ATTITUDES OF SECONDARY STUDENTS TOWARD ONLINE AND FACE-TO-FACE LEARNING IN MATHEMATICS: A QUANTITATIVE CAUSAL-COMPARATIVE STUDY

by

Rebecca Joy Martin Philyaw

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Philosophy

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APPROVED BY:

Nathan Putney, Ed.D, Committee Chair

Dr. Philip Alsup, Ed.D, Committee Member

ABSTRACT

The purpose of this quantitative, causal-comparative study is to investigate the current differences between online and face-to-face student attitudes toward mathematics and computer-based learning at the high school level. Because instruction and technology use have been influenced by the Covid-19 pandemic, it is important to assess student attitudes toward mathematics and computer-based learning in both traditional face-to-face and online settings. This study was conducted with 70 face-to-face students and 67 online high school students in a single school district in North Carolina. The Galbraith-Haines Mathematics-Computer Attitude Scales were used as the data collection instrument measuring student confidence toward mathematics, mathematics motivation, computer confidence, and computer-mathematics interaction. A secure Google form was used for data collection in the spring of 2023. A one-way MANOVA was used to determine if there was a difference in attitudes between the online and face-to-face participants in the dependent variables. The result of the MANOVA was significant, where $F(4, 127) = 10.448$, $p < .001$, Pillai's Trace = .248, and partial $\eta^2 = 0.248$, suggesting there are significant differences on the dependent variables by setting type for high school mathematics students in online and face-to-face settings. Results indicated a higher confidence in mathematics held by face-to-face students, higher mathematics motivation held by online students, and higher computer-mathematics interaction held by online students. No significant difference was found between online and face-to-face students in the area of computer confidence. Recommendations for further studies include a larger sample size, a comparison of technology uses, and a qualitative study.

Keywords: online learning, face-to-face learning, mathematics attitude, computer attitude, mathematics engagement, computer-mathematics interaction

Dedication

With God's blessings and with tremendous gratitude, I dedicate this dissertation to my family. Zac, you are the love of my life and God's perfect mate for me. Thank you for being my support and my cheerleader throughout the journey. You kept me grounded as a wife and mother. You read everything from the first paper I wrote in fifteen years to this final draft. Caiden, Bailey, Annabeth, and Maggie, thank you for being my inspiration and for putting up with my work times and frustrations. You will always be my greatest achievement. I pray I have encouraged you to develop your relationship with God and listen for his voice. I dedicate this to my father and mother, who are rejoicing in Heaven. Thank you for encouraging me to follow my dreams, for always supporting me in every big and small endeavor, and for showing me how to put my trust in Jesus. All of you make life so meaningful every day, and I am truly blessed that God made us a family.

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List of Abbreviations

Computer Algebra Systems (CAS)

Fennema-Sherman Mathematics Attitude Scales (FSMAS)

Galbraith-Haines Mathematics-Computer Attitude Scales (GHMCAS)

Information and Communication Technologies (ICT)

Institutional Review Board (IRB)

Multivariate Analysis of Variance (MANOVA)

National Council for Teachers of Mathematics (NCTM)

Science, Technology, Engineering, and Mathematics (STEM)

Technology-Assisted Learning (TAL)

CHAPTER ONE: INTRODUCTION

Overview

The purpose of this quantitative, causal comparative study is to investigate the current differences in student attitudes toward mathematics and computer-based learning at the high school level. Chapter One provides a background for the topics of attitudes toward mathematics and technology and traditional and online settings. Included in the background is an overview of the theoretical frameworks for this study. The problem statement addresses the extent of the recent literature on this topic. The purpose of this study is followed by the significance of the current study, and the research questions. The final portion of the chapter is a list of key terms and their definitions.

Background

Student attitudes toward mathematics have been the focus of studies for many decades (Fennema & Sherman, 1976; Haladyna et al., 1983; Ma & Kishor, 1997; Plank, 1950; Poffenberger & Norton, 1959; Porter, 1938). Attitudes toward learning have been linked to achievement and engagement (Birgin & Topuz, 2021; Fidan & Tuncel, 2019; Taylor et al., 2021; Yeşilbağ & Korkmaz, 2021). Implementing Technology-Assisted Learning (TAL) has become more prevalent in modern times (Borba et al., 2016). Teachers have integrated TAL into their classrooms, and the COVID-19 pandemic has given many teachers motivation to appreciate digital resources and technology that they may not have considered previously (Mulenga & Marbán, 2020), as well as incorporate new techniques of teaching into their lessons. The use of technology in the classroom has been found to be most effective when combined with a variety of techniques and teaching methods (Demir & Önal, 2021). The pandemic also caused students to be thrown into remote learning and the opportunity to develop independent thinking and working skills (Burke, 2020). Students are using technology to learn in ways that were not explored in the past (Borba et al., 2016). All of these components factor into student attitudes toward learning mathematics and technology, which in turn affect achievement. As the pandemic recovery process continues, it is crucial to reevaluate student attitudes and views toward online and face-to-face learning in the wake of major changes in technology implementation and instructional practices.

Historical Overview

Attitude and Achievement

Consideration of attitudes toward mathematics have been included in studies for many years. The question of the relationship between attitude and achievement has often been a topic of study, especially prevalent in the 1980s. Increased confidence in ability has also been shown to improve achievement in mathematics (Cheung, 1988; Ling Tsai et al., 1983). The relationship between attitude and achievement is stronger in boys than girls (Harnisch et al., 1986; Schofield, 1982), and it increases with grade level (Schofield, 1982). The strength of this relationship varies by country (Harnisch et al., 1986). In Belgium, England, Finland, France, Japan, Netherlands, Scotland, and the United States, the Harnisch et al. (1986) study found seventeen-year-old male attitudes to be more positive toward math than their female counterparts and male achievement was also higher. In West Germany, the female attitudes were found to be more positive than males, and in Sweden, no difference was found between the male and female attitudes toward math (Harnisch et al., 1986). However, male achievement also exceeded females in both countries (Harnisch et al., 1986). Hannula et al. (2019) also found gender to have “a moderating role on the effect of motivation” (p. 8) with varying levels of effect across the countries of Ghana, Botswana, South Africa, Morocco, and Tunisia. Positive relationships between student attitudes toward mathematics and achievement have also been shown in modern times (Birgin & Topuz, 2021; Fidan & Tuncel, 2019; Taylor et al., 2021; Yerdelen-Damar et al., 2021; Yeşilbağ & Korkmaz, 2021). Positive attitudes produce greater persistence and more effort put forth in the area of learning engagement (Marzano, 2000; Pierce et al., 2007). In contrast, Quinn and Jadav (1987) found no relationship between attitude and achievement for elementary school students. These differences help to point out the need for additional research in the area of attitude and achievement.

Attitude Influences

Attitudes toward mathematics have been found to be influenced by several factors. In the United States, one factor influencing attitude is reinforcement, while in certain other countries teaching has more of a direct effect on attitude (Papanastasiou, C., 2000). Home conditions, especially parental education and views have also been shown to influence attitudes toward mathematics (Harnisch et al., 1986; Ling Tsai et al., 1983; Papanastasiou, C., 2000, Smith et al., 2021). Additionally, teaching strategies influence student attitudes. Project-based-learning (PjBL) incorporating technology increases student views of the importance of mathematics (Tseng et al., 2013). Cooperative learning positively influences secondary student performance and attitudes toward mathematics (Hossain & Tarmizi, 2013; Zakaria et al., 2010).

Attitudes and Technology

In more recent years, connections between mathematics attitudes and technology have been examined. Technology-enhanced instruction positively influences student motivation (Higgins et al., 2019). Improved attitudes, gains in conceptual understanding, and improvements in learning behavior have been linked to technology use in mathematics education (Ersoy & Akbulut, 2014; Eyyam & Yaratan, 2014; Pierce et al., 2007). Children's attitude toward math has been shown to influence their willingness to participate in digital games to support learning (Litster et al., 2021). Studies continue to be conducted on various types of technology and their implementation in connection with attitudes toward mathematics.

Mathematics Attitude Instruments

Early on, instruments tended to focus only on the measurement of global attitudes (Fennema & Sherman, 1976). As questions of gender differences in education came into focus in the 1970s, Fennema and Sherman (1976, 1978) initially decided to develop an instrument to measure student attitudes toward mathematics learning as a means of measuring attitude differences toward mathematics between genders. After putting their instrument to use in the intended study in 1978, popularity of the instrument grew. Known as the Fennema-Sherman Mathematics Attitude Scales (FSMAS), variations of the form have entered the research scene. For example, Mulhern and Rae (1998) produced a shortened version of the scales and Shirbagi (2008) oversaw a Persian translation. Over time, the instrument evolved from being used to measure attitude differences between genders to examination of mathematics attitude differences that exist in relation to educational trends. Biesinger, et al. (2008) used a revised version to measure student attitudes toward mathematics on a block schedule compared to a traditional schedule. However, as computers entered the educational scene, Galbraith and Haines (2011) saw that the Fennema-Sherman instrument did not address this element of student attitudes toward mathematics.

During the mid-1990s, Galbraith and Haines (2011) chose to develop and test a set of attitude scales that combined student attitudes toward mathematics with attitudes toward computer learning with components that paralleled the FSMAS (García-Santillán et al., 2013). Conducting a study with the scales in 1998, Galbraith and Haines found that computer influence had a significant impact on student attitudes toward computer-mathematics interactions. They foresaw that this computer influence would extend to graphing calculators and computer programs used in mathematics classrooms at the undergraduate level (Galbraith & Haines, 1998). Because of the focus on attitude toward both mathematics and technology, the Galbraith Haines scales will be used as the survey instrument for this study.

Society-at-Large

As the educational system continues to evolve to meet the needs of students, it is essential to gage student attitudes toward learning. Enjoyment is one of the key components contributing to attitudes toward mathematics (Fennema & Sherman, 1976). Poor achievement is linked to low levels of enjoyment and low levels of motivation (Opolot-Okurut, 2005). Teachers have the power to add enjoyment to learning for students through creating an environment that is need-fulfilling (Hagenauer & Hascher, 2010). When student attitudes become more favorable, engagement with mathematics tasks increases, and in turn, learning is increased (Ashcraft, 2002; Flores et al., 2014). As the educational system continues to recover from the COVID-19 pandemic, teachers continue to adapt their practices to meet the needs of modern students. Because of changes in teaching methods and tools, attitudes of mathematics students may differ from pre-pandemic studies. By examining the current student attitudes toward online and traditional learning of mathematics, a foundation for post-pandemic research can be established.

Theoretical Background

There are two main theories providing the background for this study: The ABC model of attitude theory and connectivism learning theory. The ABC model of attitude theory began with the foundational ideas of Alport (1935), Rosenberg (1960), Krech et al. (1962) and was further developed by Ostrom (1969) and supported by Breckler (1984). This theory divides attitude into three components: affective, behavioral, and cognitive. Feelings are represented through the affective component; intentions are represented through the behavioral component; and the cognitive component represents thoughts (Drew, 2020). Revising the original definitions to focus on beliefs, attitudes, and emotions, Hart (1989), Mandler (1989), and McLeod (1989, 1992) extended the study of attitude components. These revised definitions were the foundation of the development of mathematics and computer attitude scales by Galbraith and Haines (2011). Each type of attitude identified in the ABC model is represented through the Galbraith-Haines scales, which measure student attitudes toward mathematics confidence, mathematics motivation, mathematics engagement, computer confidence, and computer-mathematics interaction (Galbraith & Haines., 2011).

Connectivism learning theory also plays a role in this study. Originating with George Siemens (2004) and Stephen Downes (2005), connectivism learning theory asserts that learning takes place through connections that are made (Siemens, 2004). Sources of information include books, webpages, other people, task completion, and other possible in-person or digital sources (Siemens, 2004). Learning takes place through connecting information, and the connections must be maintained (Siemens, 2004). The value of the gained information must also be considered to determine what is important, relevant, and applicable (Siemens, 2004). Siemens (2004) also claims that technology is also playing an important role in rewiring our brains and supports cognitive processes. The National Council for Teachers of Mathematics (NCTM) (2023) explains that technology is an essential component to teaching and learning mathematics and that acquiring knowledge necessitates actively constructing new understanding from experiences and linking it to previously acquired information. Making connections is part of what develops conceptual understanding of mathematics (Garrett et al., 2020). The intention of this study is to examine the influence of connections made on secondary students' attitudes toward learning mathematics through the use of computers.

Problem Statement

Historically, student attitudes toward mathematics have been shown to influence motivation and achievement (Cheung, 1988; Ling Tsai et al., 1983; Yerdelen-Damar et al., 2021). Attitudes have also been connected to persistence and willingness to engage in learning (Marzano, 2000; Pierce et al., 2007). Technology has a positive impact on student attitudes, motivation, learning behaviors, and conceptual understanding in mathematics (Ersoy & Akbulut, 2014; Eyyam & Yaratan, 2014; Gjicali & Lipnevich, 2021; Higgins et al., 2019; Pierce et al., 2007).

In recent years, the COVID-19 pandemic has had a considerable impact on the use of technology in education. As a result of the transition to remote learning, and the continued implementation of online and hybrid learning options, there has been an increase in the use of online resources, e-learning activities, and digital devices (Mulenga & Marbán, 2020). Teachers learned to use the technology and educate students in different ways using online-based activities, online reading and writing, project-based learning, play-based learning, and inquiry-based learning (Burke, 2020), with many continuing to utilize these teaching skills in online and face-to-face environments. Demir and Önal (2021) recommend a combined approach of technology assisted learning (TAL) and project-based learning (PjBL) and suggest further research be conducted in student attitude and levels of motivation.

Although the pandemic is currently having less of an effect on the choice for exclusively online learning at the high school level, the influence of remote learning has fostered lasting effects on the approaches of students and teachers, and possibly on student attitudes. Fabian et al. (2018) call for further exploration of which environments are most beneficial for mobile learning of mathematics and for study of the effects of mobile learning on student attitudes toward mathematics. Although many online learning and digital resources were available prior to the pandemic, teachers had not utilized these resources to provide instruction and home learning support to the level that was necessary during the pandemic (Barbu et al., 2022; Burke, 2020). For example, only about half of the teachers in the Barbu et al. (2022) study reported using online platforms prior to the pandemic, with only 4.8% using the platforms to a large extent. Many teachers, however, accepted the challenge and implemented resources such as Twinkl, Zoom, and Aladdin Schools for the first time while adjusting for the varied digital learning skills of students and parents (Burke, 2020). Teachers devoted more time to planning and lesson preparation and institutions updated infrastructure to support remote learning (Barbu et al., 2022). After learning to use online platforms during the pandemic, many teachers have transitioned to daily use of the tool and overall digital skill levels for teachers have improved (Barbu et al., 2022). The problem is that the literature has not fully addressed what effects these pandemic-related technology and instructional implementations have had on high school student attitudes toward mathematics and technology in online and traditional settings.

Purpose Statement

The purpose of this quantitative, causal-comparative study is to investigate the current, post-pandemic, differences between online and face-to-face student attitudes toward mathematics and computer-based learning at the high school level. The independent variable for this study is post-pandemic high school math students divided into two groups: students taking the high school math course online and students taking the high school math course in the traditional, face-to-face setting. The online course is taught using the Canvas online learning platform with no in-person meetings, while the traditional course is taught in a face-to-face setting daily. Lesson materials and resources chosen by the teacher for each course. Traditional teachers also had access to the Canvas platform for use as a classroom learning management tool. The dependent variables for this study are confidence level, engagement, and computer-mathematics interaction of online and traditional high school math students toward mathematics and computers. Confidence levels in mathematics center around feelings of value for effort, expectations of results, and worry or nervousness associated with the subject (Galbraith & Haines, 1998). Mathematics confidence is related to self-efficacy in the subject and a lack of confidence is connected to anxiety and stress when attempting mathematical tasks (Mkhize, 2021). Computer confidence encompasses feelings of trust in finding correct answers, ability to master technical procedures, and beliefs about working through any technical issues that may come up (Galbraith & Haines, 1998; García-Santillán et al., 2013). Engagement is the extent to which students actively participate in learning by applying concepts, generating ideas, and creating a network of knowledge (Galbraith & Haines, 1998). Engaging behaviors include planning for studying, minimizing distractions, and timely submission of assignments (Gjicali & Lipnevich, 2021). Engagement levels are explored in the areas of mathematics and computers for this study. Computer-mathematics interaction is the level to which students actively combine their mathematical thinking with use of a computer-type device (Galbraith & Haines, 2011).

