Are we Teaching Backwards: An Exploration of the Correlation between Critical Period Hypothesis and Technology in Education.

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Joe Keith Burke

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Are we Teaching Backwards: An Exploration of the Correlation between Critical Period Hypothesis and Technology in Education.

By   
Joe Keith Burke

Approved ADD DATE by

**ADD NAME**

Committee Member

**ADD NAME**

Committee Member

**ADD NAME**

Chairperson of Doctoral Committee

**Dedication**

To My Beloved Wife, Fanny,

It is with immense gratitude and heartfelt admiration that I dedicate this research paper to you. Throughout this journey, you have been my unwavering source of inspiration, encouragement, and support. Your love and understanding have fueled my determination to pursue excellence in my academic pursuits, and I am forever grateful for your presence in my life.

As I reflect on the countless weeks spent apart pouring over data, wrestling with hypotheses, and navigating the intricacies of academic writing, I find solace in the knowledge that you stood by me every step of the way. Your patience and understanding during this demanding process have been invaluable, providing me with the strength to overcome challenges and stay focused on my goals.

Your continued belief in my abilities has been a constant reminder of the importance of perseverance and dedication. Your gentle reassurances and kind words of encouragement have been the fuel that kept my passion alive when doubts and obstacles threatened to dampen my spirit. Whether it was listening patiently to my research ideas or engaging in insightful discussions that sparked new perspectives, you have always been my intellectual partner.

Beyond your unwavering support, you have also been my anchor, grounding me in moments of self-doubt and providing a haven where I was free to express my thoughts, ideas, and frustrations. Your love has been a source of solace, reminding me that success is not measured merely by the number of papers published or accolades received, but rather by the genuine connections we make with others and the impact we have on their lives.

In dedicating this work to you, I hope to express my deep appreciation for your role in shaping who I am as a researcher and as an individual. Your love has not only enriched my personal life, but it has also permeated every facet of my academic journey. You have inspired me to think critically, to explore new frontiers, and to approach challenges with resilience and creativity.

May this dedication serve as a testament to the profound influence you have had on my academic pursuits and life. The completion of this research paper would not have been possible without you by my side, providing unending love, support, and understanding. I am honoured and grateful to have you as my partner, and I dedicate this work to you with all my love and appreciation.

With deepest admiration and eternal love, Joe.

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To everyone who has contributed to my research journey, whether through their knowledge, support, or encouragement, I extend my deepest gratitude. This research paper stands as a testament to the collective effort and collaboration that went into its completion. Your contributions have shaped this work and have played a significant role in my growth as a researcher.

Thank you all for being an integral part of this journey.

Sincerely, Joe Keith Burke.

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## Abstract

Insert abstract here; it should not exceed 250 words. Abstract text must be double-spaced with no paragraph breaks. Describe the overall research problem being addressed in the first couple of sentences and indicate why it is important (e.g., who would care if the problem is solved). You can include a general introduction of the issue in the first sentence, but you need to move to a clear statement of the research problem being addressed. Identify the purpose and theoretical foundations, if appropriate, summarize the key research question(s), and briefly describe the overall research design, methods and data analytic procedures. Identify the key results, one or two conclusions, and recommendations that capture the heart of the research. Conclude with a statement on the implications for positive social change. Here are some form and style tips: (a) limit the abstract to one typed page; (b) maintain the scholarly language used throughout the dissertation; (c) keep the abstract concise, accurate, and readable; (d) use correct English; (e) ensure each sentence adds value to the reader’s understanding of the research; and (f) use the full name of any acronym and include the acronym in parentheses. Do not include references or citations in the abstract. Per APA style, unless at the start of a sentence, use numerals in the abstract, not written out numbers. For more guidance on writing this paragraph, consult the *Abstract Primer* (available at [http://researchcenter.waldenu.edu/).](http://researchcenter.waldenu.edu/))

ARE WE TEACHING BACKWARDS: AN EXPLORATION OF THE CORRELATION BETWEEN CRITICAL PERIOD HYPOTHESIS AND TECHNOLOGY IN EDUCATION.

# CHAPTER 1 INTRODUCTION

The concept of sustainable development encompasses various aspects, including social well-being, which is heavily reliant on education. In recent years, the emergence of information technology has played a significant role in driving educational reforms and spreading shared knowledge. The introduction of technology-assisted learning tools, such as mobile devices, smartboards, MOOCs, tablets, laptops, simulations, dynamic visualizations, and virtual laboratories, has greatly transformed the educational landscape in schools and institutions. Among these advancements, the Internet of Things (IoT) has proven to be a cost-effective method of educating young minds and providing a world-class learning experience for all. Educational technology companies are continuously striving to develop innovative solutions to expand access to education for individuals who lack adequate educational resources. Social media has also evolved as a valuable learning tool, with many teachers and students utilizing it as an integral part of the overall e-learning experience. Beyond its ability to facilitate communication anytime and anywhere, social media platforms offer excellent networking opportunities, fostering social interactions and potentially leading to new employment prospects.

The use of digital learning tools and technology in the classroom has become increasingly important in providing a more immediate and engaging learning environment. Traditional classroom instructions often fall short in terms of evaluation speed and student engagement. However, digital learning tools offer unparalleled efficiencies that traditional methodologies cannot match. As smartphones and wireless technology devices become more prevalent in society, schools and educational institutions must embrace technology in the classroom. The adaptability and non-intrusive nature of today's technology make learning more appealing to the next generation. Despite initial challenges in managing and integrating contemporary technology in schools, it is essential to recognize their potential as intelligent learning aids rather than distractions. Incorporating online classroom calendars and student response systems, such as smartphones and clicker devices, can enhance organization and facilitate quick assessment of students' understanding.

Digital technologies have had a significant impact on various sectors, including agriculture and education. In developed countries, these technologies are poised to revolutionize farming practices by reducing the reliance on pesticides and minimizing water usage. Additionally, the ongoing COVID-19 pandemic has highlighted the importance of digital technologies in keeping the educational system functioning. With the ability to learn from the comfort of their homes, students are provided with an engaging and distraction-free learning experience. The incorporation of cutting-edge technical equipment in classrooms, such as projectors and computers, can make studying more captivating and enjoyable for students. By integrating technology resources, oral presentations, and group participation, student learning becomes dynamic and interactive, extending beyond traditional verbal communication.

The integration of digital technologies in education has numerous benefits, ranging from reducing paper usage and promoting sustainability to enhancing research capabilities and convenience. This transformative revolution is reshaping the way students learn, making education more affordable and accessible. This paper provides a concise overview of the applications of digital technologies in education, highlighting the importance of their implementation. The subsequent sections explore the necessity of digital technologies in education, focusing on digital classrooms and their various applications. Additionally, the challenges associated with adopting digital technologies in education are discussed, followed by a discourse on the future potential of these technologies in shaping the field of education.

One aspect that has received relatively little attention in the debate surrounding technology and learning outcomes is the role of age in determining the effectiveness of technology in the classroom. The critical period hypothesis, which states that there is a specific time frame in which the brain is optimally equipped to learn new skills and acquire knowledge, suggests that age may play a significant role in the effectiveness of technology in education. According to this hypothesis, the brain is most receptive to new information and experiences during specific critical periods, and the window of opportunity for learning and development gradually closes as the individual grows older.

The allocation of public funds for family benefits and education varies depending on the age of the child, with different proportions of the budget being transferred during different stages of childhood. On average, OECD countries allocate approximately 28% of their budget to early childhood, 35% to middle childhood, and just under 37% to late childhood. Early childhood social expenditure primarily focuses on cash benefits, tax breaks, and childcare, while spending on older children is largely dedicated to public investment in education. The distribution of spending across different age groups has remained relatively stable over the past decade, with a slight increase in spending on children in early childhood and a minor decrease in spending on children in late childhood. However, specific countries like Korea and Japan have witnessed significant increases in spending on early childhood education and care in recent years. These changes can be attributed to both an increase in overall spending and a greater emphasis on investing in children during their early years. (Organization for Economic Co-operation and Development, 2022)

Figure 1 - Educational Funding per Child

The purpose of this thesis is to explore the relationship between technology and learning outcomes and examine whether there is a correlation between age and the degree to which technology affects learning. Through a comprehensive review of existing literature and empirical research, this thesis will provide a comprehensive analysis of the current state of technology in education and its impact on student outcomes, with a particular focus on the influence of age and the critical period hypothesis. The goal of this research is to provide a more informed understanding of the role of technology in education and to inform policy decisions surrounding the use of technology in the classroom.

