					
At or Above mean	32	2.91	-0.59	-2.002	.048
Below mean	73	3.49			

Comparison of Time and Study Environment Total Scores for Digital Technology usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Schoolwork (computer)					
At or Above mean	67	3.88	-0.48	-2.979	.004
Below mean	42	4.36			
Shopping (computer)					
At or Above mean	67	2.66	0.54	2.629	.010
Below mean	42	2.12			
Movies (mobile)					
At or Above mean	67	3.40	0.55	2.131	.035
Below mean	42	2.86			
Shopping (mobile)					
At or Above mean	67	3.10	0.56	2.295	.024
Below mean	42	2.55			
Shopping (duration)					
At or Above mean	67	3.04	0.66	2.880	.005
Below mean	42	2.38			

Comparison of Effort Regulation Total scores for Digital Technology usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
Music (mobile)					
At or Above mean	38	4.21	0.51	2.009	.047
Below mean	67	3.70			
Music (duration)					
At or Above mean	38	3.92	0.53	2.360	.020
Below mean	67	3.39			
Schoolwork (duration)					
At or Above mean	38	2.95	-0.58	-2.049	.043
Below mean	67	3.52			

Comparison of Effort Regulation Total scores for Digital Technology usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Images (duration)					
At or Above mean	68	2.68	0.58	2.830	.006
Below mean	41	2.10			
YouTube (duration)					
At or Above mean	68	4.07	0.51	2.006	.047
Below mean	41	3.56			

Comparison of Peer Learning Total scores for Digital Technology usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
Video Chat (computer)					
At or Above mean	45	2.36	-0.63	-2.644	.009
Below mean	60	2.98			
Schoolwork (computer)					
At or Above mean	45	3.18	-0.64	-4.191	.000
Below mean	60	3.82			
Games (computer)					
At or Above mean	45	3.56	0.82	2.715	.008
Below mean	60	2.73			

Comparison of Peer Learning Total scores for Digital Technology usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Facebook (computer)					
At or Above mean	58	2.24	-0.60	-2.096	.038
Below mean	51	2.84			
Bank (mobile)					
At or Above mean	58	2.88	-0.49	-1.992	.049
Below mean	51	3.37			

Comparison of Help Seeking Total scores for Digital Technology usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
Games (mobile)					
At or Above mean	19	1.42	0.15	2.393	.019
Below mean	86	1.27			
Schoolwork (duration)					
At or Above mean	19	1.26	-0.14	-2.397	.018
Below mean	86	1.40			

Comparison of Help Seeking Total scores for Digital Technology usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Schoolwork (computer)					
At or Above mean	52	3.88	-0.34	-2.163	.033
Below mean	57	4.23			
Shopping (computer)					
At or Above mean	52	2.21	-0.46	-2.266	.025
Below mean	57	2.67			
Email (mobile)					
At or Above mean	52	3.58	-0.42	-2.169	.032
Below mean	57	4.00			
Schoolwork (mobile)					
At or Above mean	52	2.33	-0.60	-2.304	.023
Below mean	57	2.93			
Email (duration)					
At or Above mean	52	2.27	-0.47	-2.482	.015
Below mean	57	2.74			

Comparison of CAS Planning Subtest differences in Digital Technology usage

Scores	N	Mean	Mean Difference	T	Significance
Banking and Bill payment (computer)					
At or Above mean	65	2.78	.043	2.466	.015
Below mean	40	2.35			
Video Chat (duration)					
At or Above mean	65	2.54	-0.61	-2.135	.035
Below mean	40	3.15			
Images (duration)					
At or Above mean	65	2.12	-0.50	-2.350	.021
Below mean	40	2.63			
Shopping (duration)					
At or Above mean	65	2.06	-0.54	-1.923	.058
Below mean	40	2.60			

Comparison of CAS Planning Subtest differences in Digital Technology usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
YouTube (computer)					
At or Above mean	84	3.88	0.68	2.587	.011
Below mean	25	3.20			
Music (mobile)					
At or Above mean	84	4.54	0.38	2.162	.033
Below mean	25	4.16			

English Language course requirements differences for Digital Technology Application software usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
Facebook (computer)					
Required	58	4.19	0.96	4.017	.000
Not Required	47	3.23			
Images (computer)					
Required	58	4.09	1.11	5.472	.000
Not Required	47	2.98			
Music (computer)					
Required	58	4.36	0.55	2.911	.004
Not Required	47	3.81			
Movies (computer)					
Required	58	3.69	0.52	2.383	.019
Not Required	47	3.17			
YouTube (computer)					
Required	58	3.78	0.58	2.473	.015
Not Required	47	3.19			
Text messaging (mobile)					
Required	58	4.53	0.39	2.170	.032
Not Required	47	4.15			
Facebook (mobile)					
Required	58	4.26	1.07	4.109	.000
Not Required	47	3.19			
Images (mobile)					
Required	58	3.91	0.81	3.250	.002
Not Required	47	3.11			
Music (mobile)					
Required	58	4.10	0.49	1.986	.050
Not Required	47	3.62			
Schoolwork (mobile)					
Required	58	1.91	-0.60	-2.506	.014
Not Required	47	2.51			
Facebook (duration)					
Required	58	3.40	0.89	3.327	.001
Not Required	47	2.51			
Images (duration)					
Required	58	2.55	0.530	2.554	.012
Not Required	47	2.02			