The population for this study is composed of ninth through twelfth grade students enrolled in high school math courses in online and traditional settings in a medium-sized school district.

Significance of the Study

While attitudes toward math and their effects on learning have been studied (Birgin & Topuz, 2021; Cheung, 1988; Fidan & Tuncel, 2019; Ling Tsai et al., 1983; Taylor et al., 2021; Yeşilbağ & Korkmaz, 2021), the COVID-19 pandemic has had unprecedented impacts on education. At this crucial point in time, it is important to gauge the influence of educational changes on student attitudes. Prior to the pandemic, an Australian study examined changes in student attitudes toward math over time, finding that maintaining a sense of excitement while learning supports upward trends in student performance (Darmawan, 2020). As student attitudes can change with the environment, the contributions of teachers to that environment must be considered. Many of the studies initially conducted during pandemic restrictions and following have focused on teacher attitudes. While teachers initially reacted to the remote learning transition with bewilderment, they eventually shifted to an attitude of new considerations and educational functions (Albano et al., 2021). Some issues such as student productive struggle were more of a concern for teachers during remote learning (Russo et al., 2021). Other studies have shown effective choices in technology use. Connective technologies were found to preserve social closeness between teachers and students and were reported to have innovative implications for teaching and learning (Jafri & Guo, 2021). Teachers reported that video conferencing, screen-casting, and screen sharing improved questioning and problem-solving skills (Jafri & Guo, 2021). Collaboration was improved through the use of breakout rooms and mathematical thinking was communicated through the use of virtual whiteboards and slide-sharing (Jafri & Guo, 2021). With such changes in environment and approach, student attitudes should also be evaluated in addition to the teacher views being reported. A study conducted at the present time may produce interesting results in student attitudes toward mathematics and technology and allow for comparison between online and traditional setting students.

Results of the current study could be used to help teachers better understand student attitudes in relation to content delivery and influence lesson planning practices. Hannula et al. (2019) detail the emphasis on elements that impact shifts in beliefs, especially in e-learning environments and the widespread use of technology in mathematics curricula as one of the current “open” questions in educational research. This study could contribute information toward this question. Results could also be compared to previous studies. For example, Cretchley and Galbraith (2002), established a limited correlation between attitudes towards mathematics and computer, but a strong relationship between computer attitudes and the use of computers when learning mathematics. They suggest further investigation into the types of mathematical tasks that build on enthusiasm for computers (Cretchley & Galbraith, 2002). Results could be used to determine if increased exposure to computer assisted learning in mathematics has caused a decline in the differences between parallel attributes found in previous uses of the Galbraith Haines scales, a question originally posed by the scale creators as they looked toward the future. Additionally, there is limited understanding of the fully online learning environment in the area of mathematics (Borba et al., 2016; Boz & Adnan, 2017). New insight could also be added to online education literature through studying student attitudes toward math in online courses (Johnston, 2022). While studies in mathematics and computer attitudes have been conducted at the university level (Galbraith et al., 2001; García-Santillán et al., 2012; García-Santillán et al., 2013; Rojas-Kramer et al., 2015; et al., 2020), and at the secondary level in other countries (Abidin et al., 2017; Berger et al., 2020; Ni Shuilleabhain et al., 2021), there is a lack of research in this area in the United States at the secondary level.

Research Question

RQ: Is there a difference between online and face-to-face high school students' confidence level toward mathematics, motivation toward mathematics, confidence level toward computers, or computer-mathematics interaction?

Definitions

1. *Active learning* - techniques where students do more than simply listen to a lecture (Rennie & Smyth, 2020)
2. *Anxiety* - a human emotion marked by fear and uncertainty; occurs when a person feels that an incident threatens their self-esteem; subjective feeling of apprehension, tension, nervousness, and worry associated with the nervous system's arousal (Mamolo, 2022, p. 2).
3. *Asynchronous Learning* – does not occur live; teachers and students are not online or virtual at the same time (Long et al., 2021, p.68); term is used to describe the use of the internet for access to a learning environment at times and locations to suit the user (Rennie & Smyth, 2020)
4. *Attitude* – an emotional reaction to an object (Galbraith & Haines, 1998); the result of emotional reactions that have been internalized and automatized (McLeod, 1989); learned or established predispositions to respond (Zimbardo & Leippe, 1991); an overall positive or negative evaluation towards an entity or behavior (Gjicali & Lipnevich, 2021).
5. *Attitudes toward mathematics* – enjoyment of mathematics, perceived usefulness of mathematics and the likelihood of choosing elective mathematics (Aiken Jr., 1970; Palacios et al., 2014).

6. *Blended Learning* – combinations of online and face-to-face teaching, or other combinations of technologies, locations, or pedagogical approaches (Rennie & Smyth, 2020)
7. *Computer-Assisted Instruction* - the teaching and learning process supported by computer-based programs or applications (Xie et al., 2020).
8. *Computer-Mathematics Interaction* – an interactive process of learning and mathematics context that adds dimension to cognitive learning processes (García-Santillán et al., 2013)
9. *Digital /Online/ Web-based Learning* – Course content is delivered on the web through email, videoconferencing, discussion boards, and live lectures (video streaming) (Rennie & Smyth, 2020)
10. *Emergency Remote learning (ERL)* - the unplanned and sudden shift from the traditional form of education into a remote one following the state of emergency in different countries due to the outbreak of COVID-19 (Khlaif et al., 2021)
11. *Project Based Learning (PjBL)* - learning content centered on real-life practices with realistic questioning (Al-Balushi & Al-Aamri, 2014; Demir & Önal, 2021).
12. *Student Motivation* – the degree to which students invest attention and efforts in various pursuits; rooted in subjective experiences, especially those connected to their willingness to engage in learning activities and their reasons for doing so (Brophy, 2010, p. 3).
13. *Synchronous Learning* – instruction that occurs live, with students watching in real time as the teacher is modeling (Long et al., 2021, p. 68); allows learners to have a level of interactivity at the same moment of time, e.g., a face-to-face (f2f) meeting, a live videoconference, a telephone conversation or an audioconference discussion (Rennie & Smyth, 2020)

14. *Technology Assisted Learning (TAL)* – learning subjects such as mathematics, science, and geography utilizing computers, software, and learning packages/materials that include e-books (Demir & Önal, 2021)

CHAPTER TWO: LITERATURE REVIEW

Overview

A systematic review of the literature was conducted with the purpose of exploring student attitudes toward online and hybrid learning in the secondary mathematics classroom. This chapter will present a review of the current literature related to the topic of study. The chapter opens with the theoretical frameworks. The study is grounded in the ABC Model of Attitude exploring affective, behavioral, and cognitive domains. In addition, George Siemens' (2004) and Stephen Downes' (2005) connectivism learning theory will be discussed. A thorough review of recent literature regarding attitude and achievement and attitude toward mathematics learning and technology follows the frameworks. Lastly, literature surrounding the impact of Covid-19 on education and the possible impacts on students' attitudes will be addressed. In the end, a gap in the literature will be identified, presenting a viable need for the current study.

Theoretical Framework

ABC Model of Attitude

The ABC model of attitude theory began with the ideas of Krech et al. (1962) and was further developed by Ostrom (1969) and supported by Breckler (1984). This theory divides attitude into three components: affective, behavioral, and cognitive. Affective attitude represents feelings; behavioral represents intentions; and cognitive represents thoughts (Drew, 2020). Hart (1989), Mandler (1989), and McLeod (1989, 1992) extended the study of attitude components and revised the original definitions. Galbraith and Haines (2011) grounded the development of their mathematics and computer attitude scales in the ABC model of attitude using the adapted definitions presented by Hart (1989), Mandler (1989), and McLeod (1989, 1992). Each type of attitude identified by Ostrom is represented through the Galbraith-Haines attitude scales, which measure student attitudes toward mathematics confidence, mathematics motivation, mathematics engagement, computer confidence, and computer-mathematics interaction (Galbraith & Haines., 2011).

Connectivism Learning Theory

Connectivism learning theory originated with George Siemens in 2004, followed by Stephen Downes, who published an article in 2005 presenting his view of the theory. Both men are identified with the development of the theory. Connectivism learning theory states that learning takes place through connections that are made (Siemens, 2004). These connections can be to other people (in person or digital), books, webpages, task completion, and a multitude of other information sources. Learning is connecting information sets, and connections are more important than the current state of knowledge held (Siemens, 2004). Learning may also take place through the use of non-human appliances, such as manipulatives or digital tools (Siemens, 2004). Connections must be maintained so that learning is continual (Siemens, 2004). This means that ideas are constantly being developed, and information is being shared for consideration. Making connections between ideas is a core skill, with the ultimate goal being the currency of information in an ever-changing network (Siemens, 2004). Obtaining the most current knowledge on a particular idea helps to provide an up-to-date view of the concept. A learner develops processes to gather and analyze information, a learning process and skill that leads to further increases in knowledge. Further development of this skill is realized through the examination of more sources, or nodes, in the search for information. Siemens (2004) also asserts that the value of information being learned must be explored in this networked world. He holds that other theories only focus on the process of learning, not the value of the information being acquired (Siemens, 2004). Technology is also playing an important role in re-wiring our brains and supports cognitive processes (Siemens, 2004). In the last twenty years, technology has changed the way we live, communicate, and learn (Siemens, 2004). Technology has enabled the amount of knowledge in the world to grow exponentially while causing the length of time between when knowledge is gained to when it becomes obsolete to decrease rapidly (Siemens, 2004).

In discussing connectivism theory, Kondrashova and Solokhin (2021) explain that current trends in society and education provide an avenue for the development of this theory through accumulating experiences and other improvements. One such example is provided by Aponte and Jordan (2020) who have recently built upon the idea of connectivism to structure internationalization of curriculum at the institutional level. They hold that through computers and the internet, learning can be interactive and collaborative on a global level of nodes (Aponte & Jordan, 2020). Montebello (2019) points out that online learning environments from a connectivist viewpoint promote ubiquitous, differentiated learning with multimodal knowledge representations, active knowledge making, recursive feedback and collaborative intelligence. Daker et al. (2022) also point out that students are most successful in computer courses when they present the ability to make connections between seemingly unrelated concepts and suggest encouraging student creativity to foster these connections.

In relation to the subject of mathematics, Garrett et al. (2020) point out that conceptual understanding is framed by the connections that are made. Technology allows mathematics students to actively make connections between visual and symbolic representations (Birgin & Topuz, 2021). Student explorations with technological tools support reflection and the construction of knowledge (Turk & Akyuz, 2016) and software-supported collaborative learning has been connected with increased retention in geometry (Birgin & Topuz, 2021). The National

Council for Teachers of Mathematics (NCTM) (2023) asserts that learning must take place through actively building new knowledge from experiences and connections to prior knowledge, and that technology is crucial in the learning of mathematics in a modern world. In addition, Kondrashova and Solokhin (2021) define connectivism education as a complex process that includes components of emersion into an information-filled environment, using accumulated knowledge to the fullest, developing skills for determining whether information is timely and relevant in the modern world, using a variety of communication pathways, and identifying links between knowledge, theories, and concepts. The intention of this study is to determine if connections made, digital and otherwise, influence secondary students' attitude toward learning mathematics through the use of computers.

Related Literature

Previous studies have related student attitudes toward mathematics with achievement. The popular Fennema-Sherman mathematics attitude scales developed in 1976 have allowed study of attitudes specifically connected to learning mathematics (Fennema & Sherman, 1976; Fennema & Sherman, 1978; Hannula et al., 2019). These attitudes are influenced by many factors including, gender differences, settings, and teaching methods (Fennema & Sherman, 1976; Fennema & Sherman, 1978; Hannula et al., 2019yilm; Kennedy et al., 2018; Kiwanuka et al., 2017; Mamolo, 2022). In modern times, technology plays a factor into the learning environment and can have an impact on student attitudes toward mathematics (Awofala et al., 2017; Fabian et al., 2018). This influence led to the creation of the Galbraith-Haines mathematics-computing attitude scales used for this study (Galbraith & Haines, 1998).

How Attitudes affect Achievement in Mathematics

Attitude is described as an emotional reaction to an object (Galbraith & Haines, 1998) that has been internalized and automatized (McLeod, 1989). It is a multi-dimensional structure containing a combination of emotions and beliefs that has been learned through past experiences (Zamir et al., 2022). The attitude components of affective, behavioral, and cognitive domains are tied to learning in both traditional and online settings. Engagement in learning is linked to active participation and positive learning outcomes (Lin, 2021). Cognitive engagement leads to more complex mental representations and more controlled efforts to stay on task (Lin, 2021). Behavioral engagement is shown through persistence, attention, and concentration (Lin, 2021). Emotional engagement is a component of the affective domain (Beltran-Pellicer & Godino, 2020) and is represented through interest and enjoyment of the learning process combined with a belief that the activities are constructive and meaningful (Lin, 2021). Emotions have been shown to affect performance and memory retrieval (Hannula et al., 2019). The process of learning and problem-solving in mathematics involves attitude components of motivation, attention, interest, and concentration (Vargas, 2021).

Student attitudes toward math have been shown to affect achievement (Zamir et al., 2022). Love for mathematics has been correlated with high ability and performance (Kapetanas & Zachariades, 2007). Students control beliefs and self-efficacy beliefs can be used to predict mathematics work ethic in actions such as attention and participation in class, homework completion, and studying for exams in math (Gjicali & Lipnevich, 2021). This type of work ethic can be tied directly to student performance and achievement. A positive attitude towards mathematics leads to a view of mathematics as fundamental with a mindset to improve performance (Zamir et al., 2022). Students with positive attitudes toward mathematics are better at problem solving and have been found to be better at resolving difficult and unusual situations (Zamir et al., 2022). Students who report enjoying math have attributed their feelings to good teaching, and success at problem solving and calculating (Yılmaz et al., 2010). Attitude toward mathematics also influences a student's decision to continue into mathematics courses and/or careers (Gjicali & Lipnevich, 2021; Leder, 1985). When negative attitudes are held by students, the effects can be harmful. Dropout rates in mathematics courses, especially advanced courses, and low enrollment rates in STEM pathways have initiated concern around the world (Hannula et al., 2019). Lack of motivation is linked to attrition in distance education (Mamolo, 2022). Student perceptions of low confidence in the subject and course failure have been found to influence student decisions to drop out (Hannula et al., 2019) or at least deter them from taking further mathematics courses (Cretchley & Galbraith, 2002). Mathematics anxiety impedes student learning by affecting cognitive functioning (Mamolo, 2022). Students who report a dislike of math have attributed their feelings to an inability to solve problems, a lack of understanding, and boredom in the class (Yılmaz et al., 2010). Difficulty in mathematics has been shown to correlate with a dislike of mathematics, along with low ability and performance (Kapetanas & Zachariades, 2007). Unpleasant learning experiences can cause gains in achievement and performance to be offset by diminished attitude (Cretchley & Galbraith, 2002). Even the transition to secondary schooling has been linked to declines in positive affect in the area of mathematics (Hannula et al., 2019k). With many students not performing as expected in mathematics, the important role of attitude must be considered as students learn and work toward mathematical mastery (Zamir et al., 2022).

How Attitudes affect Achievement in Computers

Attitude is a key element to consider when assessing achievement and productivity (Yagci, 2018). Although achievement in computer programming has been shown to depend on logical and numerical thinking skills, along with the ability to problem solve, student attitudes toward programming influence their achievement (Yagci, 2018). Web-based technology helps students visualize abstract concepts and improves comprehension and have a positive impact on student learning (Ercan et al., 2016). These technologies also help to positively develop student attitudes towards computers and the subject they are studying (Ercan et al., 2016). In one example, Ciftci et al. (2014) reported that anxiety was reduced, attitudes were improved, and students were more successful when computer-based tools were used for instruction in a statistics course. Using computers in an active learning setting positively influences the interactions between students and teachers and has a positive effect on student achievement (Yagci, 2018). This is demonstrated in the Yagci (2018) study which found that online project-based learning in a blended setting had a positive effect on student attitudes toward programming. Also, Yeşilbağ et al. (2020) found that teaching activities involving educational computer games resulted in higher levels of student achievement when compared to students who were taught through traditional methods which did not incorporate computer games.