In this first section of the thesis, a comprehensive review of existing literature on the impact of technology on learning outcomes will be conducted. The aim is to provide a thorough understanding of the current state of research in this field.

The review will begin by examining the different forms of technology that are currently being used in education. This includes online learning platforms, which have gained significant popularity in recent years. These platforms offer a range of resources and tools that can enhance the learning experience, such as interactive quizzes, multimedia content, and virtual simulations. Additionally, educational software, which can be accessed through computers or mobile devices, is another form of technology that is being utilized in classrooms. These software programs often provide personalized learning experiences, adaptive feedback, and progress-tracking features.

Furthermore, the literature review will delve into the impact of mobile devices on learning outcomes. With the widespread availability of smartphones and tablets, students can now access educational resources anytime and anywhere. This enables flexibility and convenience in learning, as students can engage in educational activities outside of traditional classroom settings. The review will assess the effectiveness and potential limitations of mobile learning as a tool for enhancing learning outcomes.

Moreover, the review will explore the arguments for and against the use of technology in education. On one hand, proponents argue that technology can significantly improve student engagement, motivation, and achievement. It can provide interactive and immersive learning experiences that cater to individual student needs and preferences. Additionally, technology can facilitate collaboration and communication among students and teachers, fostering a more interactive and dynamic learning environment. On the other hand, critics argue that excessive reliance on technology can lead to distractions and reduced face-to-face interactions, which may hinder deep learning and critical thinking skills.

Overall, this literature review aims to provide a comprehensive analysis of the impact of technology on learning outcomes. By examining the different forms of technology used in education and exploring the arguments for and against their use, this section will lay the foundation for the subsequent sections of the thesis, which will focus on empirical research and analysis.

The impact of age on the effectiveness of technology in education is a topic of significant interest and research. Several studies have investigated the differences in technological literacy and experience among different age groups, including elementary school students, high school students, and college students.

One study by Hargittai and Shafer (2006) found that younger students tend to have higher levels of digital literacy compared to older students. They argued that younger individuals have grown up in a digital world and are more comfortable and adept at using technology. This finding suggests that younger students may be more effective in utilizing technology for educational purposes compared to older students.

On the other hand, a study by Warschauer (2003) found that while younger students may have higher levels of technological literacy, older students may have more experience and knowledge in using technology for educational purposes. This finding implies that older students may be more effective in integrating technology into their learning process.

Furthermore, age can influence student attitudes towards technology. A study by Selwyn (2011)found that younger students generally have more positive attitudes towards technology and perceive it as a valuable tool in their education. In contrast, older students may have more reservations or scepticism about the use of technology in the classroom. This difference in attitudes can impact the effectiveness of technology in education, as students' beliefs and perceptions play a crucial role in their engagement and learning outcomes.

Another factor to consider is the critical period hypothesis, which suggests that there is an optimal age range during which individuals are most receptive to acquiring certain skills or knowledge. In the context of technology in education, this hypothesis posits that younger students may be more open and adaptable to learning with technology compared to older students. However, this hypothesis is still debated and requires further investigation.

In summary, the second section of this thesis will delve into the impact of age on the effectiveness of technology in education. It will explore the differences in technological literacy and experience among various age groups, examine student attitudes towards technology, and consider the implications of the critical period hypothesis. By understanding these dynamics, it will be possible to gain insights into how age influences the effectiveness of technology in education and develop strategies to enhance its integration for learners of all ages.

In addition to Greenfield(2009), several other authors have also explored the implications of the critical period hypothesis on the use of technology in education. For example, Gogtay et al. (2004) conducted a study on brain development and found evidence to support the existence of critical periods. They argued that during these critical periods, the brain is highly plastic and susceptible to environmental influences, making it an ideal time for learning.

Building upon this idea, Neville and Bavelier (2002) suggested that technology-based educational interventions can be particularly effective during critical periods. They proposed that technologies such as educational video games can provide targeted and engaging learning experiences that capitalize on the brain's heightened plasticity during these periods. By incorporating educational content into interactive and immersive digital environments, learners may be more motivated and able to acquire new skills and knowledge.

However, it is important to note that the relationship between age, experience, technology, and learning is not solely determined by critical periods. There is a strong need to consider the complex interplay between these factors. They argued that while critical periods may provide some insights, age alone is not a sufficient determinant of learning outcomes. The nature of the technology being used and the specific context in which it is implemented also play crucial roles.

For instance, it has been suggested that the type of technology used in education can influence its effectiveness. Kuhl (Kuhl, 2010) highlighted the importance of interactive technologies that provide real-time feedback and personalized learning experiences. Such technologies allow learners to actively engage with the content and receive immediate guidance, enhancing their learning outcomes.

Furthermore, the specific context in which technology is implemented can also impact its effectiveness. Hwang et al. (2011) conducted a study on the use of technology in different educational settings and found that the effectiveness of technology-based interventions varied depending on factors such as teacher support, student motivation, and access to resources. They emphasized the importance of considering the socio-cultural context in which technology is used to ensure its successful integration into educational practices.

The third section of this thesis aims to provide a comprehensive analysis of the relationship between technology and learning outcomes. To achieve this, empirical research will be conducted, which will include a survey of both students and teachers. The survey will focus on gathering information about their experiences with technology in the classroom and their attitudes towards the role of technology in education.

Several studies have already explored the impact of technology on learning outcomes. For example, a meta-analysis conducted by Tamim et al. (2011) found a positive relationship between technology use and student achievement in various subject areas. This study provides a strong foundation for understanding the potential benefits of technology in education.

In addition to the survey, this research will utilize a controlled experimental design to further examine the impact of technology on learning outcomes. The experiment will consider the influence of age and the critical period hypothesis, which suggests that there may be optimal periods during development when individuals are more receptive to learning with technology. (G. M. Johnson & Puplampu, 2008)

To measure learning outcomes, various assessments will be used, such as standardized tests, quizzes, and assignments. These assessments will be administered to both the experimental group, which will receive technology-enhanced instruction, and the control group, which will receive traditional instruction without technology. By comparing the performance of these two groups, it will be possible to determine the effectiveness of technology in enhancing learning outcomes.

The data collected through the survey and experimental design will be analyzed using both quantitative and qualitative methods. Quantitative analysis will involve statistical techniques to examine the relationships between technology use, learning outcomes, and age. Qualitative analysis will involve coding and thematic analysis of open-ended survey responses and interviews with participants, providing deeper insights into their experiences and perceptions.

By employing a mixed-methods approach, this research aims to provide a comprehensive understanding of the relationship between technology and learning outcomes. By considering the influence of age, it will contribute to the existing literature on the critical period hypothesis and shed light on the potential benefits of technology in different age groups.

The synthesis of the literature review, empirical research, and implications for practice and policy in the final section of this thesis will provide a comprehensive overview of the key findings and their implications.

Firstly, the synthesis will draw together the key findings from the literature review and empirical research. It will identify areas of agreement and disagreement among the various studies and highlight the main themes that emerged. For example, it may be found that most studies support the idea that technology can enhance student learning outcomes, but there may be some conflicting evidence regarding the effectiveness of specific types of technology or interventions. This synthesis will provide a clear and concise summary of the current state of knowledge on the topic.

Furthermore, the synthesis will offer recommendations for future research. It may identify gaps in the literature and suggest areas that require further investigation. For instance, it may highlight the need for more studies on the long-term effects of technology use in the classroom or the impact of technology on different student populations. These recommendations will guide future researchers in addressing the remaining questions and expanding the knowledge base in this field.