English Language course requirements differences for Digital Technology Application software usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Games (duration)					
Required	28	3.79	0.70	2.174	.034
Not Required	81	3.09			

Family university completion differences for Digital Technology Application software usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
Schoolwork (computer)					
Family university completion	42	3.83	0.48	3.033	.003
Family no university completion	63	3.35			
Bank and Bill Payment (duration)					
Family university completion	42	2.83	0.66	2.714	.008
Family no university completion	63	2.17			
Schoolwork (duration)					
Family university completion	42	3.74	0.71	2.597	0.11
Family no university completion	63	3.03			

Family university completion differences for Digital Technology Application software usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Movies (mobile)					
Family university completion	71	2.99	-0.59	-2.273	.025
Family no university completion	38	3.58			
Bank and Bill Payment (mobile)					
Family university completion	71	2.87	-0.68	-2.656	.009
Family no university completion	38	3.55			

Total Academic Performance Mean Group differences for Digital Technology Application software usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
YouTube (mobile)					
At or Above mean	56	2.55	-0.63	-2.484	.015
Below mean	49	3.18			

Total Academic Performance Mean Group differences for Digital Technology Application software usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Facebook (computer)					
At or Above mean	62	2.19	-0.76	-2.673	.009
Below mean	47	2.96			
Shopping (computer)					
At or Above mean	62	2.27	-0.41	-1.998	.048
Below mean	47	2.68			
Banking and bill payment (computer)					
At or Above mean	62	1.90	-0.50	-2.362	.020
Below mean	47	2.40			
Facebook (mobile)					
At or Above mean	62	3.02	-0.64	-2.205	.030
Below mean	47	3.66			
Facebook (duration)					
At or Above mean	62	2.56	-0.61	-2.058	.042
Below mean	47	3.17			

Numeracy Mean Group differences for Digital Technology Application software usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
YouTube (computer)					
At or Above mean	50	3.24	-0.52	-2.213	.029
Below mean	55	3.76			
Schoolwork (mobile)					
At or Above mean	50	2.50	0.61	2.638	.010
Below mean	55	1.89			
Facebook (duration)					
At or Above mean	50	2.70	-0.57	-2.096	.039
Below mean	55	3.27			
YouTube (duration)					
At or Above mean	62	3.02	-0.64	-2.205	.030
Below mean	47	3.66			

Literacy Mean Group difference for Digital Technology Application software usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
Games (mobile)					
At or Above mean	13	1.92	-0.91	-2.377	.019
Below mean	92	2.84			
Schoolwork (mobile)					
At or Above mean	13	1.38	-0.91	-3.658	.001
Below mean	92	2.29			
Games (duration)					
At or Above mean	13	2.23	-0.98	-2.116	.037
Below mean	92	3.21			

Reading Comprehension Mean Group difference for Digital Technology Application software usage scores (2012)

Scores	N	Mean	Mean Difference	T	Significance
Text messaging (computer)					
At or Above mean	62	3.21	-0.58	-2.006	.047
Below mean	43	3.79			
Games (mobile)					
At or Above mean	62	2.42	-0.74	-2.925	.004
Below mean	43	3.16			
Video chat (mobile)					
At or Above mean	62	2.06	-0.63	-2.408	.018
Below mean	43	2.70			
Schoolwork (mobile)					
At or Above mean	62	1.98	-0.48	-2.025	.045
Below mean	43	2.47			
Video chat (duration)					
At or Above mean	62	2.52	-0.62	-2.207	.030
Below mean	43	3.14			

Reading Comprehension Mean Group difference for Digital Technology Application software usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Facebook (duration)					
At or Above mean	76	2.62	-0.68	-2.162	.033
Below mean	33	3.30			

Language Conventions Mean Group difference for Digital Technology Application software usage (2012)

Scores	N	Mean	Mean Difference	T	Significance
Text messaging (computer)					
At or Above mean	76	3.22	-0.81	-2.970	.004
Below mean	29	4.03			
Video chat (mobile)					
At or Above mean	76	2.14	-0.65	-2.234	.028
Below mean	29	2.79			
Schoolwork (mobile)					
At or Above mean	76	1.96	-0.80	-3.134	.002
Below mean	29	2.76			
Email (duration)					
At or Above mean	76	1.92	-0.49	-2.241	.027
Below mean	29	2.41			

Language Conventions Mean Group difference for Digital Technology Application software usage (2020)

Scores	N	Mean	Mean Difference	T	Significance
Shopping (computer)					
At or Above mean	65	2.26	-0.47	-2.279	.025
Below mean	44	2.73			
YouTube (duration)					
At or Above mean	65	4.12	0.60	2.284	.025
Below mean	44	3.52			

Appendix M Correlation between measures of Digital Technology Usage

Correlation between MSLQ and Frequency of Computer Software Application Usage (2012)