Factors That Influence Attitude

Karahan (2021) defines attitude as "the perspective based on the knowledge, skills, experience, and emotions that an individual gain throughout her life" (p. 136 – 137). Closely related aspects of attitude that are often explored in relation to mathematics are enjoyment, self-confidence, and self-efficacy (Hannula, 2007). Leder (1985) expands on this definition of attitude, describing it as a learned behavior that leads to actions and responses that are consistent in falling into favorable or unfavorable categories. Those who have a negative attitude toward a certain phenomenon will respond and act negatively when presented with that situation. A positive attitude, in turn, would illicit a positive response. “The concept of attitude generally expresses the individual’s reaction disposition to any case or object around her” (Karahan, 2021, p. 136). It has been shown that when a student has a positive disposition toward mathematics, their emotions are more positive and less negative in their learning experiences than students who hold negative dispositions toward mathematics (Hannula et al., 2019). However, because attitude is learned, student attitudes toward mathematics can be influenced by different factors, and can be changed (Hannula, 2002; Zamir et al., 2022).

A popular research topic has been to explore gender differences in mathematics attitudes (Almasri, F., 2022; Gevrek et al., 2020; Hannula et al., 2019; Leder, 1985; O’Rourke & Prendergast, 2021). Older studies found large differences between the attitudes of males and the attitudes of females toward mathematics (Fennema & Sherman, 1978). The popular Fennema-Sherman Mathematics Attitude Scales (FSMAS) assesses multiple elements of beliefs about mathematics, including the consideration of mathematics as a realm predominately associated with males (Hannula et al., 2019). Because the FSMAS authors found changing social circumstances to influence gender beliefs about mathematics, they were driven to develop two other scales to examine gender influences on beliefs about mathematics (Hannula et al., 2019). Other studies have also examined these differences. For example, a study by Leder (1985) linked differences in play activities between genders to differences in male and female attitudes toward math. Additionally, Fennema and Sherman (1978) found significant differences in the confidence levels of males and females toward mathematics and in the viewpoint of mathematics as a realm predominantly associated with males. Gender differences continue to be studied as society and attitudes change. In a 2001 study by Huang and Brainard results indicated that the biggest predictor of self-confidence in STEM fields for female students was respect from professors. Males were influenced more by the quality of teaching present (Huang & Brainard, 2001). More recently, gender has been linked to differences in mathematics confidence levels (Hannula et al., 2019). Hannula (2007) found confidence levels and perceived mathematical difficulty to be influenced by gender and that gender affected student views of the teacher. In 2007 Hannula et al. reported findings that when in the same class, 11th graders of both genders evaluated the teacher similarly and had similar effort and enjoyment levels (as cited in Potari et al., 2018). This information was echoed by Nguyen et al. (2016) who found that the perception of the learning environment was similar between males and females in a statistics course. Kennedy et al. (2018) found females to have lower self-efficacy in mathematics than males with additional views that mathematics was less enjoyable and less useful, and that mathematics lessons were harder than other subjects. Kapetanas and Zachariades (2007) found that girls view mathematics as more of a computational process than boys. In a recent study in Ireland, gender differences were shown to still be significant with males reporting stronger interest levels and self-confidence (O'Rourke & Prendergast, 2021). Interestingly, Almasri (2022) found girls to have a more positive attitude in single gender e-learning setting than boys and boys to have a more positive attitude in mixed gender e-learning settings. Also, both genders were found to profit from an e-learning setting (Almasri, 2022). In mixed gender traditional settings, males were found to have more positive attitudes toward the subject than females (Almasri, 2022). In other modern cases, mixed results for gender stratification and attitudes toward mathematics have been found (Gevrek et al., 2020).

Gender differences have also been explored in other STEM areas, including those focusing on computers (Akcaoglu et al., 2021; Cheryan et al., 2017; Huang & Brainard, 2001). Cheryan et al. (2017) report that women are underrepresented in computer science, possibly due to views that the field is masculine. Females also report a lower self-efficacy in the computer science field than males (Cheryan et al., 2017). Although girls performed acceptably in performance areas, boys in the Akcaoglu et al. (2021) study reported significantly higher levels of self-efficacy in the area of computer programming than girls. This result was echoed by Huang and Brainard (2001) who found that even though females received high grades in STEM courses, many continued to report lower self-efficacy levels.

Social context also plays an influential role in student beliefs (Hannula et al., 2019). Since attitudes begin to develop early on, the familial field plays a significant role in student views of mathematics (Evans & Field, 2020; Quaye & Pomeroy, 2022). In fact, parental influence has been found to account for up to 40% variance between achievement and attitudes toward mathematics of secondary students (Quaye & Pomeroy, 2022). Beliefs of friends and peers has also been shown to have a moderate influence on student interest in studying mathematics and beliefs about the importance of mathematics (Kiwanuka et al., 2017). Kennedy et al. (2018) found that early high school experiences influenced student attitudes toward mathematics, science, and technology. Students in advanced courses hold more positive beliefs toward mathematics (Hannula et al., 2019; Rösken et al. 2007), possibly enhanced by the shared views of peers at this level. However, positive views are found to be stronger at the elementary level as compared to the high school level (Kapetanas & Zachariades, 2007). High performance in mathematics correlates with positive beliefs and self-efficacy (Hannula et al., 2018). Additionally, the type of school attended influences student beliefs (Kapetanas & Zachariades, 2007). Students in private schools show stronger beliefs in the usefulness of mathematics in general and students in public technical schools believe in a procedural understanding that provides a computational way to solve problems (Kapetanas & Zachariades, 2007). Kapetanas and Zachariades (2007) found no link between socioeconomic status and student attitudes toward mathematics.

Teacher content knowledge, classroom resources, personality, methods, and attitudes all influence student attitudes toward mathematics (Smith et al., 2021; Zamir et al., 2022). Types of teaching activities, teacher roles, and active learning strategies have been found to influence attitudes (Hannula, 2007; Kiwanuka et al., 2017; Mamolo, 2022; Uusimaki & Nason, 2004; Yagci, 2018). Because many students today enter math classes believing that they are not good at mathematics, teachers play a large role in influencing student attitudes and achievement (Zamir et al., 2022). Teaching practices are powerfully affected by negative teacher beliefs about mathematics (Uusimaki & Nason, 2004). Uusimaki and Nason (2004) found that over 70 percent of negative mathematical experiences are attributed to the teacher. For example, anxiety toward mathematics often surfaces when students are asked to communicate their understanding (Uusimaki & Nason, 2004). The method of this assessment communication is chosen by the teacher (Uusimaki & Nason, 2004) who should utilize means of assessment that support students and maximize student performance (Nguyen et al., 2016). The context of the classroom has been shown to affect the enjoyment students experience and the effort that they display (Hannula, 2007). A motivating, enjoyable culture is created through instructional choices (Hannula, 2007). Effective teaching, which develops this culture, has a positive effect on student attitudes (Kennedy et al., 2018). When teachers implement new practices, positive changes in affect and motivation have been recorded (Hannula et al., 2019). These positive changes are not simply the result of changes in activities, but in a shift in the way teachers and students engage during the lesson (Kapetanas & Zachariades, 2007). Schoenfeld (1989) points out that experiences that require substance, such as creativity, discovery, and problem solving are needed to improve student beliefs and connections, a point echoed by Daker et al. (2022). Studies support a shift from teacher-centered to student-centered approaches (Kennedy et al., 2018; Yagci, 2018). One student-centered approach, cooperative learning, has been found to positively influence secondary student performance and attitudes toward mathematics (Hossain & Tarmizi, 2013; Zakaria et al., 2010). Cooperative learning is a highly structured approach allows students to interact, share thoughts and collaborate and reach learning goals (Xie et al., 2020). Students prefer to share knowledge and feel more confident when working in a group (Hossain & Tarmizi, 2013) and cooperative learning has been shown to be more effective than individual learning methods (Xie et al., 2020). Just building a cohesive group environment in the classroom itself has been found to reduce anxiety (Nguyen et al., 2016). Teaching strategies using manipulatives in mathematics lessons have also been shown to improve student attitudes toward math (Kontas, 2016). Secondary math students who worked with manipulatives during lessons were shown to have increased attitude scores compared to a control group that were not provided manipulatives during the learning process (Kontas, 2016). Strategies involving teacher questioning play a role in influencing student attitudes toward math, especially when the focus is on a problem-solving approach (Kiwanuka et al., 2017; Schoenfeld, 1989). In addition, students are more likely to be enthusiastic about and enjoy a subject when they are able to see purpose in assigned tasks and make connections between theory and practice (Nguyen et al., 2016). Context personalization, a strategy that connects the academic topic being studied to student interests, has also been shown to have a positive influence on student attitudes toward mathematics (Garrett et al., 2020). When combined with example choice, context personalization increased interest and effort toward tasks (Garrett et al., 2020). Students with low interest and perceived competence for mathematics showed the most gain, and students with high interest and perceived competence were found to benefit less from the context personalization (Garrett et al., 2020). Additionally, teachers who hold a positive attitude toward mathematics pass on this positive attitude to their students (Kiwanuka et al., 2017). When teachers are enthusiastic and implement accessible activities, student attitudes are improved (Regna & Dalla, 1993). Mamolo (2022) notes that teacher characteristics of enthusiasm, sincerity, and approachability establish a level of motivation for online students.

The Influence of Technology on Attitudes Toward Mathematics

With the improvements and developments in information and communication technologies in recent years, the use of technological tools and educational software has increased in education worldwide (Pilli & Aksu, 2013) and in the area of mathematics teaching (Birgin et al., 2020). Students can use these advancements to improve their mathematical knowledge (Zamir et al., 2022). Trgalova et al. (2018) classify digital mathematical tools as everything from computers and spreadsheet programs to graphing programs, applets, microworlds, special learning programs, digital books, online courses such as Khan Academy, dynamic geometry systems, and computer algebra systems. Pilli and Aksu (2013) point out that with the use of technology, the teaching of mathematical ideas has been transformed from abstract examples to methods that are clear and easy to understand because of the ability to simulate and redefine the concepts. This study provides evidence that computer-assisted learning has an immediate positive effect on student achievement and attitudes toward mathematics, along with positive attitudes toward computer-assisted instruction (Pilli & Aksu, 2013). As technology evolves, research is often conducted on particular devices or programs and their influence on student achievements and attitudes (Birgin & Uzun Yazıcı, 2021; Eyyam & Yaratan, 2014; Matias & Ramon, 2002; Turk & Akyuz, 2016). Findings on the influence of technology tend to be mixed. For example, some negative views of technology use for education were reported by Awofala et al. (2017), Rantanen et al. (2021), and Fabian et al. (2018), while positive views were reported by Cretchley and Galbraith (2002), Matias and Ramon (2002), and (Pilli & Aksu, 2013). Mixed views are even found in the same study as demonstrated by Eyyam and Yaratan (2014) who found that while many students in their study held a positive view of the use of educational technology, a large number of students were still indecisive in their opinions.

Negative views are often associated with anxiety and difficulties with devices and connections. Computer anxiety is strongly correlated with user attitudes toward computers and self-efficacy (Awofala et al., 2017). Often a lack of digital skills or a lack of access to appropriate technology combined with negative attitudes leads to social and digital exclusion (Rantanen et al., 2021). Technical issues can also disrupt learning activities and lead to frustration (Fabian et al., 2018). For example, internet connectivity problems can be frustrating for situations involving online learning (Karjanto & Acelajado, 2022). The development of negative attitudes can lead to an unwillingness to work with new technologies (Rantanen et al., 2021). The quality of the e-learning system also has a direct impact on student satisfaction, and therefore must be easy to navigate to avoid negative views (Long et al., 2019).

Positive attitudes are expected when students are familiar with technology and the assumption is typically made that modern American students are skilled at computer use (Koroghlanian & Brinkerhoff, 2008). Experience with computers has been related to positive attitudes toward Internet – delivered courses (Koroghlanian & Brinkerhoff, 2008). Positive attitudes, along with high degrees of confidence, motivation, and engagement have been reported when technology and Computer Algebra Systems (CAS) were used (Eyyam & Yaratan, 2014; Matias & Ramon, 2002). Well executed flipped learning has been shown to improve confidence and enjoyment, and to give students a sense of control over their own learning (Karjanto & Acelajado, 2022). Using computers has inspired confidence and provided security and motivation for students to participate in activities where they are used (Matias & Ramon, 2002). Notable increases in positive attitudes of students have been observed when computer-enhanced activities have been used (Matias & Ramon, 2002). Cretchley and Galbraith (2002) found that mathematics attitudes significantly correlate with academic performance, while attitudes toward technology usage in the learning process strongly relate to overall computer attitudes.

However, teachers are significant drivers of technology integration and their attitudes towards technology are connected to the usage and intentions to use technology in schools (Awofala et al., 2017). Technology must be combined with effective teacher practices to drive improvement in the classroom (Fabian et al., 2018). Yagci (2018) argues that students must be participating and actively engaged to become academically successful. Teachers shoulder the responsibility to manage technical breakdowns, adapt to student characteristics, and practice effective learning design and must be trained to do so (Fabian et al., 2018). Some studies have shown no differences in attitudes toward mathematics of secondary students are found when technology is incorporated (Bayturan & Keşan, 2012; Fabian et al., 2018). It is possible that the role of the teacher and the chosen methods influenced these results more than technology. In addition, while the use of tablets has been shown to produce gains in student performance, technical issues are often disruptive of the learning environment and are cited as reasons for a lack of improvement in attitudes toward mathematics (Fabian et al., 2018).

Online Learning and Performance

Online learning and hybrid learning settings are becoming increasingly popular (Koroghlanian & Brinkerhoff, 2008; Long et al., 2019) and there have been many educational technology advancements in the last few decades (Zamir et al., 2022). Koroghlanian and Brinkerhoff (2008) found that students taking online courses rate themselves as having fairly good computer skills when considering lower-level tasks. However, online students did not rate themselves as high with skills such as Web page creation and working with compressed files, which were considered high level computer skills (Koroghlanian & Brinkerhoff, 2008). Additionally, students who had taken multiple online courses and those who use computers more frequently rated themselves more proficient at the high-level skills than students who had not taken multiple online courses and those who did not use the computer as frequently (Koroghlanian & Brinkerhoff, 2008). Two-thirds of university students taking online courses identified their experience as Very Good or Excellent (Koroghlanian & Brinkerhoff, 2008). In some cases, online environments are associated with a lack of critical thinking and passive attitudes (Nonnecke et al., 2006). In other situations, students are encouraged to take an active approach to internet use and web tools and student-centered learning has replaced teacher-centered classrooms (Peled et al., 2019). Active learners take responsibility for their progress and acquire competence and skills to meet their goals (Peled et al., 2019). Connectivism relies on this active approach to learning (Siemens, 2004).

Online learning can occur in synchronous or asynchronous settings. Teaching mathematics through synchronous, explicit instruction involves the use of a virtual meeting platform and requires screensharing, virtual whiteboards, or necessary camera tilts to model problem solving (Long et al., 2021). Asynchronous, explicit mathematics instruction typically involves videos created while utilizing those tools of screensharing, virtual whiteboards, or appropriate camera angles showing the teacher solving problems (Long et al., 2021). In the asynchronous setting there is a communication delay which affects feedback and questioning, but the negative effects can be improved through the use of discussion boards in a LMS and additional, optional instructional videos (Long et al., 2021). Researchers have found that online instruction in both settings requires more time than in the face-to-face classroom and that instruction, guided practice, and independent practice amounts should be reduced to meet student needs (Long et al., 2021).

Several factors play into the relationship between online learning and student performance. The effects of mobile learning on student performance are often influenced by the course or subject, not by education level or implementation period (Talan, 2020). Also, the way strategies are implemented can have large effects on enjoyability, accessibility, and effectiveness of the digital tools and instructional approach (Gillis & Krull, 2020). Long et al. (2021) suggests that the teacher be prepared for technical difficulties during synchronous instruction by having low-tech tools on hand, such as a whiteboard and marker, or manipulatives that can be viewed simply through the video conferencing platform. The relationship in online courses between teacher presence and student satisfaction and perceived learning is reported as moderately strong (Caskurlu et al., 2020). The frequency of student-student and student-instructor interactions influences the level of engagement and learning outcomes for online courses (Tsai et al., 2021).