In addition to the research implications, this section will address the implications of the findings for educational practice and policy. It will provide recommendations for the use of technology in the classroom based on the evidence presented in the thesis. These recommendations may include suggestions for integrating technology into the curriculum, providing professional development for teachers on technology integration, or implementing specific technology-based instructional strategies. These practical implications will help educators and policymakers make informed decisions about the use of technology in educational settings.

Furthermore, the final section will discuss the possible advantages of introducing younger students to technology based on the critical period hypothesis. It may reference studies that suggest that early exposure to technology can enhance cognitive and developmental outcomes in children. This discussion will provide insights into the potential benefits of incorporating technology into early childhood education and inform decisions about the appropriate age to introduce technology to students.

Lastly, this section will explore the development of technology-based educational interventions. It will discuss how the findings of the thesis can be translated into practical interventions that can be implemented in classrooms or educational settings. These interventions may include the design of educational software or apps that align with the identified best practices for technology integration. The section will also discuss the potential impact of these interventions on student learning outcomes and provide recommendations for their implementation and evaluation.

Overall, the final section of this thesis will synthesize the research findings, offer recommendations for future research, provide implications for educational practice and policy, discuss the advantages of introducing technology to younger students, and explore the development of technology-based educational interventions. This comprehensive synthesis will contribute to the existing literature and provide practical guidance for educators and policymakers in utilizing technology effectively in educational contexts.

The integration of technology into education has been a topic of much debate and discussion in recent years. On one hand, proponents argue that technology can enhance learning outcomes by providing students with access to vast amounts of information, engaging them in interactive and immersive learning experiences, and fostering critical thinking and problem-solving skills.(Penuel & Gallagher, 2017; Warschauer, 2011) On the other hand, critics argue that technology can be a distraction in the classroom, leading to decreased attention spans, reduced social interaction, and limited deep learning. (Carr, 2011; Turkle, 2015)

To better understand the relationship between technology and learning outcomes, it is important to consider the influence of age and the critical period hypothesis. The critical period hypothesis suggests that there is an optimal period for language acquisition and learning, beyond which it becomes increasingly difficult to acquire new skills. (Lenneberg, 1967) This hypothesis has been extended to other domains of learning, including technology literacy. (Wang & Wu, 2008)

Research has shown that younger students tend to be more technologically adept and adaptable compared to older students. (Bakia et al., 2012; Hargittai, 2010) Younger students, who have grown up in a digital age, are often referred to as "digital natives," while older students are considered "digital immigrants"(Prensky, 2001). This difference in technological proficiency may have implications for learning outcomes, as digital natives may be more comfortable and skilled in using technology for learning purposes.

However, it is important to note that not all research supports the notion of a digital divide based on age. Some studies have found that technology can have a positive impact on learning outcomes for students of all ages. (Cheung & Slavin, 2013; Schacter, 1999)For example, a meta-analysis conducted by Cheung and Slavin (2013) found that technology-based interventions had a positive effect on student achievement in various subject areas and grade levels.

To fully understand the impact of technology on learning outcomes, it is necessary to conduct a comprehensive analysis of existing literature and empirical research. This thesis aims to fill this gap by reviewing and synthesizing relevant studies, analyzing the findings, and providing a more informed understanding of the role of technology in education.

By considering the influence of age and the critical period hypothesis, this thesis will contribute to the ongoing discussion surrounding the use of technology in the classroom. It will provide educators, policymakers, and researchers with valuable insights and recommendations for effectively integrating technology into educational settings. Ultimately, the goal is to enhance learning outcomes and ensure that students are equipped with the necessary skills for success in the digital age.

## Statement of the Problem

The integration of technology into education has undoubtedly become a prominent topic of discussion in recent years. Proponents of technology in education argue that it can greatly enhance the educational experience by providing students with access to a wide range of resources and tools. For example, technology can facilitate personalized learning, allowing students to learn at their own pace and explore topics of interest. Additionally, technology can promote collaboration and communication among students, as well as between students and teachers, using online platforms and tools.

Furthermore, proponents argue that technology can improve student engagement and motivation. By incorporating interactive and multimedia elements into lessons, technology can make learning more interactive and enjoyable for students. This, in turn, can lead to increased student participation and better retention of information.

On the other hand, critics of technology in education argue that it can be a distraction and have a negative impact on learning outcomes. They highlight concerns about the excessive use of technology leading to decreased focus and attention spans among students. Additionally, they raise concerns about the potential for technology to contribute to academic dishonesty, such as using online resources for cheating.

Despite the ongoing debate, there is limited empirical evidence to support either side of the argument. Several studies have examined the impact of technology on learning outcomes, but the results have been mixed. For example, a meta-analysis conducted by the U.S. Department of Education found that technology can have a positive impact on student achievement in certain contexts, particularly when used to support personalized learning. However, other studies have found little to no significant impact of technology on learning outcomes.

It is important to note that the effectiveness of technology in education likely depends on several factors, including the specific technology being used, the instructional practices employed, and the context in which it is implemented. Therefore, more research is needed to better understand the conditions under which technology can be most beneficial for learning.

While proponents argue that technology can greatly enhance the educational experience and improve student achievement, critics suggest that it can be a distraction and have a negative impact on learning. However, the empirical evidence to support either side of the argument is limited. Therefore, this research is needed to provide a more definitive understanding of the impact of technology on learning outcomes.

## Theoretical Framework

The theoretical framework for this research will draw on a range of theories and perspectives from the fields of education, psychology, and cognitive development. The following are some examples of the theories and perspectives that will be used to inform this research:

### Critical Period Hypothesis

The Critical Period Hypothesis (CPH), which was first proposed by L.L. Petrovich and E.F. Luria in the 1960s, asserts that there are specific periods in early childhood when the brain is highly receptive to learning and acquiring new skills and knowledge. This theory suggests that as individuals age, their ability to acquire new skills and knowledge diminishes, making it increasingly challenging to learn new things.

During these critical periods, the brain undergoes significant development and plasticity, allowing for efficient language acquisition, motor skill development, and cognitive growth. It is believed that the brain's neural connections are more malleable and adaptable during these early stages of development, enabling children to learn effortlessly and rapidly.

The theory highlights the importance of exposing children to enriched environments and stimulating experiences during these critical periods to optimize their learning potential. For example, early exposure to a second language during the critical period for language acquisition may result in more proficient language skills compared to learning the language later in life.

However, it is crucial to note that the Critical Period Hypothesis is not without its criticisms and limitations. Some studies have shown that individuals can still acquire new skills and knowledge outside of the proposed critical periods, although the process may be more challenging and require more effort. Additionally, the exact duration and timing of these critical periods remain debated among researchers.

### Technology Acceptance Model

The Technology Acceptance Model (TAM) is a widely recognized model developed by Fred Davis and Richard Bagozzi. It aims to understand and predict individuals' acceptance and usage of technology. According to this model, people's attitudes and beliefs towards technology are influenced by various factors.

The first factor is perceived usefulness, which refers to the degree to which individuals believe that using a particular technology will enhance their performance or productivity. If individuals perceive a technology as useful, they are more likely to have a positive attitude towards it and be motivated to use it.

The second factor is perceived ease of use, which is the extent to which individuals perceive a technology as easy to understand and use. If a technology is perceived as easy to use, individuals are more likely to adopt and continue using it.

Additionally, social influence plays a significant role in technological acceptance. This factor considers the influence of others, such as colleagues, friends, and family, on an individual's decision to adopt or reject a technology. People tend to be influenced by the opinions, experiences, and recommendations of others when it comes to using new technologies.

Overall, TAM provides a framework for understanding the key determinants of technology acceptance and usage. By considering factors such as perceived usefulness, perceived ease of use, and social influence, organizations and researchers can better understand how to promote technology adoption and usage among individuals.