	Games	Video Chat	Text message	Email	Images	Music	Movies	School work	Shop
MSLQ Total	-.244**	.179*			-.196*			.497**	
Metacognition	-.223*				-.206*		-.183*	.406**	
Resource Management	-.223*	.215*						.488**	
Time and Study	-.174*				-.187*	-.206*	-.199*	.434**	-.171*
Effort Regulation	-.259**							.359**	
Peer Learning		.308**	.313**					.389**	
Help Seeking				-.188*					

** $p < 0.01$; * $p < 0.05$

Correlation between MSLQ and Frequency of Computer Software Application Usage (2020)

	Email	Facebook	School work	Shopping
MSLQ Total	-.207*		-.315**	
Metacognition			-.196*	
Resource Management			-.316**	
Time and Study			-.333**	.290**
Effort Regulation				
Peer Learning		-.201*		
Help Seeking			-.198*	-.254**

** $p < 0.01$; * $p < 0.05$

Correlation between MSLQ and Frequency of Mobile Phone Software Application Usage (2012)

	Video Chat	Images	Music	School work
MSLQ Total		-.193*		
Metacognition		-.206*		
Resource Management				
Time and Study		-.209*		
Effort Regulation			-.173*	
Peer Learning	.193*			.217*
Help Seeking				

** $p < 0.01$; * $p < 0.05$

Correlation between MSLQ and Frequency of Mobile Phone Software Application Usage (2020)

	Email	Music	Movies	School	Shop	Bank
MSLQ Total	-.230**	-.210*		-.207*		
Metacognition				-.211*		
Resource Management	-.216*	-.208*				
Time and Study			.247**			
Effort Regulation						
Peer Learning						
Help Seeking	-.332**	-.196*	-.291**	-.220*	-.332**	-.213*

** $p < 0.01$; * $p < 0.05$

Correlation between MSLQ and Duration of Software Application Usage (2012)

	Games	Video Chat	Text message	Music	School work
MSLQ Total					.212*
Metacognition	-.167*				
Resource Management			-.164*		.235**
Time and Study					.227*
Effort Regulation				-.185*	.219*
Peer Learning		.181*			
Help Seeking					

** $p < 0.01$; * $p < 0.05$

Correlation between MSLQ and Duration of Software Application Usage (2020)

	Games	Email	Image	Music	Schoolwork	YouTube	Shopping
MSLQ Total	.205*				-.243*	.238*	
Metacognition	.202*				-.218*		
Resource Management					-.192*	.282**	
Time and Study			.206*		-.218*	.273**	.265**
Effort Regulation							
Peer Learning							
Help Seeking		-.307**		-.285**			-.200*

** $p < 0.01$; * $p < 0.05$

Correlation between CAS Planning Subtest and Frequency of Computer Software Application Usage (2012)

	Computer Usage
	Text
Total CAS Planning	-.196**

** $p < 0.01$; * $p < 0.05$

Correlational between Academic Performance and Frequency of Computer Software Application Usage (2012)

	Chat	Texting	Email	Facebook	Movies	Schoolwork	YouTube	Banking
Performance Total	-.207*	-.176*					-.213*	
Literacy	-.161*	-.343**		.185*		-.209*		-.221*
Reading		-.233**						
Language Conventions		-.261**	-.184*					-.222*
Numeracy					-.189*		-.203*	

** $p < 0.01$; * $p < 0.05$

Correlational between Academic Performance and Frequency of Computer Software Application Usage (2020)

	Games	Facebook	YouTube	Shopping	Banking
Performance Total		-.240**	-.166*	-.215*	-.189*
Literacy	.162*	-.244**			
Reading Comprehension					-.186*
Language Conventions					
Numeracy					-.204*

** p < 0.01; * p < 0.05

Correlational between Academic Performance and Frequency of Mobile Phone Software Application Usage (2012)

	Games	Video Chat	School work
Performance Total		-.185*	
Literacy		-.267**	-.365**
Reading	-.193*	-.212*	-.233**
Language Conventions		-.172*	-.295**
Numeracy			.188*

** p <0.01; * p <0.05

Correlational between Academic Performance and Frequency of Mobile Phone Software Application Usage (2020)

	Video Chat	Facebook	Movies	Schoolwork	Shopping	Banking
Performance Total	-.168*	-.261**				
Literacy	-.182*	-.224**	-.180*			
Reading					-.257**	
Language Conventions	-.185*	-.200*			-.226**	-.178*
Numeracy		-.201*		-.221*		

** p <0.01; * p <0.05

Correlational between Academic Performance and Duration of Software Application Usage (2012)

	Video Chat	Email	Facebook	Music	YouTube
Performance Total	-.176*	-.170*			
Literacy		-.205*	.182*		
Reading				.184*	
Language Conventions					
Numeracy					-.214*

** p <0.01; * p <0.05

Correlational between Academic Performance and Duration of Software Application Usage (2020)

	Facebook
Performance Total	-.255**
Literacy	-.221*
Reading	-.243*
Language Conventions	
Numeracy	

** p <0.01; * p <0.05