Often, teachers equate participation with acquiring knowledge. While participation is crucial for learning, teachers should be cautious of referring to student performance in online learning programs as an indication of knowledge (Haleva et al., 2021). Additionally, students' final academic performance can be predicted after only one third of the course had been completed in a blended setting (Lu et al., 2018). Factors that influence a student's final score include participation elements: number of activities a student engages in per week, number of times a student clicks "Play" during video viewing per week, number of times a student clicks "Backward seek" during video viewing per week, and number of times a student participates in after-school tutoring per week (Lu et al., 2018).

Studies have indicated positive relationships between online environments and student experiences. Koroghlanian and Brinkerhoff (2008) found that older learners view online courses more positively than younger students and that females preferred online courses over face-to-face courses due to the convenience factor. Students are not limited to a certain time period or learning space and can structure their educational learning periods around a job (Long et al., 2019). One study showed a connection between online learning and retention of content (Edwards et al., 2017). Students who were taught a math topic online in sixth grade had higher final eighth grade test scores on that topic (Edwards et al., 2017). In a more recent study, online courses that included self-efficacy strategies had positive effects on student motivation and anxiety, and improved learning performance (Huang & Mayer, 2019). Long et al. (2019) agree that the overall quality of service in an e-learning environment impacts student satisfaction and student loyalty. Sindi et al. (2021) supports the use of educational games in the learning process at the primary level.

Other studies show mixed results. Online learning is often used at the high school level for credit recovery as well as regular course requirements (Hart et al., 2019). Participating in a course online raises the chance of successfully passing it by 18% (Hart et al., 2019). However, it diminishes the probability of enrolling in and succeeding in a subsequent course within the same subject by about 2% and decreases the chance of achieving high school graduation by 4% (Hart et al., 2019). Students who take virtual courses for credit recovery have a 4.7% higher chance of passing their remedial course, a 1.7% increased likelihood of both taking and passing future courses in the same subject, and are 6.5% more likely to be seen in an anticipated final term during their senior year of high school, in contrast to peers retaking coursework in traditional face-to-face settings (Hart et al., 2019).

Computer-Assisted Learning

Face-to-face classrooms also incorporate computers into the learning process (Chevalère et al., 2021). It has been shown that learning is positively affected by computer-assisted instruction (Chevalère et al., 2021). Computer-assisted instruction is the term used to describe the situation when traditional teaching methods are supported by computer applications or computer-based programs and is typically used in pre-college schooling (Xie et al., 2020). This blended type of instruction is used with the purpose of improving student achievement in mathematics but does not focus on improving computer skills (Xie et al., 2020). Teachers can use a mixture of conventional instruction and computer-assisted instruction to meet the needs of students who are at multiple learning levels within the same class (Chevalère et al., 2021). Computer-adaptive programs that allow for personalized learning experiences are one way that computer-assisted learning can be incorporated to accomplish this differentiation (Sutter et al., 2020). Utilizing this type of instruction effectively can also reduce the workload on the teacher (Chevalère et al., 2021). For example, computer-adaptive programs reduce test creation and grading time, allowing the teacher to spend more time planning for effective instruction (Sutter et al., 2020). However, educators should view the whole picture when using CAI programs, considering the educational idea, integration process, and new teaching methods along with the new delivery tool in the form of educational technology (Xie et al., 2020). Viljoen et al. (2019) verify that the use of computer-based instruction alone is not better than face-to-face teaching. However, blended learning utilizing face-to-face and computer-assisted instruction was more effective than face-to-face instruction alone (Viljoen et al., 2019). Although it has been shown that socioeconomic status affects student achievement, Chevalère et al. (2021) found that students considered disadvantaged who received computer assisted instruction performed at the same level as highly privileged students who were taught using conventional methods. Additionally, both disadvantaged students and highly privileged students who received computer assisted instruction performed better than students receiving conventional instruction (Chevalère et al., 2021). Similarly, Xie et al. (2020) reports positive benefits of computer-assisted instruction on mathematics education in general.

Impact of Covid-19 on Education

The COVID-19 pandemic forced school closures across the nation and the world. The ripple effects include both positive and negative results in the field of education. The pandemic stimulated an appreciation for technology, social media, and online resources (Mulenga & Marbán, 2020). Teachers and students turned to new ways of teaching, learning, and collaborating (Burke, 2020), and are increasing their use of best practices in the online environment (Kumar & Verma, 2021). Independent working skills were developed (Burke, 2020). Negative effects include an increase in the digital divide, a lack of connection for students, increased absenteeism, and a decrease in student learning. With many states suspending end-of-year assessments for the 2019-2020 school year, the ability to compare pre- and post-pandemic achievement was lost (Rutherford et al., 2021). Because the concept of attitude is influenced and changed by exposure to environment, further examination of these effects is needed to determine if educational practices have influenced student attitudes toward mathematics learning.

Transition to Online Learning

The transition to online learning was abrupt and affected students, teachers, parents, and all members of the education community in some way. Shortly after the transition to remote learning, an assessment in Ireland reported that although the learning curve was steep, skills required for online learning and teaching were being developed and the progress was going well (Burke, 2020). Educators were forced to turn to different ways of thinking and problem solving that required collaboration and communication (Burke, 2020). The whole process of being educated and educating students was radically different (Burke, 2020). The remote learning period provided an opportunity for students to spend time with family, develop new interests, and develop independent thinking and working skills (Burke, 2020). Student teaching arrangements were beneficial during the transition period. Virtual co-teaching supported students and increased family engagement because there were two teachers providing instruction and building community (Chizhik & Brandon, 2020). Veteran teachers willing to mentor student teachers were able to find a teaching partner who was often familiar with technology approaches (Chizhik & Brandon, 2020). Together the veteran and student teachers could collaborate in a way that was effective and led to a better experience for their students (Chizhik & Brandon, 2020).

Although several positives can be noted, many components of the transition were difficult and challenging. Digital learning, especially in the area of mathematics, was not well established in countries such as Zambia, where, prior to the pandemic, there were no colleges or universities offering online mathematics courses (Mulenga & Marbán, 2020). Although this was not the case in America, there were elementary, middle, and high school teachers who were not trained for online teaching. There was a lack of experience with the online format of regulated education (Hossein-Mohand et al., 2021). Expectations were that teachers would develop the knowledge and skill required to teach remotely with little professional development in only a few days (Gore et al., 2021). Bojović et al. (2020) found that in the rapid transition to distance learning, working with digital learning platforms was more difficult for teachers than students. Students were also expected to adapt with possible challenges to internet access, devices, and various levels of parental supervision (Gore et al., 2021). The adaptation was challenging for both students and teachers entering into a new reality for education (Hossein-Mohand et al., 2021).

Not only did content and methods require adaptation, but teachers had to consider student characteristics, especially of those at-risk, that might be affected by remote learning (Hossein-Mohand et al., 2021). It became a concern that students who were already considered vulnerable or disadvantaged were now expected to learn from home (Gore et al., 2021). Teachers were anticipated to adopt an approach to teaching that included self-assessment and assessing students through new modalities (Hossein-Mohand et al., 2021). A variety of challenges for teachers and students were presented in a short time period. Outside factors affected student focus. While students dealt with challenges such as leaving a textbook in an inaccessible dorm room, communicating with group members, or having work hours changed due to the pandemic, other mental issues also came into play (Gillis & Krull, 2020). Reports showed that the influence of COVID-19 caused anxiety for students along with feelings of being unmotivated and distracted (Gillis & Krull, 2020). These factors led to beliefs that their academic success was inhibited during this time (Gillis & Krull, 2020). One in four students at the university level reported that worries about personal finance and health care impacted their academics (Gillis & Krull, 2020). Most students experienced a decrease in motivation, but some learning barriers were reduced when instructors adapted courses to meet student needs (Gillis & Krull, 2020). Concerns were also expressed toward short and long-term effects of the pandemic on teacher morale, self-efficacy, and skill (Gore et al., 2021).

Remote Learning

The term "remote learning" was chosen by many educational leaders to describe the new environment for learning that began when schools closed due to pandemic restrictions. Although many outsiders viewed the transition as a shift to online learning, there were many students who lacked the capability to virtually connect. Prior to the onset of the pandemic, Koroghlanian and Brinkerhoff (2008) found that two-thirds of university students taking online courses had broadband connectivity. Online transitions allowed students at all levels to learn and study in the comfort of their homes with a front row seat, but some did not have access to digital devices or internet (Mulenga & Marbán, 2020). It is well known that inequality exists in the access that students of differing socioeconomic backgrounds have to digital learning (Chevalère et al., 2021). These students without access were, in many cases, provided some form of pencil and paper learning opportunity, or were asked to visit sites in their area with free Wi-Fi. These variations in instruction meant that students were receiving information from different nodes and acquiring knowledge through different connections, possibly influencing their viewpoints toward content.

No matter the location or education level, the rush to transition to remote learning was felt across the board. Although online learning was not a new idea, the speed and urgency surrounding the transition, combined with the uncertainty of the pandemic created a sense of anxiety in teachers and students (Green et al., 2020). In Zambia, universities quickly moved to e-learning platforms, and asked staff members to quickly locate and implement learning support material (Mulenga & Marbán, 2020) so that they could begin teaching online. Guidance was also provided to students so that they could register and connect to the online platforms to keep up with learning and complete final exams at the end of the term (Mulenga & Marbán, 2020). In the United States, many instructors chose to embed their existing course content into a learning management system (LMS) and conduct synchronous class meetings, although they had little or no prior training in the use of these tools (Gillis & Krull, 2020). The transition for teachers who were familiar with and had been using a LMS was much smoother (Iivari et al., 2020). There was an obvious need for teachers to acquire basic technology skills (Iivari et al., 2020). Questions of internet access and connectivity often arose (Green et al., 2020).

On the positive side, it was the belief of prospective teachers that there would be a pedagogical shift in the area of mathematics from a traditional practice to a less formal, more interesting and entertaining instructional method supported by digital learning (Mulenga & Marbán, 2020). The use of digital learning in mathematics in response to the pandemic has stimulated growth in areas that have been resistant to digital learning in the past (Mulenga & Marbán, 2020). Although Zambia faced more extreme changes, similar changes in teaching methods took place in the United States. The opportunity to have productive discussion, learn new teaching techniques, and to find new ways to promote student engagement and collaboration presented itself to teachers in the extraordinary moment brought on by the pandemic (Green et al., 2020). Bojović et al. (2020) point out that data gathered during the transition provided teachers with more complex information about their students, including habits, potential, and level of knowledge. Additionally, the Bojović et al. (2020) study found that the rapid transition to online learning did not harm the continuity or quality of learning. As previously mentioned, teacher presence influences student attitude toward mathematics, and it is possible that online and hybrid environments had different effects on students' attitudes.

Technology Used

Because many students were forced to stay at home during the unfortunate situation, an expectation to learn though the use of web 2.0 tools surfaced (Mulenga & Marbán, 2020). Video conferencing through platforms such as Zoom or Google Meet became popular along with collaboration tools like Padlet, Google Classroom, and Microsoft Teams (Jafri & Guo, 2021). The use of technology became a key to monitor student learning (Hossein-Mohand et al., 2021) and teachers were expected to deliver content to students through digital teaching methods (Mulenga & Marbán, 2020). In many cases, a virtual meeting platform, such as Zoom, was used for instruction and meetings with parents (Iivari et al., 2020). A call for such a transformation was made prior to the pandemic, but the unprecedented situation sparked change toward an extensive digital transformation (Iivari et al., 2020). In schools where technology was already being used comprehensively, the transition may have had a few challenges, but was ultimately a smooth one (Iivari et al., 2020).

The pandemic allowed teachers the opportunity to learn and use new tools and many came to appreciate the potential for student learning. When technology is utilized in mathematics education practices, learning is improved (Niess, 2006), and when technology is appropriate and effective, students learn mathematics better (Perienen, 2020). However, for those teachers unfamiliar with technology options, the learning curve had to be mastered fast. During the remote learning period, teachers considered that in order for students to reach their learning goals, they would need to support those students in technology use (Chizhik & Brandon, 2020) which became an area of professional development. Teachers knew that learning to use the software programs and apps would be necessary to engage their students (Chizhik & Brandon, 2020). Selection of appropriate technology and apps also plays an important role in learning. The perceived usefulness for learning and potential to improve academic performance are factors that influence secondary students using technology to learn mathematics (Hossein-Mohand et al., 2021). Student attitude toward a technology tool is also influenced by parent views of the tool (Hwang, 2020). Parents place value on the perceived usefulness and ease of use and encourage their students to use the tool when those characteristics are present (Hwang, 2020). The implication for teachers is that selected tools should be appropriate and helpful to learning the domain. There is also an association between the use of information and communication technologies (ICT), the educational level of students, and the duration of time spent for educational purposes on the Internet (Hossein-Mohand et al., 2021).

Some studies have not identified expected differences. For example, Hossein-Mohand et al. (2021) found no gender differences were found between mathematics students using ICT. Additionally, there were not associations found between family socioeconomic levels, technological resources at home, and the use of ICT for educational practices (Hossein-Mohand et al., 2021). This finding contradicts media reports focusing on technology barriers for those families in low socioeconomic settings. In April 2020, 64% of districts in North Carolina were distributing devices to some or all students and 57% were providing some type of internet access for students (Hassel & Hassel, 2020). These numbers suggest the existence of a digital divide present at the onset of the pandemic. A May 9, 2020, report asserted that numbers of students in North Carolina still had no access to the online lessons being provided (Public Schools First NC, 2020), and that inequity in education had been exacerbated by the crisis (Public Schools First NC, 2020).

As the previously mentioned, studies of Eyyam and Yaratan (2014) and Matias and Ramon (2002) found positive and mixed attitudes towards the use of technology to learn mathematics. Pandemic-related shifts to technology and online tools were widespread and varied. These new instructional practices could impact student attitudes differently due to the unique implementation. The lingering effects could include student attitudes toward learning mathematics in online and in traditional settings.

Views of Online Learning During Pandemic Restrictions

A mixture of synchronous and asynchronous methods was adopted by teachers and instructors from pre-K to the university level during remote instruction. Some students struggled with online delivery, while others thrived (Bojović et al., 2020). Students who preferred online courses felt that they gained more knowledge in the online format (Bojović et al., 2020). Synchronous methods involved teachers conducting live, virtual class meetings, while asynchronous methods involved components such as videos and discussion posts that could be conducted at different times. The views of students in higher education toward asynchronous, synchronous, and hybrid online lecture courses were explored by several researchers during the unprecedented period. Asynchronous elements were viewed as easily accessible, but less enjoyable than synchronous components of courses (Gillis & Krull, 2020). A blend of synchronous and asynchronous practices was preferred by students at the university level (Busto et al., 2021; Gillis & Krull, 2020; Tyaningsih et al., 2021).

Impact on Learning

Several deficiencies can be noted as the pandemic forced the education system away from traditional policies and practices. For example, adequately supervising mathematics instruction during the COVID-19 lockdown period was not possible (Hossein-Mohand et al., 2021). It was predicted that another confinement period during the pandemic would “have greater repercussions on school failure, especially among younger students due to their low digital competence and in countries with exclusively face-to-face educational models” (Hossein-Mohand et al., 2021, p. 14). These types of predictions are based on effects felt from weather-related shutdowns in the past (Hoofman & Secord, 2021). Previous studies on test scores following weather-related shutdowns found that math scores were significantly negatively affected, and that they were more negatively affected than English language scores (Hoofman & Secord, 2021). A study conducted early on by Bojović et al. (2020) found that the rapid transition to online learning did not harm student learning because scores appeared to be similar to previous years. However, one year after the initial shutdown, Gore et al. (2021) report that policy changes and debates in education settings have been driven by “estimation and speculation” (p.607) mainly stemming from knowledge of shutdown effects related to previous natural disasters. However, evidence is now being presented that students around the world have lost progress (Gore et al., 2021). Research has also shown that online instruction during the pandemic led to decreases in motivation and self-efficacy of students and increases in anxiety (Mamolo, 2022).