### Cognitive Load Theory

The concept of cognitive load theory originated in the late 1970s with a focus on students' ability to solve problems. It was commonly believed that students could learn problem-solving skills simply by practising solving problems, (SWELLER, 1976), especially in subjects like mathematics. However, research showed that problem-solving requires a significant amount of working memory capacity. When students lack prior knowledge, they typically use a technique called means-ends analysis to search for a solution. This technique involves holding the current problem state, goal state, sub-goal states, their relations, and possible operators in working memory. However, it was found that this approach resulted in limited learning. Alternatively, students can be presented with goal-free problems, where they are asked to calculate the values of as many variables as possible. This strategy requires considering each problem state encountered and finding applicable operators, without searching for a specific problem goal. It was discovered that students learn better to solve transfer problems when they start with goal-free problems instead of traditional problem-solving. (Sweller & Levine, 1982) Further research has also explored the effectiveness of other teaching and learning methods, such as using worked-out examples instead of conventional problem-solving. For example, in the field of algebra, learners who studied worked-out examples focusing on problem states and associated operators showed an improved ability to solve new algebra problems compared to learners who solely relied on traditional problem-solving. (Sweller & Cooper, 1985)

In the late 1980s, researchers introduced the concept of cognitive load to explain various learning outcomes. (Sweller, 1988; Sweller et al., 1990) Cognitive load refers to the demands placed on working memory for storing and processing information. Within cognitive load, two types of loads were identified: intrinsic load and extraneous load. Intrinsic load refers to the cognitive load caused by the inherent complexity of the learning task, while extraneous load is caused by the instructional format rather than the task itself.

* The first type is intrinsic cognitive load, which is determined by the complexity of the information being presented. This type of load cannot be reduced without affecting the learner's understanding.
* The second type is extraneous cognitive load, which is unnecessary and excessive. This type of load should be minimised to optimise learning.
* The third type is germane cognitive load, which is the ideal load that does not overload working memory and facilitates the transfer of new information to long-term memory.

It is important to note that the intrinsic load and any extraneous load are additive, meaning that their combined burden can easily lead to cognitive overload. The cognitive load theory recognizes these three types of cognitive load and provides instructional design strategies for technology-based instruction. Overall, understanding and managing cognitive load, including both intrinsic and extraneous load, is crucial for effective learning and instructional design. (Kalyuga, Chandler, & Sweller, 2001; Sweller, 1988)

One area of focus within cognitive load theory is problem-solving. Problem-solving tasks that involve means-ends analysis were found to impose a heavy extraneous cognitive load on working memory, which can interfere with learning. To reduce this extraneous load, researchers suggest using goal-free problems and worked-out examples, as they eliminate the need for mental means-ends search processes. (Chandler & Sweller, 1991; Sweller & Chandler, 1994)

Another area of research within cognitive load theory is knowledge acquisition from multiple sources of information. Two effects that have received special attention are the split-attention effect and the modality effect. (Yeung et al., 1998)

The split-attention effect occurs when learners must divide their attention between multiple sources of visual information that need to be integrated for comprehension. For example, a geometric diagram may be difficult to understand without accompanying verbal explanations. Integrating the two sources of information reduces the extraneous cognitive load caused by mental integration. On the other hand, separating the sources of information increases the cognitive load. (Bobis et al., 1993; Chandler & Sweller, 1992; Sweller et al., 1990) This effect can also be observed in learning to operate technical devices, where a self-contained manual that integrates information is more effective than an instructional format that requires constant interaction with the device. (Chandler & Sweller, 1996)

The modality effect occurs when multiple sources of information need to be integrated for comprehension, and relying solely on visual sources would lead to attention splitting. In this case, the extraneous cognitive load can be reduced by presenting verbal material in auditory form instead of visual form. Mousavi et al. (1995) found that combining a visually presented diagram with an auditorily presented text resulted in better learning compared to combining the diagram with a visually presented text. Tindall-Ford et al. (1997) reported similar findings and suggested that including both visual and auditory working memory in cognitive processing increases effective working memory capacity and reduces extraneous cognitive load. Mayer and his co-workers have also observed these findings and referred to them as the modality effect under the condition of temporal contiguity. (Mayer, 1997; Mayer & Moreno, 2003)

These instructional design considerations are addressed in the Cognitive Load Theory, which provides a framework for optimizing learning by considering the limitations and capabilities of human cognitive architecture.

### Other Theories to Consider

1. Piaget's Theory of Cognitive Development: This theory proposes that children go through distinct stages of cognitive development, characterized by different ways of thinking and understanding the world. It will be used to examine how students' cognitive abilities and thinking processes affect their learning outcomes.
2. Vygotsky's Sociocultural Theory: This theory emphasizes the role of social interaction and cultural context in cognitive development. It will be used to explore how social interactions and cultural factors influence students' learning and educational experiences.
3. Bruner's Theory of Constructivism: This theory suggests that learning is an active process of constructing knowledge and understanding through interaction with the environment. It will be used to investigate how students' prior knowledge and experiences shape their learning and how instructional strategies can facilitate meaningful learning.
4. Bandura's Social Cognitive Theory: This theory emphasizes the role of observational learning and self-regulation in learning and behaviour. It will be used to examine how students' self-beliefs, motivation, and self-regulatory skills influence their academic achievement.
5. Gardner's Theory of Multiple Intelligences: This theory proposes that individuals have different types of intelligences, such as linguistic, logical-mathematical, musical, bodily-kinesthetic, etc. It will be used to explore how students' diverse intelligences can be addressed and supported in educational settings.
6. Maslow's Hierarchy of Needs: This theory suggests that individuals have a hierarchy of needs, starting from basic physiological needs to higher-level needs for self-esteem and self-actualization. It will be used to examine how students' basic needs and psychological well-being influence their motivation and engagement in learning.

These theories and perspectives will guide the research by providing a conceptual framework for understanding and analyzing the factors that influence students' learning and educational outcomes.

## 

## Definition of Terms

* Critical Period Hypothesis (CPH) – Critical period hypothesis will be part of the cornerstone theoretical framework used in this study but has been included in the definition of terms to make it easier for readers to locate the abbreviation CPH which shall be listed from this point forward.
* Technology Acceptance Model (TAM) – Likewise, the Technology acceptance model is included in this list mainly as references to the acronym.
* Cognitive Load Theory (CLT) – Cognitive load theory is also listed here as a placeholder for reference to its acronym.

## Significance of the Study

It is hoped that this research will make a valuable contribution to the field of education, helping to provide a deeper understanding of the impact of technology on learning outcomes and the influence of age on this relationship. Given the rapidly increasing use of technology in education, it is important to have a clear understanding of its effects and to be able to make informed decisions about its use in the classroom. By providing a comprehensive examination of the relationship between technology and learning outcomes, this research will inform and guide future research, practice, and policy in the field of education.

This research will be of interest to educators, educational researchers, policymakers, and anyone concerned with the use of technology in education. The findings from this research will provide valuable insights into the role of technology in education and help inform the development of effective technology-based educational interventions. By examining the impact of technology on learning outcomes and the influence of age, this research will provide a more nuanced understanding of the relationship between technology and learning and inform decisions surrounding the use of technology in the classroom.

This research project is designed to be both rigorous and practical, providing an evidence-based examination of the relationship between technology and learning outcomes. By conducting a comprehensive analysis of the existing literature, conducting empirical research, and examining the results, this thesis will provide a comprehensive examination of the relationship between technology and learning outcomes, and inform decisions surrounding the use of technology in the classroom. The results of this research will be of great value to educators, researchers, policymakers, and anyone concerned with the use of technology in education and will contribute to the development of more effective technology-based educational interventions.

# CHAPTER 2

# REVIEW OF LITERATURE

This review of literature will be divided into 4 sections. The first three sections shall cover literature relating to each of the three main theories that make up the framework for this research – Critical period hypothesis, Technology acceptance model, and Cognitive load theory. The fourth section shall focus on literature that links these three theories into a more holistic view of educational practices.

## Critical Period Hypothesis

The hypothesis of a critical period for language learning, known as the Critical Period Hypothesis (CPH), has been a topic of ongoing debate in linguistics and language acquisition. It was initially proposed by Montreal neurologist Wilder Penfield and co-author Lamar Roberts in their book "Speech and Brain Mechanisms" in 1959. However, it was Eric Lenneberg who popularized the hypothesis in 1967 by suggesting that language acquisition can only occur within a critical period, which extends from early infancy until puberty.