One of the issues faced initially during remote instruction was lack of attendance and engagement. When measuring engagement, performance, and motivation were studied, results were affected by a 30% drop-out rate at the time of the transition to online learning (Rutherford et al., 2021, p. 24). Additionally, engagement of students continuing with the online program decreased, although performance with the software increased (Rutherford et al., 2021, p. 24). The pandemic also sparked changes in student motivation including lower mathematics expectancy and lower emotional cost for mathematics (Rutherford et al., 2021). Engagement levels for students with disabilities who initially showed low engagement levels increased when virtual rewards were provided during the remote period (Kim & Fienup, 2021)

Problems with dropouts and participation were widespread. The McLaren et al. (2022) study reported that completion rates for an online learning game were 88% before the pandemic, falling to 56.5% during the remote learning period. Large numbers of students did not show up for online or in-person instruction (Mitropoulos, 2021). These students were a concern for school officials who had no knowledge or information on their whereabouts (Mitropoulos, 2021). The problem seemed to disproportionately affect vulnerable student populations including the homeless, those with disabilities, immigrant children, those in foster care, and children of color (Mitropoulus, 2021). Because of a lack of research, the exact magnitude of the problem was difficult to determine (Mitropoulus, 2021). Almost a year after initial shutdowns, the number of students of color who were considered chronically absent had doubled (Saslow, 2021). Problems with lack of attendance are extending past the pandemic quarantine and are predicted to have lasting effects. Some predictions include increases in inequity between public and private educational institutions, decreases in the graduation rates of at-risk students, and declines in lifetime earnings for people of color (Saslow, 2021). Gore et al. (2021) notes that prior disruptions to education in times of natural disasters have brought existing inequities to light. Even before COVID-19, factors such as access to technology and internet have had major impacts on the quality of the educational experience provided to different groups of students, but school shutdowns and the remote learning situation made these inequities more significant for struggling populations (Carrillo & Flores, 2020).

In contrast, the studies focusing on the use of mathematics educational technology during remote learning reported positive impacts. When students were actively engaged with the Spatial Temporal (ST) Math program created by MIND Research Institute (MIND), performance was not negatively affected (Rutherford et al., 2021, p. 2). A particular online geometry program used during pandemic-related remote learning allowed teachers to engage students in authentic learning in real-world situations and increased "motivation to learn geometry during the COVID-19 pandemic" (Hwang, 2020, p. 14). Alabdulaziz (2020) believe that COVID-19 is considered the entry point to digital learning in mathematics education and most participants saw large expansions of online learning during the pandemic. In many situations teachers reported an increase in student abilities with technology due to the requirement to learn at home (Gore et al., 2021). An interesting study that began prior to the Covid-19 pandemic and continued during remote learning found that environment played a role in student learning (McLaren et al., 2022). While studying the use of an online learning game, researchers found that females outperformed males in a classroom setting, but that the two groups performed similarly in the remote setting (McLaren et al., 2022). Researchers contribute the overall decline in completion rates to differences in the time pressure, structure, and noise levels between a face-to-face classroom and the home setting for remote learning (McLaren et al., 2022).

With data collected on successful technology use, participation, and engagement during the pandemic, implications for future learning can be proposed. While preferences for course delivery remain mixed, students and teachers in the Bojović et al. (2020) study indicated that all online classes should not end once the state of emergency was over. For this reason, Koroghlanian and Brinkerhoff (2008) suggest that student reasons for taking online courses and the characteristics of those learners should be important factors considered in online course design. Educational institutions should rework the current educational model into one that is more sustainable (Hossein-Mohand et al., 2021, p. 14). Teachers should incorporate relevant online activities that fit with student goals and interests (Mamolo, 2022). For example, the Bojović et al. (2020) study concluded that students found more enjoyment in online learning that included gaming elements and social networking features. Also, mathematics teachers should implement instructional designs that encourage and promote technology use for projects, activities, and tasks both inside and outside of the classroom (Hossein-Mohand et al., 2021, p. 14). When considering individual mathematics tutoring sessions, video conferencing using shared whiteboards is recommended (Johns & Mills, 2021, p. 111). In asynchronous learning situations discussion boards and email where students are encouraged to share their thoughts provide communication options (Johns & Mills, 2021, p. 111). Cooperative learning with technology should also be incorporated to cause a positive influence on student attitudes toward learning (Hossain & Tarmizi, 2013; Zakaria et al., 2010).

Summary

Borba et al. (2016) highlights the need for research on various teaching methods (traditional, online, and blended) used in modern times. The Covid-19 pandemic created an unprecedented situation in education. As schools closed around the world, students and teachers transitioned to an online environment, which many districts have continued to offer. High school mathematics is often a challenging subject for students. By gaining insight into student attitudes and beliefs toward math we can learn how technology affects the educational environment. Research has previously been conducted on the relationship between positive attitudes and achievement and on attitudes toward learning math with the use of technology. However, with the massive and enduring implementation of technology in response to Covid-19 restrictions, it is possible that student attitudes toward math with the use of technology have changed. Although there was an abrupt transition to online learning, many teachers adapted quickly and began using technology in ways that were not previously utilized. Some studies were conducted during remote learning that provide information on teaching practices and student learning. Other negative effects of the transition were reported in the media as well. Although the world is not currently experiencing the same level of restrictions as were enforced early on, the adaptations made by teachers have forever changed traditional and online classroom practices. A gap exists in the literature pertaining to student attitudes toward technology in mathematics in a recovering and post-pandemic world.

Additionally, in consideration of previous studies, attitudes toward mathematics learning and technology have not been studied at the upper-secondary level. Most research in high school math courses is conducted in Math 1 or Algebra I, which is often taken in ninth grade. By examining attitudes toward technology and learning in multiple high school courses, teachers and course developers can better understand how technology affects the learning environment at the high school level and plan for more effective uses of technology in their courses.

CHAPTER THREE: METHODS

Overview

The purpose of this quantitative, causal-comparative study is to compare attitudes of online and traditional setting high school math students toward mathematics and computers. This chapter begins by introducing the design of the study, including full definitions of all variables. The research question and null hypothesis follow. The participants and setting, instrumentation, procedures, and data analysis plans are presented.

Design

This research study will use a quantitative causal-comparative design. This design allows the researcher to investigate differences between two or more groups. The purpose of causal-comparative research is to explain "educational phenomena through the study of cause-and-effect relationships" (Gall et al., 2007, p. 306). This type of design is non-experimental and relationships between independent and dependent variables occur naturally (Gall et al., 2007). For this study, participants will not be randomly assigned to the independent groups study, and researcher manipulation will not be involved. Therefore, the process is considered non-experimental. Without manipulation of the independent variable, strong causal conclusions cannot be drawn based on the differences found (Johnson & Christensen, 2016). However, a causal relationship between independent and dependent variables will be shown as a difference between the independent variable groups (Gall et al., 2007). A key feature of the causal-comparative design is that independent variables are measured in categories (Creswell, 2015; Gall et al., 2007). A causal-comparative design is appropriate in this study because the researcher seeks to determine if learning environment (online or face-to-face setting) affects student confidence level toward mathematics, confidence level toward computers, mathematics motivation, computer engagement, and computer-mathematics interaction. For this study, the independent variable will be the delivery method: online or face-to-face. The dependent variables for this study will be confidence level toward mathematics, confidence level toward computers, mathematics motivation, computer engagement, and computer-mathematics interaction as measured by the Galbraith-Haines Mathematics-Computer Attitude Scales (GHMCAS). Confidence levels in mathematics center around feelings of value for effort, expectations of results, and worry or nervousness associated with the subject (Galbraith & Haines, 1998). Mathematics confidence is related to self-efficacy in the subject and a lack of confidence is connected to anxiety and stress when attempting mathematical tasks (Mkhize, 2021). Computer confidence encompasses feelings of trust in finding correct answers, ability to master technical procedures, and beliefs about working through any technical issues that may come up (Galbraith & Haines, 1998; García-Santillán et al., 2013). Engagement is the extent to which students actively participate in learning by applying concepts, generating ideas, and creating a network of knowledge (Galbraith & Haines, 1998). Engaging behaviors include planning for studying, minimizing distractions, and timely submission of assignments (Gjicali & Lipnevich, 2021). Engagement levels are explored in the areas of mathematics and computers for this study. Computer-mathematics interaction is the level to which students actively combine their mathematical thinking with use of a computer-type device (Galbraith & Haines, 2011).

Attitude is characterized as the outcome of internalized and automated emotional responses (McLeod, 1989). Zimbardo and Leippe (1991) add that attitudes are learned or established predispositions to respond. Student attitudes towards mathematics and computers are based on this internalization of emotions related to previous encounters with the topics. For this study, attitude will be measured by subsections of the GHMCAS: confidence toward mathematics, mathematics motivation, computer confidence, and computer-mathematics interaction sections. These components will be administered to online and traditional high school math students through a Google form.

Research Question

RQ: Is there a difference between online and face-to-face high school students' confidence level toward mathematics, motivation toward mathematics, confidence level toward computers, or computer-mathematics interaction?

Hypothesis

The null hypothesis for this study is:

H_0: There is no difference between online and face-to-face high school students' confidence level toward mathematics, motivation toward mathematics, confidence level toward computers, or computer-mathematics interaction as measured by the Galbraith-Haines Mathematics-Computer Attitude Scales.

Participants and Setting

Participants for this study will be taken from a convenience sample of 137 high school math students in a single district located in western North Carolina during the 2022-2023 school year. Participants will include students enrolled in traditional sections of high school math courses in various face-to-face classes throughout the district and students who opt to take math courses online as offered by the district.

Population

The participants for the study will be drawn from a convenience sample of high school students located in a single, medium-sized district in western North Carolina during the 2022-2023 school year. The district reported 10,969 students in the 2021-2022 school year, with 3,532 being high school students ranging in age from fourteen to nineteen years old (Caldwell County Schools, 2021). Online enrollment was reported at 314 middle and high school students (Caldwell County Schools, 2021). As of September 10, 2021, 53% of the district population qualified for free or reduced lunch with 2,431,797 meals distributed between March 2020 and June 2021 in response to Covid-19 shutdowns (Caldwell County Schools, 2021). Approximately 4,200 students, or 38%, are reported to ride school buses as daily transportation to or from school (Caldwell County Schools, 2021). The district serves 11.7% of its students in Academically Gifted programs, 14.6% in Exceptional Children programs, and .04% as English Learners (Caldwell County Schools, 2021). Student race and ethnicity breakdowns for the district were reported as 75.27% White, 12.68% Hispanic, 5.57% Multi-Racial, 5.45% African American, 0.91% Asian, and 0.06% Alaskan Native/American Indian (Caldwell County Schools, 2021). The district student population is 48% female and 52% male enrolled in the 2018-2019 school year (U.S. News & World Report, 2018).

Participants

There were 137 students sampled for this study: 70 face-to-face setting students, and 67 online students. According to Warner (2021), 108 students is the required minimum for a MANOVA when assuming a small effect size with statistical power of .7 at the .05 alpha level (p. 367-368). The number of participants sampled was 137 students, which according to Warner (2021) exceeds the required minimum sample size of 108 for a MANOVA when assuming a medium effect size with statistical power of .7 at the .05 alpha level.

The sample consists of face-to-face students from three traditional high schools. The online students were from the online high school within the same district. The high school math courses are based on the North Carolina Standard Course of Study for Math I, Math II, or Math

III with major topics including polynomials, rational functions, trigonometry, circles, volume, and quadrilaterals. All versions of the course are being taught as semester-long courses during the 2022-2023 school year.

Participants in the face-to-face setting were selected from three traditional high schools. School A population is 1% Asian, 12% Hispanic, 11% Black, 70% White, and 6% two or more races, with 41% eligible for free or reduced lunch (Public School Review, n.d). School B population is 1% Asian, 9% Hispanic, 1% Black, 85% White, and 4% two or more races, with 35% eligible for free or reduced lunch (Public School Review, n.d). School C population is 17% Hispanic, 9% Black, 67% White, and 7% two or more races, with 48% eligible for free or reduced lunch (Public School Review, n.d). Participants in the online setting were selected from the online high school for the district. The online school population is 0.6% Asian, 12.7% Hispanic, 3.5% Black, 74.6% White, and 8.7% two or more races.

Setting

The setting for this study is a single school district in western North Carolina. Participants are enrolled in the NC Math I, Math II, or Math III courses at either a traditional high school, or in an online math course. These courses are three out of four required for high school graduation in North Carolina. Topics covered in the NC Math I course include properties of exponents, quadratic functions, operations with polynomials, solving linear equations, systems of linear equations and inequalities, key features of graphs, histograms, and box plots (NCDPI, 2017). The NC Math II course includes topics of solving quadratic, square root, and inverse variation equations, an introduction to complex numbers, solving systems of equations by graphing, key features of graphs, geometric transformations and symmetry, parallel line properties, similar triangles, congruent triangles, the Pythagorean Theorem, special right triangles, and basic probability (NCDPI, 2017). Topics covered in the Math III course include the complex number system, structure of expressions, reasoning with equations and inequalities, function interpretation, function building, linear, quadratic, and exponential models, trigonometric functions, geometric congruence, circle theorems and applications, geometric measurement and modeling, and statistical sampling (NCDPI, 2017). Both face-to-face and online versions of the courses are taught in one semester. Teachers for each course are asked to follow a county-determined pacing guide and should be teaching similar material at the time of the survey. Both online and face-to-face teachers are provided with the Canvas platform as a learning management system.

Instrumentation

For this study, selected subsets of the Galbraith-Haines Mathematics-Computer Attitude Scales (GHMCAS) will be used as the data collection instrument. The purpose of this instrument is to allow for the investigation of the "extent to which attitudes to computer use and mathematics represent different inputs into technology-based teaching contexts involving mathematics and learning" (Galbraith & Haines, 1998). The GHMCAS is used to measure student attitudes toward mathematics and computer confidence, motivation, engagement, and interaction. Because of the focus on attitude toward both mathematics and technology, the GHMCAS will be used as the survey instrument for this study.

Galbraith-Haines Mathematics-Computer Attitude Scales

After creating the scales in 1998, Galbraith and Haines conducted a study among first-year university students and found that computer influence had a significant impact on student attitudes toward computer-mathematics interactions. They foresaw that this computer influence would extend to graphing calculators and computer programs used in mathematics classrooms at the undergraduate level (Galbraith & Haines, 1998). This instrument was used in numerous studies (Cretchley & Galbraith, 2002; Galbraith & Haines, 1998; García-Santillán et al., 2013).

The full instrument consists of six sections: confidence toward mathematics, mathematics motivation, mathematics engagement, computer confidence, computer motivation, and computer-mathematics interaction (Galbraith & Haines, 1998). The instrument creators state that the various sections can be selected and combined for research purposes (Galbraith & Haines, 1998). The independent variable for this study is which of two groups the math students are in: students taking the math course online and students taking the math course in the traditional, face-to-face setting. The dependent variables for this study are confidence level, engagement, and computer-mathematics interaction of online and traditional high school math students toward mathematics and computers, which will be measured using the GHMCAS subscales one, three, four, and five. Each section contained eight items measured on a five-point Likert scale ranging from lowest to highest. Responses are as follows: Highest = 5, High = 4, Neutral = 3, Low = 2, Lowest = 1. Four of the questions in each section represent positive beliefs and attitudes and four represent negative beliefs and attitudes. These positive and negative questions alternate within each section. For this study, answers to the negative questions will require reversal of polarity after collection. The highest score possible, 40, in each section would indicate strong positive views of that component. A score of eight for a section is the lowest possible value for the section and would represent strong negative views of that component.

Galbraith and Haines (1998) state that "the scales are coherent with α-reliability coefficients from strong to moderate" (p. 27) and explain that the scales were repeatedly administered at least two universities in Australia with consistent patterns demonstrated in rank ordering, "calculated reliability coefficients, and in the structural properties displayed by the factor analyses" (p. 28). Scale reliabilities are reported with the Rasch equivalent to the Cronbach's alpha statistic with levels as follows: mathematics confidence 0.96, mathematics motivation 0.94, mathematics engagement 0.99, computer confidence 0.94, computer motivation 0.78, computer-mathematics interaction 0.95 (Galbraith & Haines, 1998, p. 284). Validity of the instrument is confirmed through the consistency of responses across multiple repeated administrations at the two Australian universities (Galbraith & Haines, 1998).

Permission was granted for use of this instrument for the current study. See Appendix A for permission to use instrument. The time needed for students to complete the survey is estimated at ten minutes.