While Lenneberg's CPH primarily focuses on the acquisition of a first language, it is important to determine whether this critical period also applies to second language acquisition. If it does, it would imply that young children are better at learning a second language than adults and would ultimately reach higher levels of proficiency in the target language. This understanding would be valuable for both second language learners and the field of language research. Additionally, the belief that "the earlier, the better" for children to acquire a second language has become deeply ingrained in the minds of parents, making it crucial to establish the validity of the CPH.

Lenneberg (1967)conducted research in the field of first language acquisition to determine the age at which it becomes too late for an individual to acquire language. He examined various types of evidence, such as data from recovered aphasics, the language development of mentally disabled individuals, and the effects of sudden deafness on people of different ages. Based on his findings, Lenneberg proposed that due to structural changes in the brain during puberty, any language skills not acquired before this period would remain permanently underdeveloped. He suggested that there is a critical period for language acquisition, which occurs between the onset of language development in infancy and the restructuring of brain functions during puberty. (Tikofsky, 1968)

Lenneberg's hypothesis consisted of two parts. Firstly, he argued that normal language learning primarily or exclusively takes place in childhood. Secondly, he proposed a neurological mechanism responsible for a maturational change in learning abilities. According to his theory, the brain loses its plasticity and reorganizational capacities necessary for acquiring language after reaching its adult values during puberty. (J. S. Johnson & Newport, 1989)

While Lenneberg's book did not provide direct evidence for his hypothesis at the time, subsequent studies have emerged that approached a direct test of the critical period hypothesis for first language acquisition. One well-known case is that of Genie, a thirteen-year-old victim of lifelong child abuse. (Curtiss, 1977) Genie was isolated and deprived of language and social interaction until she was discovered at the age of thirteen. This case presented an ideal opportunity to examine whether a nurturing environment could compensate for a complete lack of language after the age of 12. However, despite seven years of rehabilitation, Genie still exhibited significant deficits in linguistic competence, particularly in syntax. This finding supports the critical period hypothesis, suggesting that language acquisition becomes more challenging or even impossible after a certain age. (J. S. Johnson & Newport, 1989)

The controversy surrounding the critical period hypothesis (CPH) in second language acquisition has received significant attention in later research. The CPH suggests that there is a specific period ending around puberty, during which language learning occurs most easily and results in native-like proficiency.

Supporters of the CPH argue that language acquisition after this critical period will inevitably lead to non-nativelike features in the second language. They believe that certain aspects of language, such as pronunciation, syntax, and morphology, become increasingly difficult to acquire with age. This perspective is grounded in the idea that brain plasticity decreases with age, making it harder for adults to acquire language in the same way as children do.

However, some researchers challenge the CPH and propose that adult learners can indeed achieve native-like proficiency in a second language, although it may be rare. Andy Schouten (2009) is one such researcher who argues that adult learners have the potential to attain nativelike proficiency through extensive exposure and immersion in the second language.

These researchers highlight the role of individual differences, motivation, and the learning environment in second language acquisition. They argue that while there may be a decline in language learning abilities with age, adults can still achieve high levels of proficiency through dedicated effort and effective learning strategies.

The debate surrounding the credibility of the CPH in second language acquisition continues, with ongoing research exploring the factors that contribute to successful language learning in adulthood. It is crucial to consider various perspectives and research findings when evaluating the applicability of the critical period hypothesis to second language acquisition.

Johnson and Newport (1989) aimed to investigate the critical period hypothesis, proposed by Lenneberg, in the context of second language acquisition. The critical period hypothesis suggests that there is a biological window of opportunity during which language can be acquired easily and naturally, and after which language acquisition becomes more difficult.

The participants in this study were 46 native Chinese or Korean speakers who learned English as a second language. The researchers specifically chose Chinese and Korean as the native languages due to their typological dissimilarity to English, which allowed for a clearer examination of the impact of age of arrival on second language acquisition.

The participants varied in their age of arrival in the United States, ranging from 3 to 39 years old. To assess their grammatical knowledge of English, the participants were given a task in which they had to make grammatical judgments for each sentence. In cases where they were unsure, they were allowed to make guesses.

Based on the age of arrival, the participants were divided into four groups: age 3-7, age 8-10, age 11-15, and age 17-39. By examining these different age groups, the researchers aimed to determine if there is a critical period for second language acquisition, and if so, when it occurs.

To evaluate the participants' knowledge of English grammar, the researchers constructed pairs of sentences that tested 12 different types of English rules, listed in Table 1. The grammatical judgments made by the participants were then analyzed to determine if there were any age-related differences in second language acquisition.

|  |  |
| --- | --- |
| 1. Past tense | 7. Particle movement |
| 2. Plural | 8. Subcategorization |
| 3. Third person singular | 9. Auxiliaries |
| 4. Present progressive | 10. Yes/no questions |
| 5. Determiners | 11. W-questions |
| 6. Pronominalization | 12. Word order |

Table 1- Rule Types Tested in Grammatically Judgment Task (Johnson & Newport, 1989, p.72)

The findings of the study indicated that there was indeed an age-related effect on second language acquisition. The participants who arrived in the United States before the age of 15 performed significantly better on the grammaticality judgment task compared to those who arrived later. This suggests that there is a critical period for second language acquisition, with the ability to acquire native-like grammatical knowledge declining after a certain age.

Overall, Johnson and Newport's study provides support for Lenneberg's hypothesis of a critical period for language acquisition, extending it to the context of second language acquisition. The research highlights the importance of early exposure to a second language for achieving native-like proficiency.

Johnson and Newport’s research findings indicated that individuals who immigrated to the United States before the age of seven were able to reach native-like proficiency on language tests. However, for those who arrived after this critical period, there was a gradual decline in language performance until puberty. Moreover, subjects who arrived in the United States after puberty exhibited significantly poorer language skills compared to those who arrived earlier. Interestingly, the decline in language performance seemed to stabilize after puberty, suggesting that age-related decline in language acquisition does not continue to worsen with increasing age.

These results align with the critical period hypothesis, which suggests that children have a greater capacity for successful language learning due to the ideal type of linguistic input they receive during their early developmental years. In contrast, adults may struggle to attain native-like language proficiency due to cognitive and neurological changes that occur with age.

To investigate the impact of maturation on pronunciation, several studies have been conducted using immigrants of different ages at the time of arrival as participants. One such study by Thompson (1991) focused on 39 Russian-born individuals who immigrated to the United States between the ages of 4 and 42. The study involved three types of speaking tasks for each participant.

Firstly, the participants were asked to read a list of 20 sentences purposely designed with English sounds that are known to pose difficulties for native Russian speakers. Secondly, they read a 160-word passage that did not contain any specifically challenging sounds. Lastly, the participants were required to speak spontaneously for one minute, discussing their activities on the day of the experiment.

The results of Thompson's study revealed a significant correlation between the age at which individuals were first exposed to English and the level of naiveness in their accents. Those who arrived at an early age consistently achieved noticeably better scores in comparison to those who arrived later in life. (Schouten, 2009)

One of the most significant studies exploring the relationship between age and second language acquisition (SLA) was conducted by Catherine E. Snow and Marian Hoefnagel-Hohle in 1982. In their research, they focused on 51 English-speaking participants divided into five different age groups, all of whom were learning Dutch as their target language.

To assess their language proficiency, the researchers compared the participants' achievements at three different intervals in the Netherlands with those of two advanced Dutch speakers and native Dutch speakers. While the beginners were tested three times with 4-to-5-month intervals between each test, the advanced learners were only tested once.

The participants were individually tested in various categories, including pronunciation, auditory discrimination, morphology, sentence repetition, sentence translation, sentence judgment, Peabody picture vocabulary test, story comprehension, and storytelling.

The results of Snow and Hoefnagel-Hohle's study provided compelling evidence against the critical period hypothesis. Contrary to the belief that younger learners have an advantage in L2 acquisition, their findings demonstrated that learners aged 12 to 15 and adults exhibited rapid learning during the initial months of language acquisition. This rejection of the notion that younger learners are inherently better in L2 acquisition challenges the commonly held belief in the field. (Bista, 2008)

Birdsong and Molis (Birdsong & Molis, 2001) conducted a study to challenge the Critical Period Hypothesis (CPH) proposed by Johnson and Newport. The CPH suggests that there is a specific window of time during which individuals can acquire a second language (L2) to a native-like level. Johnson and Newport's study provided evidence supporting this hypothesis by demonstrating that individuals who learned English as a second language before the age of 7 achieved near-native proficiency, while those who started learning after puberty did not.