Procedures

Liberty University's Institutional Review Board (IRB) provided consent for this study prior to gathering any data. See Appendix C for IRB approval. Parental consent and child assent were obtained in accordance with IRB policy. The parental recruitment letter can be found in Appendix E and student recruitment letter in Appendix F. The parental consent form can be found in Appendix G. The student consent form was provided electronically as the first page of the Google form used for the survey. This form can be found in Appendix H.

The researcher gained preliminary approval to use the high school math student data from the district associate superintendent to make sure the study would be feasible. See Appendix B for school permission. Once IRB approval was received, the researcher requested the enrollment data from the math coordinator at the district level. The researcher created a Google form version of the GHMCAS including the consent form as the first page. The researcher created a recruitment letter for teachers explaining the research study and requesting that teachers share the link or QR code to the GHMCAS Google form with students who received consent to participate. See Appendix D for the letter. The researcher provided copies of the recruitment letters and consent forms to the district math coordinator who selected high school math teachers in the district to participate. Students were given three weeks in which to complete the form. The researcher asked the district math coordinator to forward a reminder email containing the original recruitment letter to teachers after two weeks. As students completed the GHMCAS, information populated into a Google sheet of raw data. No identifying information was collected from student participants. The spreadsheet was protected from public view and only visible to the researcher, district math coordinator, the online school administrator, and the associate superintendent. The researcher then used the Statistical Package for the Social Sciences (SPSS) software program to run the statistical analysis. For each research question, the researcher computed both visual and numeric summaries using the software.

Data Analysis

The data analysis used in this study is the multivariate analysis of variance (MANOVA). The selection of this test was based on the comparisons that could be made on multiple dependent variables between the two independent variable groups (Warner, 2021). Data screening was conducted on each group's dependent variables to search for missing values, implausible values, and extreme outliers. Data was removed for five participants in the face-to-face category who left one or more questions unanswered. Data was examined for outliers using box and whisker plots. No extreme outliers were identified. Descriptive statistics were then calculated and reported. The Kolmogorov-Smirnov test and visual inspection of histograms were then used to test normality. The Pearson correlation coefficients between dependent variables were then used to test the assumption of non-multicollinearity. Scatterplot matrices were used to examine the assumption of multivariate normal distribution and the assumption of linearity. The

Box’s M test was used to assess the assumption of homogeneity of variance-covariance matrices. The *F*- statistic is reported at the alpha level of .05. The data was checked for multicollinearity. Partial η2 was used to measure effect size. Post-hoc tests were reported.

CHAPTER FOUR: FINDINGS

Overview

This study examined high school math students' attitudes toward mathematics and computers in online and face-to-face settings. Dependent attitude variables included mathematics confidence, mathematics motivation, computer confidence, and computer mathematics interaction. The study was conducted with participants from three traditional high schools and one online high school in a single school district. This chapter presents the quantitative findings.

Research Question

RQ: Is there a difference between online and face-to-face high school students' confidence level toward mathematics, motivation toward mathematics, confidence level toward computers, or computer-mathematics interaction?

Null Hypothesis

H_0: There is no difference between online and face-to-face high school students' confidence level toward mathematics, motivation toward mathematics, confidence level toward computers, or computer-mathematics interaction as measured by the Galbraith-Haines Mathematics-Computer Attitude Scales.

Descriptive Statistics

The original data set included 137 participants. Original data obtained for the dependent variables of mathematics confidence, mathematics motivation, computer confidence, and computer mathematics interaction can be found in Table 1.

Table 1

Descriptive Statistics

Setting Type	Variable	*n*	*M*	*SD*
Online	Mathematics Confidence	67	20.27	6.271
	Mathematics Motivation	67	28.40	2.818
	Computer Confidence	67	28.39	5.027
	Computer Mathematics Interaction	67	29.24	3.215
Face-to-Face	Mathematics Confidence	67	23.46	6.219
	Mathematics Motivation	68	26.90	3.191
	Computer Confidence	70	28.21	4.869
	Computer Mathematics Interaction	68	25.68	4.621

Results

Data Screening

Data screening was conducted on each group's dependent variables (mathematics confidence, mathematics motivation, computer confidence, computer mathematics interaction) to search for missing values, implausible values, and extreme outliers. Five participants in the face-to-face category left one or more questions unanswered. Data for these participants was removed, reducing the data set to 132 participants. Descriptive statistics for this adjusted data set can be found in Table 2.

Table 2

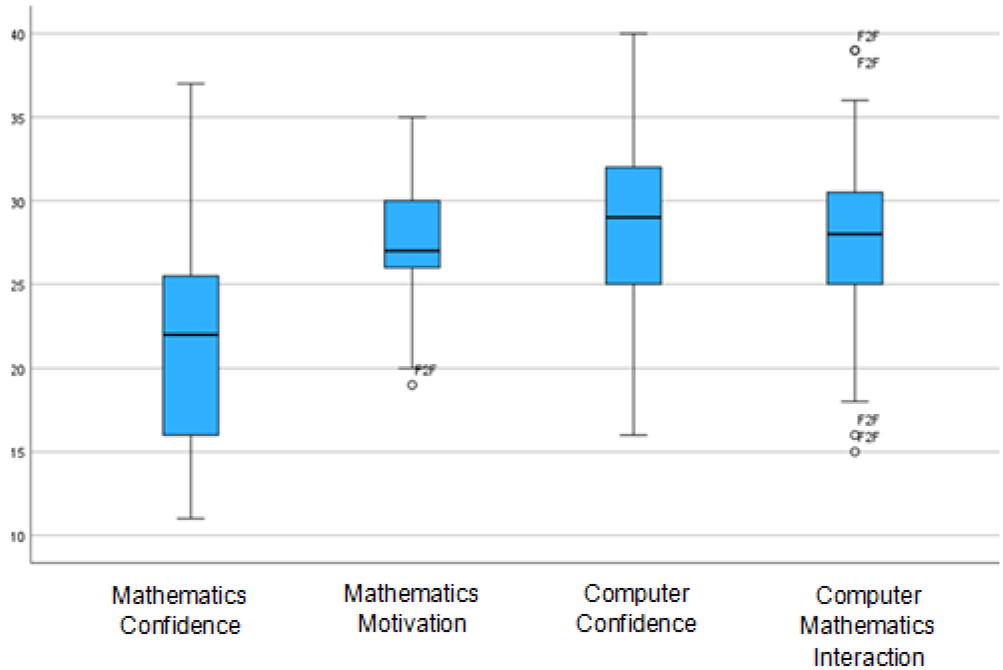
Descriptive Statistics Adjusted Data Set

Setting Type	Variable	*n*	*M*	*SD*
Online	Mathematics Confidence	67	20.27	6.271
	Mathematics Motivation	67	28.40	2.818
	Computer Confidence	67	28.39	5.027
	Computer Mathematics Interaction	67	29.24	3.215
Face-to-Face	Mathematics Confidence	65	23.58	6.225
	Mathematics Motivation	65	26.95	3.184
	Computer Confidence	65	28.26	4.947
	Computer Mathematics Interaction	65	25.62	4.676

No other data errors or inconsistencies were noted. Box and Whisker plots for each group were used to display data to look for extreme outliers. No extreme outliers were identified. See Figure 1 for Box and Whiskers plots of the dependent variables.

Figure 1

Box and Whiskers Plot for Dependent Variables



Assumptions

A one-way multivariate analysis of variance (MANOVA) was conducted to test the null hypothesis that looked at the difference in attitudes between online and face-to-face participants in high school math classes toward mathematics and computers on the dependent variables mathematics confidence, mathematics motivation, computer confidence, and computer mathematics interaction. The assumptions of no extreme outliers, normality of distribution, linearity, multivariate normal distribution, and homogeneity of variance were tested to evaluate the validity of the data (Warner, 2021).

The assumption of no extreme outliers was met. Box and Whisker plots were examined for extreme outliers. See Figure 1. No extreme outliers were present.

Normality was examined using a Kolmogorov-Smirnov test. Violations of the assumption of normality were found in the mathematics confidence, mathematics motivation, and computer mathematics interaction domains. See Table 3 for Tests for Normality.

Table 3

Tests for Normality

Variable	Kolmogorov-Smirnov	*df*	*p*
Mathematics Confidence	.093	132	.007
Mathematics Motivation	.111	132	<.001
Computer Confidence	.073	132	.080
Computer Mathematics Interaction	.118	132	<.001

The assumption of normality was violated for the mathematics confidence, mathematics motivation, and computer mathematics interaction domains. Therefore, the researcher used histograms to examine normality graphically (Stevens, 2012; Warner, 2021). Warner (2021) suggests the MANOVA statistic is robust to violations of Normality, especially when there is visual evidence of relative normality. Examination of histograms indicated relatively normal distributions for all domains. See Figure 2 for the histogram of mathematics confidence. See Figure 3 for the histogram of mathematics motivation. See Figure 4 for the histogram of computer confidence. See Figure 5 for the histogram of computer mathematics interaction. The assumption of normality was held tenable based upon visual examination of the data distributions, and the analysis was continued.

Figure 2

Histogram of Mathematics Confidence

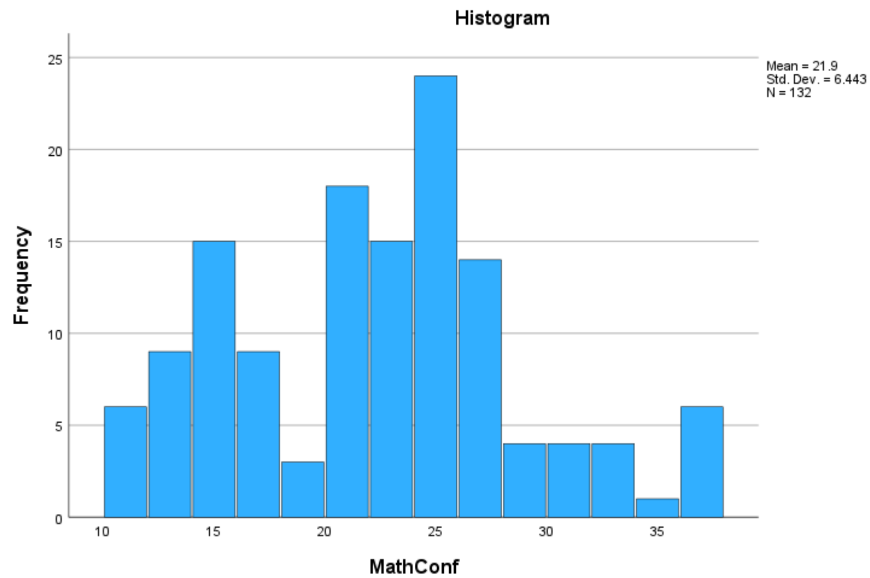


Figure 3

Histogram of Mathematics Motivation

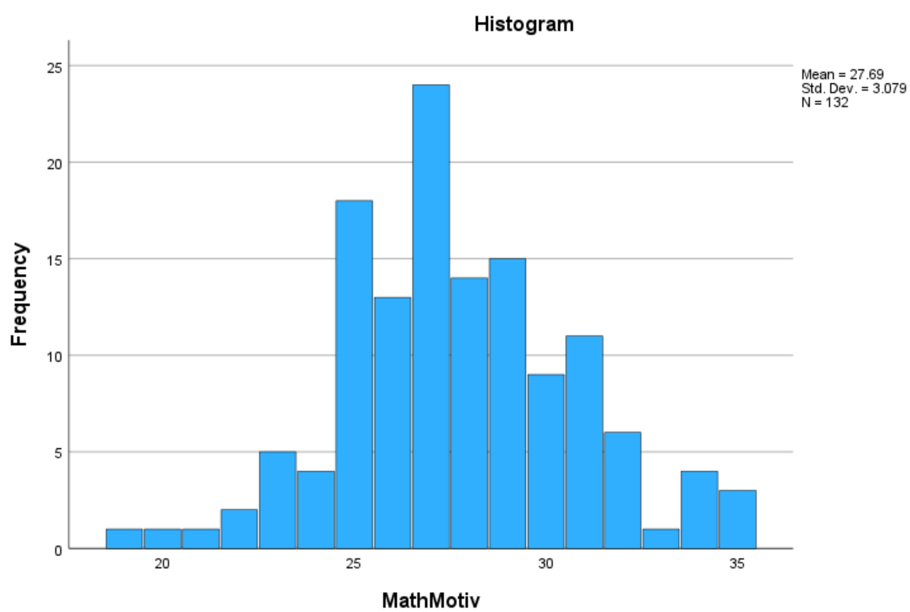


Figure 4

Histogram of Computer Confidence

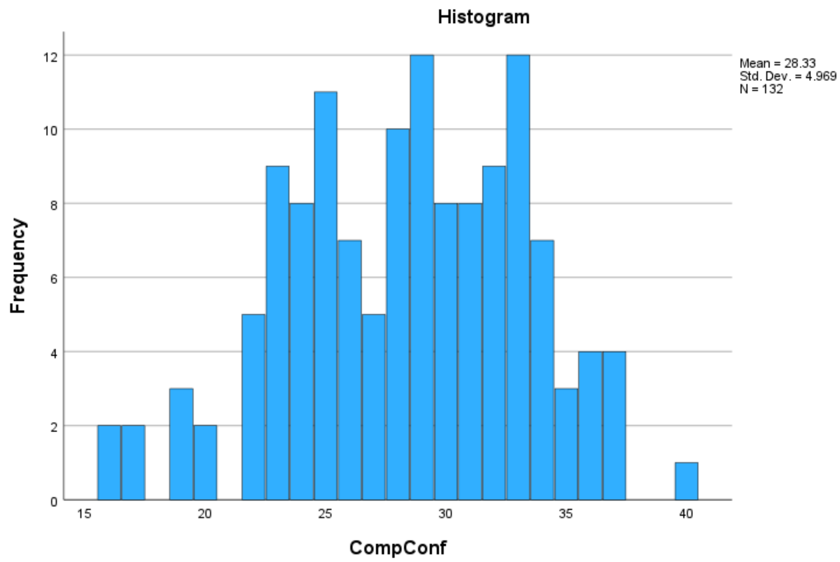
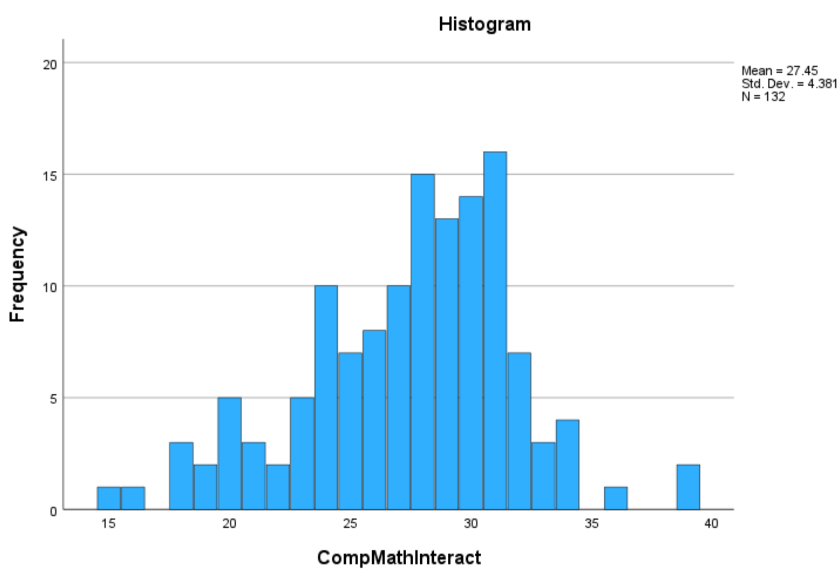


Figure 5

Histogram of Computer Mathematics Interaction



The next assumption was the assumption of non-multicollinearity. To test the assumption of non-multicollinearity, the researcher used Pearson correlation coefficients between dependent variables to determine if there are any relationships that are too strongly correlated (Warner, 2021). The assumption of non-multicollinearity held tenable with no Pearson values greater than or equal to .80. See Table 4 for the correlations.

Table 4

Correlations

		Mathematics Confidence	Mathematics Motivation	Computer Confidence	Computer Mathematics Interaction
Mathematics	*r*	1	-.077	.305**	-.093
Confidence	*α*		.380	<.001	.289
	n	132	132	132	132
Mathematics	*r*	-.077	1	.115	.318**
Motivation	*α*	.380		.190	<.001
	n	132	132	132	132
Computer	*r*	.305**	.115	1	.475**
Confidence	*α*	<.001	.190		<.001
	n	132	132	132	132
Computer	*r*	-.093	.318**	.475**	1
Mathematics	*α*	.289	<.001	<.001	
Interaction	*n*	132	132	132	132

**Correlation is significant at the 0.01 level (2-tailed).

To test the assumptions of multivariate normal distribution and linearity, the researcher used a scatterplot matrix for each group of the independent variable: setting type (online or face-to-face). The scatterplot matrix for the face-to-face is shown in Figure 6. The scatterplot matrix for the online setting is shown in Figure 7.

Figure 6

Scatterplot Matrix for Face-to-Face Setting

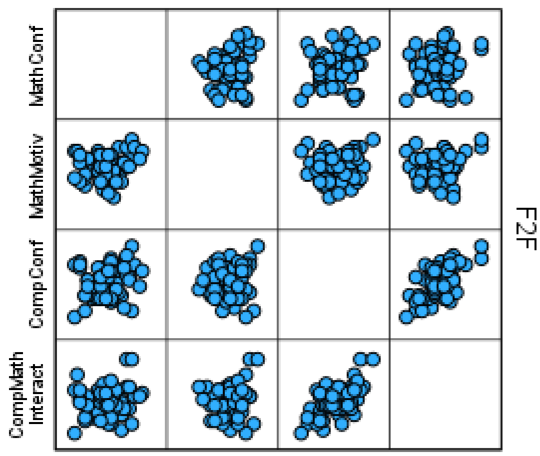
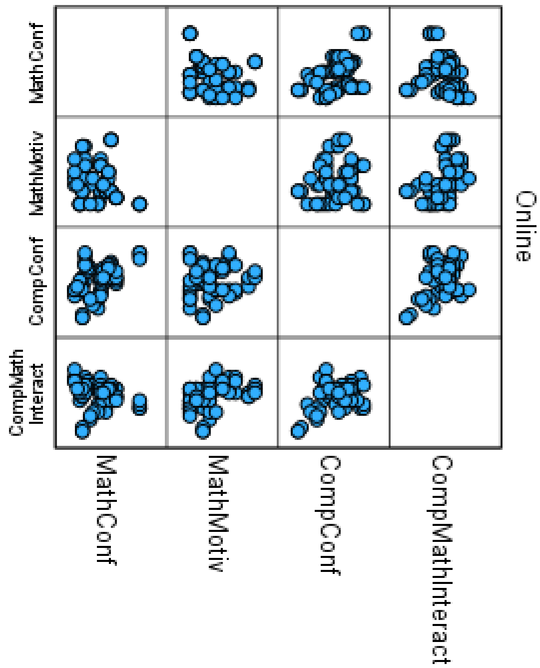


Figure 7

Scatterplot Matrix for Online Setting



The matrix scatterplot shows the multivariate distribution is normal. The assumption of multivariate normal distribution is held tenable. There was a linear relationship between Mathematics Confidence, Mathematics Motivation, Computer Confidence, and Computer Mathematics Interaction for each independent variable, as assessed by scatterplot.

The final assumption tested was the assumption of homogeneity of variance. This assumption was assessed by Box's M test of equality of covariance matrices and the assumption was violated. Results for Box's M test of equality of covariance matrices are found in Table 5.

Table 5

Box's M Test of Equality of Covariance Matrices

Box's M	43.860
F	4.240
df1	10
df2	80624.215
Sig.	<.001

The assumption of homogeneity of variance was further examined using Levene's Test of Homogeneity of Variance. The assumption was met for mathematics confidence, mathematics motivation, and computer confidence. A violation of the homogeneity of variance was found for the computer mathematics interaction domain. However, because the MANOVA is considered a robust test against the homogeneity assumption (Stevens, 2012), the analysis was able to continue. See Table 6 for the Levene's Test.

Table 6

Levene's Test of Equality of Error Variances

Value	Levene Statistic	*df1*	*df2*	Sig.
Mathematics Confidence	.054	1	130	.816
Mathematics Motivation	.387	1	130	.535
Computer Confidence	.433	1	130	.870
Computer Mathematics Interaction	14.147	1	130	.010

Null Hypotheses

A one-way MANOVA was conducted to determine if there was a statistically significant difference in attitudes towards computers and mathematics between online and face-to-face high school mathematics students. The Pillai's Trace statistic was used as the determining statistic. MANOVA results are shown in Table 7.

Table 7

MANOVA Results

Effect	Pillai's Trace	*F*	*df*	Error *df*	Sig.	Partial eta squared
Pillai's Trace	.248	10.448	4.000	127.000	<.001	.248

The result of the MANOVA was significant, where $F(4, 127) = 10.448$, $p < .001$, Pillai's Trace = .248, and partial η^2 = 0.248, suggesting there are significant differences on the dependent variables (mathematics confidence, mathematics motivation, computer confidence, computer mathematics interaction) by setting type for high school mathematics students in online and face-to-face settings. The effect size as measured by partial eta squared was .248, indicating that about 24.8% of the variance in the independent variables can be explained by the dependent variable (Warner, 2021).

Post-hoc analysis shows that there is a significant difference between the two settings for mathematics confidence where $F(1, 130) = 9.29$, $p = .003$, partial $\eta^2 = .067$, mathematics motivation where $F(1, 130) = 7.679$, $p = .006$, partial $\eta^2 = .056$, and computer mathematics interaction $F(1, 130) = 27.052$, $p < .001$, partial $\eta^2 = .172$. There was no significant difference for computer confidence where $F(1, 130) = .021$, $p = .884$, partial $\eta^2 = .000$. See Table 8 for the Test of Between-Subjects Effects by setting and Table 9 for Pairwise Comparisons.

Table 8

Test of Between-Subjects Effects by Setting

	F	Sig.	Partial eta squared
Mathematics Confidence	9.293	.003	.067
Mathematics Motivation	7.679	.006	.056
Computer Confidence	.021	.884	.000
Computer Mathematics Interaction	27.052	<.001	.172

Table 9

Pairwise Comparisons

Dependent Variable	(I) Setting	(J) Setting	Δ_{μ} *(I-J)*	*SE*	α^b	*LL*	*UL*
Math Confidence	Online	F2F	-3.316*	1.088	.003	-5.468	-1.164
	F2F	Online	3.316*	1.088	.003	1.164	5.468
Math Motivation	Online	F2F	1.449*	.523	.006	.415	2.484
	F2F	Online	-1.449*	.523	.006	-2.484	-.415
Computer Confidence	Online	F2F	.127	.868	.884	-1.592	1.845
	F2F	Online	-.127	.868	.884	-1.845	1.592
Computer Mathematics Interaction	Online	F2F	3.623*	.697	<.001	2.245	5.002
	F2F	Online	-3.623*	.697	<.001	-5.002	-2.245

Based on estimated marginal means

*The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Because a significant difference was found on the dependent variables of mathematics confidence, mathematics motivation, and computer mathematics interaction by setting type, null hypotheses one, two and four were rejected. Null hypothesis three, which stated that there is no difference in the engagement toward mathematics among traditional and online high school math students, was accepted.

A one-way multivariate analysis of variance was run to determine differences in attitudes of online and face-to-face students toward mathematics confidence, mathematics motivation, computer confidence, and computer mathematics interaction. Attitudes were measured using the Galbraith-Haines Mathematics-Computer Attitude Scales. Participants were from three traditional high schools where mathematics instruction is face-to-face and one online high school where instruction is virtual. The differences between the settings on the combined dependent variables was statistically significant where $F(4, 127) = 10.448$, $p < .001$, Pillai's Trace = .248, and partial $\eta^2 = 0.248$. Post-hoc analysis confirmed a significant difference on the dependent variables of mathematics confidence ($F(1, 130) = 9.29$, $p = .003$, partial $\eta^2 = .067$) mathematics motivation ($F(1, 130) = 7.679$, $p = .006$, partial $\eta^2 = .056$), and computer mathematics interaction ($F(1, 130) = 27.052$, $p < .001$, partial $\eta^2 = .172$) by setting type.

CHAPTER FIVE: CONCLUSIONS

Overview

This chapter provides a brief overview of the study. It includes conclusions based on data findings for each dependent variable (mathematics confidence, mathematics motivation, computer confidence, and computer mathematics interaction) in comparison with previous research. The researcher also discusses the implications and limitations of the findings, along with recommendations for future research.

Discussion

The purpose of this quantitative, causal-comparative study is to compare attitudes of online and traditional setting high school math students toward mathematics and computers, as measured by the responses of online and face-to-face high school mathematics students on the Galbraith-Haines Mathematics-Computer Attitude Scales (GHMCAS) instrument (Galbraith & Haines, 1998). District leadership from a Western North Carolina school district selected classes at three traditional high schools and the district's online school to participate. The researcher provided survey links to district leadership for distribution. Sixty-seven participants were online students, and seventy students were in a face-to-face setting.

The study took place in the spring semester of 2023 at the convenience of each cooperating teacher. Students who received parental consent to participate were given a QR code or link to the survey. The first page of the survey was the student consent form. By completing the survey participants agreed to the consent form. The collected data was an analyzed using a MANOVA with the independent variable being the setting (online or face-to-face) and the dependent variables being mathematics confidence, mathematics motivation, computer confidence, and computer mathematics interaction. Responses from five students were removed due to unanswered items. The research question for this study sought to determine if there was a difference in attitudes toward mathematics and computers between students in online and face-to-face settings. The null hypothesis stated that is no difference in the confidence level toward mathematics, motivation toward mathematics, confidence level toward computers, or computer-mathematics interaction between traditional and online high school math students. The result of the MANOVA was significant, where $F(4, 127) = 10.448$, $p < .001$, Pillai's Trace = .248, and partial $\eta^2 = 0.248$, suggesting there are significant differences on the dependent variables (mathematics confidence, mathematics motivation, computer confidence, computer mathematics interaction) by setting type for high school mathematics students in online and face-to-face settings.

Mathematics Confidence

In this study mathematics confidence was measured through items on the GHMCAS that addressed value for effort, expectation of results, worry associated with learning new mathematics topics, and overall confidence in the subject (García-Santillán et al., 2013). These items represent the affective, behavioral, and cognitive components of the ABC model of attitude (Drew, 2020), as well as the extended components of the theory explored by Hart (1989), Mandler (1989), and McLeod (1989, 1992). Galbraith and Haines (1998) worded items carefully throughout the instrument to focus specifically on the attitude domain.

When analyzing the mean differences between the settings on the mathematics confidence domain in this study, a significant difference was found between the online and face-to-face students, with face-to-face ($M = 23.58$, $SD = 6.225$) students reporting a higher level of confidence than online students ($M = 20.27$, $SD = 6.271$) where $F(1, 130) = 9.29$, $p = .003$, and partial $\eta^2 = .067$. Therefore, null hypothesis one was rejected. This finding indicates that students in face-to-face settings agree that value is obtained through effort, expect good results, and show little worry in learning new topics (Galbraith & Haines, 1998).

It is also important to consider that during pandemic shut-downs all participants in this study were taught in an online environment. In a study that took place shortly after pandemic emergency shutdowns, 48.2% of participants reported decreased confidence in the ability to succeed in STEM courses, which includes mathematics courses (Brown et al., 2022). The current study results for mathematics confidence were similar to the overall findings of Almasri (2022) who found positive attitudes in the traditional setting compared to the e-learning setting in Biology courses.

Mathematics Motivation

The affective domain is one of the key components of the ABC model of attitude (Drew, 2020). Huitt (2011) explains that the affective domain is a source of motivational needs where there is a desire to increase good feelings, decrease bad feelings, and increase feelings of security. Positively worded items on the mathematics motivation section of the GHMCAS reflect the value that highly motivated students place on understanding mathematical concepts (García-Santillán et al., 2013). Certain negatively worded items in the section reflect the desire to yield to efforts quickly (García-Santillán et al., 2013). When analyzing the mean differences between the settings on the mathematics motivation domain in this study, a significant difference was found between the online and face-to-face students, with online students (M = 28.40 , SD = 2.818) reporting a higher level of motivation than face-to-face students (M = 26.95 , SD = 3.184) where F(1, 130) = 7.679, p = .006, and partial η^2 =.056. Therefore, null hypothesis two was rejected. Means on the mathematics motivation domain were higher than for online students than those in the face-to-face setting. This finding indicates a higher desire to understand mathematical concepts and a stronger willingness to continue efforts toward understanding for the online students compared to those in the face-to-face setting.

Motivational goals and coping strategies used when approaching mathematical challenges have been found to differ between students who hold positive, negative, and average self-schemas in relation to mathematics (Ng, 2021). Mathematics motivation is also strongly associated with engagement (Galbraith & Haines, 1998). Research supports that self-motivation is needed for success in online courses (Burton & Goldsmith, 2002). Findings of this study add to this claim because higher mathematical motivation scores were reported for students in online courses compared to students in face-to-face courses. Johnston (2022) also found a difference in the mathematics motivation of undergraduate students in online and face-to-face courses. Opposite of this study, her results indicated that students in online classes were less motivated than students in face-to-face classes (Johnston, 2022). However, attitudes toward mathematics were more positive for students who had previously taken online courses (Johnston, 2022).

Computer Confidence

Computer confidence represents a belief in competence with necessary software procedures and a confidence with answers obtained using computer equipment (García-Santillán et al., 2013). Negative views in this category reflect anxiety using computers to solve problems and an overall disadvantage when using computers (García-Santillán et al., 2013). GHMCAS items related to computer confidence addressed mastering computer procedures, trusting answers from computers, and belief in one's ability to deal with mistakes when using computers (García-Santillán et al., 2013). When analyzing the mean differences between the settings on the computer confidence domain, no significant difference was found between the online students

(M = 28.39, SD = 5.027) and face-to-face students (M = 28.26, SD = 4.947) where $F(1, 130)$ = .021, p = .884, and partial $\eta^2 =.000$. Therefore, the null hypothesis failed to be rejected.

The result from the computer confidence component of this study could be connected to findings of studies held around the time of pandemic shutdowns. In one case, Kastorff et al. (2023) studied adolescent technology use before, during, and after the pandemic. The use of technology for almost all types of use increased significantly for adolescents during the pandemic (Kastorff et al., 2023). Adolescents became more target-oriented during the pandemic, which had a positive impact on their digital skills (Kastorff et al., 2023). In another study, Sonnenschein et al. (2023) found that student access to digital devices was high both before and after the pandemic, but there was a shift in the most common type of device used from tablets to computers or laptops. Sonnenschein et al. (2023) also found that parents felt confident in supporting student use of technology during the shutdown.

Additionally, in his explanation of connectivism learning theory, Siemens (2004) claims that technology is playing an important role in rewiring our brains and supporting cognitive processes. Since all students in this study were impacted by pandemic shutdowns and digital learning changes, this improvement in digital skills could influence computer confidence levels for all students, explaining that no difference could be found in this domain for online and face-to-face students.

Computer Mathematics Interaction

When analyzing the mean differences between the settings on the computer mathematics interaction domain, a significant difference was found between the online and face-to-face students, with online students (M = 29.24 , SD = 3.215) reporting a higher level of interaction than face-to-face students (M = 25.62, SD = 4.676) where $F(1, 130)$ = 27.052, $p < .001$, and partial $\eta^2 = .172$. Therefore, the null hypothesis was rejected. This result supports analysis by Higgins et al. (2019) who states that technology-enhanced instruction positively influences student motivation. Ober et al. (2023) discovered a correlation between math self-assurance and identity with all four areas of attitudes towards computer programming. Additionally, students who displayed favorable perceptions of mathematics also exhibited favorable attitudes towards computer programming (Ober et al., 2023). The influence of technology use in mathematics education has been shown to improve student attitudes, lead to gains in conceptual understanding, and improve learning behaviors (Ersoy & Akbulut, 2014; Eyyam & Yaratan, 2014; Pierce et al., 2007). This finding also aligns with connectivism learning theory, a theoretical framework which asserts that learning takes place through connections that are made (Siemens, 2004). The computer mathematics interaction section of the GHMCAS instrument contained statements about computers allowing students to link knowledge of graph shapes and equations, providing lots of examples, and taking notes or using printouts of material found digitally (García-Santillán et al., 2013). These questions speak to the sources of information including books, webpages, other people, task completion, and other possible in-person or digital sources that Siemens (2004) uses in his explanation of connectivism learning theory.