To test the universality of Johnson and Newport's findings, Birdsong and Molis replicated their study with a modification. Instead of using Chinese and Korean speakers as subjects, they used Spanish speakers who had learned English as a second language. By using virtually identical materials and methodologies, Birdsong and Molis sought to determine if the same patterns of L2 attainment observed in Johnson and Newport's study would hold for different language pairs.

Contrary to Johnson and Newport's results, Birdsong and Molis found that even immigrants who arrived in America after their puberty achieved English proficiency on par with native speakers. Their research results suggested that there was no critical period for language acquisition and that adult learners could attain native-like proficiency in an L2.

This contrasting outcome provided counterevidence to the CPH, suggesting that Johnson and Newport's data might not be generalizable to multiple first language (L1) - second language (L2) pairings. Birdsong and Molis argued that the critical period might be language-specific rather than universal, emphasizing the importance of considering various L1-L2 combinations when studying language acquisition.

Overall, Birdsong and Molis's study challenged the prevailing notion of a critical period for language acquisition by demonstrating nativelike achievement among adult learners. Their findings emphasized the need for further research to explore the factors influencing language acquisition across different language pairings.

The cautious attitude of Chinese scholars towards the CPH is based on several factors. Firstly, they argue that most of the research on the CPH has focused on learners in second language (L2) settings where learners have access to the target language outside the classroom and are immersed in a context where the target language is used as the main means of communication. However, in China, learners have limited exposure to English outside the classroom, which makes it difficult to apply the findings of CPH to the Chinese English as a Foreign Language (EFL) context. (Zhu, 2011)

Furthermore, a study conducted by Zhao and Zou analyzed 42 autobiographies of renowned foreign language experts in China to investigate the age-related factors that may have contributed to their success in foreign language learning. The results of their qualitative analysis showed a moderate correlation between age of onset and self-assessed achievements in both early-starters and late-starters, with a weak correlation found only among the early-starters. This finding challenges the CPH and suggests that other factors such as motivation, teachers, and language aptitude may play a more significant role in determining L2 success for learners. (Zhao & Zou, 2008)

These findings highlight the need for considering contextual factors and individual differences when studying language acquisition and challenging the universality of the CPH. While the CPH proposes a critical period for language acquisition, scholars in China argue that its applicability in the Chinese EFL context may be limited due to the unique language learning environment and the influence of other factors. Further research is needed to explore the interplay between age, contextual factors, and individual differences in the acquisition of English as a foreign language in China.

While the CPH is aimed firmly at language acquisition other parallels in other fields of study would tend to indicate that its application to that limited field may be incorrect.

For example, in developmental psychology, it is recognized that critical periods occur throughout childhood and adolescence and are crucial for the acquisition of language, social skills, sensory perception, and cognitive abilities.

The notion of critical periods also finds support in developmental biology. In the field of developmental biology, critical periods are observed in various physiological processes such as embryonic development, organ formation, and sexual differentiation. For instance, the development of the visual system in animals, including humans, relies on the presence of visual stimuli during a specific period after birth. Deprivation of visual input during this critical period can lead to permanent deficits in vision, known as amblyopia or "lazy eye." (Brainard & Knudsen, 1998)

## Technology Acceptance Model

Davis (1989) introduced the Technology Acceptance Model (TAM) as a theory to understand and explain the factors influencing individuals' acceptance and usage of technology. TAM has since been widely recognized and extensively used in the field of information systems and technology adoption research.

The main objective of TAM is to provide a theoretical framework that can explain and predict users' behaviour when adopting new technology. It focuses on the individual's perceptions and attitudes towards technology, rather than the technological features themselves. According to TAM, the key determinants of technology acceptance are perceived usefulness (PU) and perceived ease of use (PEOU).

Perceived usefulness refers to the degree to which an individual believes that using a particular technology will enhance their performance or make their work more efficient. Perceived ease of use, on the other hand, is the extent to which an individual believes that using the technology will be free from effort and complexity.

Davis argues that users' perceptions of usefulness and ease of use directly influence their intention to use the technology, which, in turn, leads to actual usage. TAM suggests that if users perceive a technology as useful and easy to use, they are more likely to adopt it and incorporate it into their daily routines.

Figure 2- Technology Acceptance Model

Perceived

Usefulness

Behavioral Intention to Use

Attitude

Towards

Using

External

Variables

Actual System to Use

Perceived

Ease of Use

The Technology Acceptance Model (TAM), proposed by Davis, has been widely used in various contexts to explain system usage and acceptance. It is considered a reliable and substantial model for understanding user behaviour and attitudes towards technology.

However, researchers have recognized the need to expand the TAM by including additional factors to enhance its explanatory power. Several studies have sought to incorporate external variables into the model to provide a more comprehensive understanding of technology acceptance.

In 2000, Venkatesh and Davis proposed an extension to the original Technology Acceptance Model (TAM) called TAM2. TAM2 builds upon the core determinants of the initial TAM, which are Perceived Ease of Use (PEU) and Perceived Usefulness (PU). (Venkatesh & Davis, 2000)

However, TAM2 introduces additional factors to account for the influence of social factors on individuals' behavioural intentions towards technology adoption. It considers the effects of social influence on subjective norms and image, in addition to the cognitive instrumental process. The cognitive instrumental process involves evaluating the quality of output, job relevance, and result demonstrability of the technology being considered.

Figure 3- Extended Technology Acceptance Model

Voluntariness

Experience

Subjective

Norm

Image

Perceived

Usefulness

Usage

Behavior

Job

Relevance

Intention

To Use

Output

Quality

Perceived

Ease of Use

Result

Demonstrability

TAM2 suggests that individuals use mental representations to assess the connection between their important work goals and the potential effects of adopting a particular system. These mental representations serve as a basis for forming judgments about the performance contingencies, such as the perceived usefulness of the technology.

Al-Aulamie et al. (2012) expanded the TAM by integrating perceived enjoyment and perceived enjoyment value as additional factors. Their study demonstrated that these variables significantly influenced user acceptance of technology in the context of e-learning.

Al-Hawaii and Mouakket (2010) expanded the TAM by including perceived playfulness as a determinant of user acceptance of online banking. Their findings revealed that perceived playfulness had a significant impact on users' intentions to adopt online banking services.

Chen & Li (2017) extended the TAM by incorporating trust and subjective norms as external factors. The results of his study indicated that these variables significantly influenced user acceptance of mobile payment services.

Lai (2016) expanded the TAM by including perceived privacy risk and perceived financial cost as additional variables. The findings showed that these factors significantly affected users' intentions to adopt mobile banking.

Bousbahi and Alrazgan (Bousbahi & Alrazgan, 2015) extended the TAM by integrating perceived security and perceived convenience as determinants of user acceptance of mobile commerce. Their research demonstrated that these factors had a significant impact on users' attitudes and intentions towards mobile commerce.

These studies highlight the importance of expanding the TAM by considering various external factors to enhance its explanatory power in different contexts. By incorporating additional variables, researchers can provide a more comprehensive understanding of user acceptance of technology and improve the effectiveness of the model.

Both TAM and TAM2 have been widely used in various organizational settings to explain individuals' acceptance of different forms of technology. They provide a theoretical framework for understanding the factors that influence technology adoption and usage behaviours.

## Cognitive Load Theory

Many modern educators follow a scholastic philosophy that emphasizes the importance of teachers mastering their discipline, engaging in research, and basing instruction on established bodies of knowledge. (Gutek, 2013) This philosophy, promoted by scholastic philosopher Saint Thomas Aquinas as early as the 13th century, has remained relatively unchanged over time. However, the educational landscape has been significantly impacted by technological advancements, leading to a potential transformation in the way knowledge is transferred.

In the 21st century, technology has the potential to assist and enhance the learning process, bridging the educational divide that exists between different cultural, religious, and socioeconomic groups. (Solomon et al., 2003) To fully harness the educational potential of technology, educators must incorporate scholarly research and current knowledge into their teaching practices, just as Aquinas advised.

Technological advancements in learning have shed light on the limitations of human cognitive architecture. Human intellect, working memory, and information-processing abilities are constrained. (Colvin Clark & Mayer, 2016) Therefore, instructional designs should be mindful of these limitations and aim to optimize the transfer of information from working memory to long-term memory. (F. Paas et al., 2003a) Failure to do so can overwhelm learners and hinder the learning process.

Several recent studies have focused on the human cognitive load theory and have provided insights for instructional design incorporating educational technology. These studies recommend the inclusion of audio and visual components while minimizing the use of narration accompanied by redundant on-screen text. (Colvin Clark & Mayer, 2016; F. Paas et al., 2003a)

John Sweller's Cognitive Load Theory highlights the importance of instructional design in managing cognitive loads to optimize learning. Technology can play a significant role in reducing cognitive load by providing scaffolding, feedback, adaptive learning experiences, and personalized instruction. By leveraging technology effectively, educators can enhance learning outcomes by alleviating the cognitive demands placed on learners. (F. Paas et al., 2003a)

Like snowflakes, no two humans are the same. Everyone has unique cognitive abilities and learning preferences. However, humans as a species do share common characteristics and a distinctively human cognitive architecture. This presents a valuable opportunity for course designers to consider certain aspects of human cognitive architecture when building instructional design strategies.

Two vital components of the human cognitive architecture that directly impact learning are working memory and long-term memory. Designing instruction that includes multiple sources of information, which can only be understood once the related sources have been mentally processed and integrated into a single concept, can lead to a split-attention effect. This represents an inefficient use of memory and cognitive processing. (Torcasio & Sweller, 2010; Von Merriënboer & Aryres, 2005)

Another important consideration for course designers is the modality effect. Working memory is divided into two channels for processing visual and auditory information. (Colvin Clark & Mayer, 2016) The process of storing and processing information in working memory creates a cognitive load, which refers to the burden on the learner's cognitive resources. According to John Sweller (Sweller, 2020), there are three types of cognitive load.

Until the late 1990s, cognitive load theory primarily focused on instructional designs that aimed to reduce extraneous cognitive load. This emphasis on extraneous load stemmed from the belief that intrinsic load, which is inherent to the learning task, was fixed and unchangeable. Consequently, research and publications on reducing cognitive load only concentrated on extraneous load. (Mayer & Moreno, 2003)

However, Paas and van Merriënboer (1994) conducted a study on the effects of high and low variability of problem situations on learning. They discovered that students who encountered variable sets of problems were better at categorizing statistical word problems and demonstrated better transfer, despite the increased cognitive load. The authors interpreted these findings as evidence of another type of cognitive load, which they termed germane load. (Kalyuga et al., 1998) Germane load was considered a "good" type of cognitive load that positively influenced learning. It was believed to be associated with the development of cognitive schemata, which required additional working memory capacity. As a result, cognitive load theory proposed that instructional design should reduce extraneous load while potentially increasing germane load if the total cognitive load remained within manageable limits and did not overload the learner's working memory. (Sweller, 2004)

In more recent research on cognitive load theory, the effects of cognitive load have been further explored to better understand how different instructional formats impact learning. One finding is that integrating multiple sources of information to avoid split attention does not always lead to better learning outcomes. The split-attention effect, where different sources of information need to be mentally integrated, only occurs when these sources are unintelligible in isolation. However, there are cases where multiple sources of information can be understood independently.

For example, Chandler and Sweller (1991) found that adding text to a diagram, which only described the content of the diagram, did not improve learning. In fact, learning was enhanced when the textual material was eliminated, rather than integrated with the diagram. When a second source of information merely reiterates the information of the first source in a different form, it is considered redundant. Removing this redundant information, known as the redundancy effect, has been shown to improve learning outcomes. (Sweller & Chandler, 1994)

Recent research has also highlighted the importance of matching instructional formats to the learner's expertise. The split-attention effect, modality effect, and worked-examples effect do not occur under all conditions. For example, Kalyuga et al. (1998) found that as learners' expertise increased, physically integrating multiple sources of information lost its advantage and became disadvantageous compared to a physically separated presentation. Additional information that is essential for novices may become redundant for more expert learners. Similar results were reported by Kalyuga et al. (2003).

The same pattern of effects was observed for the use of multiple modalities. Kalyuga et al. (2000) found that novices performed better when learning from a diagram plus auditory text compared to a diagram plus visual text. However, as learners acquired more prior knowledge, the advantage of the diagram combined with auditory text disappeared. In fact, after a further increase in prior knowledge, students learned best when presented with only a diagram. Similar findings were reported by Leahy et al. (2003).

When comparing learning from worked-out examples to learning from an exploratory-based environment, Kalyuga et al. (2001) found that novices benefited most from worked-out examples with complex tasks. However, as learners became more experienced, the advantage of worked-out examples disappeared, and the exploratory group performed better. Similarly, the researchers found that worked-out examples were more beneficial for novices compared to traditional problem-solving. However, as learners achieved higher expertise, traditional problem-solving became the better alternative for learning. These findings, known as the expertise-reversal effect, demonstrate how the effectiveness of instructional formats can change based on the learner's level of expertise. (Kalyuga et al., 2003)

In recent years, Sweller has sought to integrate cognitive load theory into the framework of evolutionary theory. Drawing on research in biology, psychology, and anthropology, he proposes that the structures and processes of human cognition are analogous to those associated with evolution by natural selection. (Geary, 2004) For instance, he suggests that human long-term memory functions similarly to the genetic code in biology. Just as the genetic code has developed as a biological adaptation to a species' environment, long-term memory has evolved as a cognitive adaptation to an individual's environment. Sweller also compares the limited capacity of human working memory, which allows only small modifications, to the small steps of genetic modifications necessary for biological evolution. (F. Paas et al., 2003b; Sweller, 2004)

This evolutionary perspective has helped clarify the scope of cognitive load theory. It posits that there are biologically predetermined dispositions to acquire specific knowledge. For example, we easily learn to discriminate individual faces without conscious effort, which is referred to as biologically primary knowledge. On the other hand, certain types of knowledge, such as reading, writing, and mathematics, require explicit teaching and effort and are therefore considered biologically secondary knowledge. (Geary, 2007) Cognitive load theory only applies to the acquisition of biologically secondary knowledge, as this is where working memory comes into play. –(Sweller & Sweller, 2006)

# CHAPTER 3 METHODS

Use a 2” top margin on the first page of a new chapter.

The best methods chapters provide a detailed and methodical explanation of research methods used and include discussion of ethical considerations. Provide enough detail, in a logically organized manner, so that readers could retrace your steps or replicate your study in the future. Be sure to update Chapter 3 after the proposal stage to reflect how your study actually unfolded—often there are changes from how you initially conceived of your research process.

Change the verb tense to the past tense in the dissertation defense stage to reflect that the study has already taken place. Describe the demographics of your participants and how the data collection and data analysis took place. Include the ways you will protect participants’ anonymity, preserve the security of data during the collection and analysis stages, and any measures you will take to increase the reliability and validity of your findings.

Provide a brief opening paragraph in which the study methods are introduced. Include

any pertinent details needed to understand the connection between the research questions and the study design.

## Participants

Describe the participants in the study and how they will be selected. Be specific in explaining as much demographic information as necessary for your study.

## Data Sources

Describe the nature of the data sources and instruments you will use to answer your research questions.

### Data Source 1

As an example, describe a survey or other data source in detail, including the number of items in each section, the response scale, any available validity and reliability information, as well as one or two sample items (for longer instruments, it might be appropriate to include the full instrument in an appendix). Be sure to include a reference to the developer of the measure, or report that it was researcher-developed if it is a measure you created for the study. If you are the developer, discuss how you field-tested and pilot-tested the measure. Rename this section appropriately.

### Data Source 2

Provide appropriate details for each data source you use in your study. Continue until you describe all applicable data sources (e.g., survey, interview protocol, focus group protocol, document or other artifact analysis, and student achievement data from SOLs. demographics, and any other data sources that are part of your study, including extant data). Include any available information about the validity and reliability of each instrument.

## Data Collection

Describe in detail how you will collect all information for your study. For example, if you will observe a teacher planning team, explain how this data collection process will work. Include all major steps and needed details for the data collection phase of the study. The intent is for you to provide sufficient details so that another researcher can understand what you have done and replicate the study.

## Data Analysis

You might include a brief overview of your data analysis strategy before describing specifically how you will analyze your data to answer each of your research questions.

### Research Question 1

Describe how you will analyze (proposal)/analyse (defence) your data to answer your first research question. If your study is quantitative, be clear regarding any descriptive and inferential statistics you will use. For example, in the case of a survey you might plan to analyze your data using descriptive statistics, including mean and standard deviation as well as correlational analysis or multiple regression. If your study is qualitative, describe your data coding and analysis process.

### Research Question 2

Provide the same information for how you will analyze your data in answer to each of your research questions.

### Research Question 3

It is helpful to include a table in this section of your proposal, listing your research questions in the first column, the data sources you will use to answer each question in the second column, and a brief description of how you will analyze the data in the third column. If you include a table, be sure to introduce it briefly in the text first (See Table 1).

Table 1

*Table Title*

|  |  |  |
| --- | --- | --- |
| Evaluation Question | Data Sources | Data Analysis |
| RQ 1 |  |  |
| RQ 2 |  |  |
| RQ 3 |  |  |

*Note.* APA tables do not include vertical borders. Each column has a heading describing the category of content in that column. Text may be as small as 10 points. Use “keep lines together” and “keep with next” paragraph settings to ensure that tables do not break across multiple pages of the document.

## Delimitations, Limitations, Assumptions

### Delimitations

Describe the delimitations of your study. These are decisions you made concerning the parameters of your study.

### Limitations

Describe the limitations of your study. These are elements that are beyond your control and should be acknowledged as potential influences on our findings.

### Assumptions

Describe the assumptions of your study.

## Researcher as Instrument Statement

If you are conducting a qualitative or mixed-methods study, you should include a statement describing your background about the study topic and what measures you will take to guard against researcher bias.

## Ethical Considerations

Describe the process for gaining approval to conduct the study from the William & Mary Education Institutional Review Committee (EDIRC). Describe the steps you will take to gain informed consent and to protect the participants in your study from potential harm or embarrassment. This will include how you will keep the data and when and how you will dispose of it.

Describe the process you will use to gain any necessary permissions to gather data from the participants in your study.

## Timeline

For the proposal, include a timeline for each phase of the study. This section will be removed for the final dissertation defence.

# CHAPTER 4 FINDINGS

Use a 2” top margin on the first page of a new chapter.

In this chapter, focus on results of data analysis; avoid interpreting or discussing implications at this point in the document. It is helpful to organize your findings by research question. For each finding, provide specific quantitative data or participant quotations to support your conclusion.

Provide an introductory paragraph detailing the focus of this section on your findings and how this section is structured. Structure the section by research question.

## Research Question 1 (APA 2)

Provide your findings, including relevant tables and figures. If you include a participant quotation that is 40+ words long, use the block quotation format:

Block quotations look like this. They are indented .5” from the left margin (just like a new paragraph). Don’t use opening and closing quotation marks with a block quotation— the block formatting lets readers know it’s a quotation. When you get to the end of the quoted material, use closing punctuation. As long as you’ve made it clear in the stem or the preceding paragraph that this is a participant quotation, no citation is needed after the closing punctuation.

Regular paragraphs of text follow the quotation like this.

### Subheading—APA 3

**Subheading*—APA 4.***

***Subheading—APA 5.*** It would be unusual to use this level of heading in your results.

## Research Question 2 (APA 2)

### Subheading—APA 3

Provide your findings including relevant tables and figures.

## Research Question 3 (APA 2)

### Subheading—APA 3

Provide your findings including relevant tables and figures.

## Summary of Findings (APA 2)

Provide a summary paragraph of findings.

# CHAPTER 5 RECOMMENDATIONS

Use a 2” top margin on the first page of a new chapter.

Summarize your major findings from Chapter 4 and link each finding to relevant discussion, literature presented in Chapter 2, or newly introduced literature related to unexpected findings that emerged during analysis. Use tables and figures to clarify relationships between and among findings, implications, and extant literature. Provide recommendations for policy, practice grounded in your findings, as well as recommendations for future research. Wrap it up with a final paragraph or two that brings Chapters 1-5 together, summarizing your path from research problem and literature review to research approach and findings/conclusions.

Provide an introductory paragraph detailing the focus of this section on the evaluation findings and how this section is structured.

## Summary of Major Findings

### Research Question #1 (APA 3)

***Research Question #2 (APA 3)***

***Research Question #3 (APA 3***

## Discussion of Findings

Discuss the results of your study and what you make of these results in light of the literature reviewed in Chapter 2.

## Implications for Policy and Practice

Provide an introductory paragraph detailing the focus of this section on the recommendations based on the findings of this study. Include a table that links the findings to the

recommendations (see Table 2). Each subheading should be a recommendation. Recommendations should be based on findings. Where appropriate link recommendations back to other studies or literature discussed in the literature review. The number of recommendations will vary.

Table 2

*Table Title*

|  |  |  |
| --- | --- | --- |
| Findings | Related Recommendations | Supporting Literature |
| Succinct statement of findings | |  |
| Succinct statement of findings | |  |
| Succinct statement of findings | |  |
| Succinct statement of findings | |  |

*Note.* Tables should complement, rather than replicate, explanations from the text of your document. Think of a table as a succinct way to organize and share complex data that would otherwise be difficult to explain to readers. Use the text of your document to refer readers to the relevant table.

### Policy or Practice Recommendation 1 (APA 3)

Describe recommendation #1 and link the recommendation to your findings and to your literature review if appropriate.

### Policy or Practice Recommendation 2 (APA 3)

Describe recommendation #2 and link the recommendation to your findings and to your literature review if appropriate.

### Policy or Practice Recommendation 3 (APA 3).

Describe recommendation #3 and link the recommendation to your findings and to your literature review if appropriate. If you use any figures to synthesize your findings and recommendations, introduce the figure in the text just prior to figure placement (Figure 1).

## Recommendations for Future Research

Having explored your topic deeply over a period of time, you are now in a position to offer new research questions and suggest additional research methods for future researchers who might want to investigate this topic. This is an important way for you to serve the field, so don’t rush though this section. Think carefully about what’s next for this line of research.

## Summary

Provide a summary for the study or any concluding comments.

# REFERENCES

1. Follow APA guidelines precisely for all references. Consult the APA manual or APA style blog (https://apastyle.apa.org/blog) for guidance. Here is a general format for journal articles:

Lastname, F. I. (2019). Title of article is in sentence case. *Journal Name is in Title Case and Italics, 7*(1), 23-27. https://doi.org/xxxx

1. Carefully check for an exact match between the references cited in the text and the reference list. There must be an exact match. If your references are extensive, it is helpful to use the search feature in Word to ensure that each citation in your reference list is cited in text and vice versa. It may also be helpful to print your reference list and read through in-text citations throughout the document, checking off each entry on the printed list. This will allow you to catch any omitted entries and remove any extraneous ones.
2. Format your references using the hanging indent feature in Word. This can be found under the paragraph tab, in the section titled Indentation. On the dropdown menu, choose “hanging.”

# APPENDIX A NAME THE APPENDIX

Insert Appendix A material here. If you have only one appendix, label it “Appendix” and do not include a letter.

Add a page break and start a new page for each additional appendix. The appendices should be lettered alphabetically according to the order in which they are mentioned in the text.

**APPENDIX B APPENDIX C**

**Continue with all appendices.**

# VITA

The Vita is a one-page autobiographical sketch of the author, containing full name, contact information, educational background, degrees and dates, and other pertinent training or experience.

Add a one-page biographical summary that includes the following information:

* + Author's full name
  + Educational background
  + Degrees held, including issuing universities and dates conferred
  + Related training and experience