Implications

This study adds to the body of knowledge focusing on attitudes in mathematics learning environments. The findings of this study show that students in face-to-face classes are more confident in their mathematical skills. This implies that confidence is higher when students learn in the face-to-face presence of a math teacher. However, research conducted in online courses also supports teacher-student interaction (Li, 2022). In online courses where teaching is provided both synchronously and asynchronously, teaching activity interaction was found to have a strong positive correlation with content learning (Li, 2022). This implies that online teachers should include elements of teacher-student interaction within their course.

In the area of mathematics motivation, online students were shown to be more motivated than face-to-face students. Although the reasons behind this result are unknown, a study by Kumar and Verma (2021) related connections made between online students and their course to highly motivated teachers and active communication between students and teachers. Li et al. (2022) found that online learners must be more intrinsically motivated than their counterparts in face-to-face settings. Results also indicated that cognitive presence, success and focus during the learning experience, had the largest effect on student motivation in the online learning setting (Li et al., 2022). Additionally, technology has been shown to be a motivator for some students (Higgins et al., 2019). Social-emotional skills and other factors can also play a part in student motivation (Morgan & Cieminski, 2021). Findings from our study combined with others imply that teachers should engage in active communication with students, design learning experiences that capitalize on student focus, and consider student social-emotional skills when lesson planning.

Although computer confidence was found to be similar across both settings, digital learning skills are critical for students today. In 2013, under the direction of the North Carolina General Assembly, the NC State Board of Education developed standards for students in the area of digital learning (NCDPI, n.d.). These standards require students to engage in digital platforms for problem solving, collaboration, and communication (NCDPI, n.d.). Teachers in both online and face-to-face settings need to stay current on educational technology and tools and implement a variety of opportunities within their classes so that students continue to be prepared for future technology use (NCDPI, n.d.).

Computer mathematics interaction was found to be higher for online students when compared to face-to-face students. As a result of the transition to remote learning during the pandemic shutdown, and the continued implementation of online and hybrid learning options, there has been an increase in the use of online resources, e-learning activities, and digital devices (Mulenga & Marbán, 2020). The use of these tools in both the online and face-to-face settings may have influenced the result of this study. Using digital mathematics tools has been found to influence student understanding in mathematics (Arbain & Shukor, 2015; Chechan et al., 2023; Liang, 2016). For example, Liang (2016) explains that the online graphing calculator, Desmos, plays a crucial role in implementing the conceptual conflict strategy when teaching the idea of limits in Calculus. In another study by Chechan et al. (2023), a statistically significant difference was found in post-test scores of students who were taught a unit on understanding and analyzing functions using Desmos when compared to a control group who were taught the unit without the Desmos tool. A similar online tool, Geogebra, has also been studied with positive results (Arbain & Shukor, 2015). Arbain and Shukor (2015) found the use of Geogebra to have a positive impact on student achievement, confidence, and motivation. Connections between mathematics and technology need specific research attention (Galbraith et al., 2001). Although it is unknown which tools teachers in this study were using and to what extent, research supports that teachers in any setting should integrate math-specific digital tools, such as Desmos and GeoGebra, into lessons Arbain & Shukor, 2015; Chechan et al., 2023; Liang, 2016).

Limitations

Some limitations to both study population and study design may have caused threats to the internal and external validity of this study. First, the internal validity of this study may have been affected by gender. The number of online male students (N = 16) was significantly lower than the number of online female students (N = 51), which may have weakened the study. In addition, the face-to-face students (N = 70) who took part in this study may not have been representative of the student population (N = 836, N = 1365, N = 706) at each school. Students who participated in this study were from selected classes within each school and agreed to take the survey.

The external validity of this study was limited by the specific population and geographical region of the study. The scope of this study was limited to the study of high school mathematics students in North Carolina Math I, Math II, and Math III courses. The study focused on students in a single district located in the western region of North Carolina. The conclusions from this study may not necessarily be generalized to all students enrolled in high school mathematics courses in the United States or to students in higher or lower grade levels.

Recommendations for Future Research

Further studies are needed in order to gain a broader understanding of students' attitudes towards mathematics and computers, as well as on the variations in settings for instruction. Research recommendations include:

1. A future study should be conducted in a larger school district with an established online school. A larger sample with more gender balance in online students could provide further information on attitude differences. Response differences could also be considered between math courses with a larger sample.
2. A future study could also be conducted to compare the technology tools and uses between face-to-face and online teachers and compared to student attitudes in the settings. Strategies and how digital tools are incorporated in both settings could influence student attitudes.

3. With little research comparing the two settings, a qualitative study should be conducted to gather data on mathematics confidence, mathematics motivation, computer confidence, and computer mathematics motivation. Reasons behind student responses could shed light on differences between attitudes in online and face-to-face settings.

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APPENDICES

APPENDIX A

From: Martin Philyaw, Rebecca <rmartinphilyaw@liberty.edu>
Sent: Friday, April 15, 2022 1:00:00 AM
To: Peter Galbraith [redacted]
Subject: Instrument Request

Rebecca J. Martin Philyaw
Liberty University
Department of Education
1971 University Blvd.
Lynchburg, VA 24515

Dear Sir:

I am a doctoral student from Liberty University writing my dissertation titled ATTITUDES OF SECONDARY STUDENTS TOWARD ONLINE AND TRADITIONAL LEARNING IN MATHEMATICS, under the direction of my dissertation committee chaired by Dr. Nathan Putney, who can be reached at 434-582-2559 or by email at nputney@liberty.edu. The Liberty University IRB can be contacted at 434-592-5530 or by email at irb.liberty.edu.

I would like your permission to use the Galbraith-Haines Mathematics-Computer Attitude Scales survey/questionnaire instrument in my research study. I would like to use and reproduce your survey as a secure Google form under the following conditions:

I will use the surveys only for my research study and will not sell or use it with any compensated or curriculum development activities.

I will include the copyright statement on all copies of the instrument.

I will send a copy of my completed research study to your attention upon completion of the study.

If these are acceptable terms and conditions, please indicate so by replying to me through e-mail: rmartinphilyaw@liberty.edu.

Sincerely,

Rebecca J. Martin Philyaw
Doctoral Candidate

R.J.Martin Philyaw

[External] Re: Instrument Request

Peter Galbraith <[redacted]>
Thu 4/14/2022 8:32 PM
To: Martin Philyaw, Rebecca [redacted]

[EXTERNAL EMAIL: Do not click any links or open attachments unless you know the sender and trust the content.]

Rebecca,
Of course you can. And with our very best wishes.
Peter

Get Outlook for Android

APPENDIX B

[redacted] [redacted]

[redacted] Assistant Superintendent
Educational Program Services

October 31, 2022

To whom it may concern:

Joy Philyaw, high school teacher at [redacted] and doctoral student at Liberty University, has permission from [redacted] to conduct research as needed within the school district.

Should you have questions, please reach out to me.

Thank you,

[redacted]

Assistant Superintendent, Educational Program Services

[redacted]

APPENDIX C

[External] IRB-FY22-23-410 - Initial: Initial - Exempt

do-not-reply@cayuse.com <do-not-reply@cayuse.com>
Wed 2/1/2023 11:09 AM
To: Putney, Nathan (General Math and Science) <[redacted]>;Martin Philyaw, Rebecca [redacted]>

[EXTERNAL EMAIL: Do not click any links or open attachments unless you know the sender and trust the content.]

LIBERTY UNIVERSITY.
INSTITUTIONAL REVIEW BOARD

February 1, 2023

Rebecca Martin Philyaw
Nathan Putney

Re: IRB Exemption - IRB-FY22-23-410 ATTITUDES OF SECONDARY STUDENTS TOWARD ONLINE AND FACE-TO-FACE LEARNING IN MATHEMATICS

Dear Rebecca Martin Philyaw, Nathan Putney,

The Liberty University Institutional Review Board (IRB) has reviewed your application in accordance with the Office for Human Research Protections (OHRP) and Food and Drug Administration (FDA) regulations and finds your study to be exempt from further IRB review. This means you may begin your research with the data safeguarding methods mentioned in your approved application, and no further IRB oversight is required.

Your study falls under the following exemption category, which identifies specific situations in which human participants research is exempt from the policy set forth in 45 CFR 46:104(d):

Category 2.(i). Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording).
The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects.

Your stamped consent form(s) and final versions of your study documents can be found under the Attachments tab within the Submission Details section of your study on Cayuse IRB. Your stamped consent form(s) should be copied and used to gain the consent of your research participants. If you plan to provide your consent information electronically, the contents of the attached consent document(s) should be made available without alteration.

Please note that this exemption only applies to your current research application, and any modifications to your protocol must be reported to the Liberty University IRB for verification of continued exemption status. You may report these changes by completing a modification submission through your Cayuse IRB account.

If you have any questions about this exemption or need assistance in determining whether possible modifications to your protocol would change your exemption status, please email us at irb@liberty.edu.

Sincerely,
G. Michele Baker, MA, CIP
Administrative Chair of Institutional Research
Research Ethics Office

APPENDIX D

Dear Teacher:

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctoral degree. The purpose of my research is to investigate differences between online and face-to-face student attitudes toward mathematics and computer-based learning, and I am writing to request your assistance in conducting my research.

Participants must be high school students. Participants, if willing, will be asked to complete a short electronic survey indicating how much they agree with statements about mathematics or computer learning situations. It should take approximately ten minutes to complete the survey. The survey can be completed at a time that is convenient for you prior to March 16th, 2023. Please assure students that their responses will remain anonymous, and the researcher will not be able to tell which students provided which answers.
If you agree to assist me, expectations for cooperating teachers include:

1. Distribute consent forms to your math students by March 1, 2023.
2. Collect consent forms from students by March 10, 2023. Before a student can take the survey, any parents who wish for their student NOT to participate will need to sign and return the passive parental consent form.
3. Provide the link or QR code to the survey in class and allow 10-15 minutes of class time for students to complete the survey.
4. Return any signed consent forms to [redacted] at the Ed. Center through the courier.

If you have any questions, please email me at [redacted]. Thank you so much for being willing to help me with this endeavor.

Link to the survey: [redacted]

QR code:
[redacted]

Sincerely,

Rebecca J. Martin Philyaw
Liberty University Graduate Student
[redacted]

APPENDIX E

Dear Parent/Guardian:

As a student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctoral degree. The purpose of my research is to investigate differences between online and face-to-face student attitudes toward mathematics and computer-based learning and I am writing to invite eligible participants to join my study.

Participants must be high school math students. Participants, if willing, will be asked to complete a short electronic survey indicating how much they agree with statements about mathematics or computer learning situations. It should take approximately ten minutes to complete the survey. Participation will be completely anonymous, and no personal, identifying information will be collected.

A consent document is attached to this letter. The consent document contains additional information about my research. If you choose to allow your student to participate, you will not need to return the form. If you would prefer your student NOT PARTICIPATE, you will need to sign and return the form to your student's math teacher by March 10th, 2023. For participating students, their teacher will provide them with information about how to participate.

Sincerely,

Rebecca J. Martin Philyaw
Liberty University Student
[redacted]

APPENDIX F

Dear Student:

As a student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctoral degree. The purpose of my research is to investigate differences between online and face-to-face student attitudes toward mathematics and computer-based learning, and I am writing to invite eligible participants to join my study.

Participants must be high school math students. Participants, if willing, will be asked to complete a short, electronic survey, which is provided in the link or QR code below, indicating how much they agree with statements about mathematics or computer learning situations. It should take approximately ten minutes to complete the survey. Participation will be completely anonymous, and no personal, identifying information will be collected.

A consent document is included as the first page of the survey. The consent document contains additional information about my research. After you have read the consent form, please continue to the survey. Doing so will indicate that you have read the consent information and would like to take part in the survey.

Link to the survey: [redacted]

QR code:

[redacted]

Sincerely,

Rebecca J. Martin Philyaw
Liberty University Graduate Student
[redacted]

APPENDIX G

Parental Consent/Parental Opt-Out

Title of the Project: ATTITUDES OF SECONDARY STUDENTS TOWARD ONLINE AND FACE-TO-FACE LEARNING IN MATHEMATICS
Principal Investigator: Rebecca J. Martin Philyaw, Doctoral Candidate, Liberty University

Invitation to be Part of a Research Study

Your child is invited to participate in a research study. Participants must be enrolled in a high school math course. Taking part in this research project is voluntary.

Please take time to read this entire form and ask questions before deciding whether to allow your child to take part in this research project.

What is the study about and why are we doing it?

The purpose of the study is to determine if there is a difference between the attitudes of students taking math online and those taking math in a face-to-face setting toward math and computers. This information can be used to inform instructional choices in the future.

What will participants be asked to do in this study?

If you agree to allow your child to be in this study, I will ask him or her to complete an online survey provided through a link or QR code. The survey includes 32 questions asking students to rank their opinion of a statement on a scale of 1 to 5. Demographic questions will be used to collect information on whether the student is taking the course online or face-to-face, and student gender. The survey will take about ten minutes.

How could participants or others benefit from this study?

Participants should not expect to receive a direct benefit from taking part in this study.

Benefits to society include a contribution to the field of education in informing teachers about student attitudes toward mathematics and computers in a post Covid-19 world.

What risks might participants experience from being in this study?

The risks involved in this study are minimal, which means they are equal to the risks your child would encounter in everyday life.

How will personal information be protected?

The records of this study will be kept private. Research records will be stored securely, and only the researcher, the district math coordinator, and associate superintendent will have access to the records.

- Participant responses will be anonymous. Responses collected in the survey will not include any identifying information.
- Data will be stored on a password-locked computer and may be used in future presentations. After three years, all electronic records will be deleted.

What conflicts of interest exist in this study?

The researcher serves as a teacher at [redacted]. To limit potential or perceived conflicts the study will be anonymous, so the researcher will not know who participated. This disclosure is made so that you can decide if this relationship will affect your willingness to allow your child to participate in this study. No action will be taken against an individual based on her or his decision to allow his or her child to participate in this study.

Is study participation voluntary?

Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect your or his or her current or future relations with Liberty University or [redacted]. If you decide to allow your child/student to participate, he or she is free to not answer any question or withdraw at any time prior to submitting the survey without affecting those relationships.

What should be done if a participant wishes to withdraw from the study?

If you choose to withdraw your child from the study or your child chooses to withdraw, please have him or her exit the survey and close his or her internet browser. Your child's responses will not be recorded or included in the study.

Whom do you contact if you have questions or concerns about the study?

The researcher conducting this study is Rebecca J. Martin Philyaw. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact her at rmartinphilyaw@liberty.edu or [redacted]. You may also contact the researcher's faculty sponsor, Dr. Nathan Putney, at nputney@liberty.edu.

Whom do you contact if you have questions about rights as a research participant?

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board. Our physical address is 1971 University Blvd., Green Hall Ste. 2845, Lynchburg, VA 24515; our phone number is 434-592-5530, and our email is irb@liberty.edu.

Disclaimer: The Institutional Review Board (IRB) is tasked with ensuring that human subjects research will be conducted in an ethical manner as defined and required by federal regulations. The topics covered and viewpoints expressed or alluded to by student and faculty researchers are those of the researchers and do not necessarily reflect the official policies or positions of Liberty University.

Your Consent/Opt-Out

If you would prefer that your child NOT PARTICIPATE in this study, please sign this document and return it as directed in the email instructions by March 17th, 2023.

If you do not sign and return this document, you are agreeing to allow your child to be in this study. Make sure you understand what the study is about before you consent. You may keep this document for your records. If you have any questions about the study after you read this document, you can contact the study team using the information provided above.

____
Printed Child's/Student's Name

____
Parent's Signature   Date

APPENDIX H

Title of the Project: ATTITUDES OF SECONDARY STUDENTS TOWARD ONLINE AND FACE-TO-FACE LEARNING IN MATHEMATICS

Principal Investigator: Rebecca J. Martin Philyaw, Doctoral Candidate, School of Education, Liberty University

Invitation to be Part of a Research Study

You are invited to participate in a research study. To participate, you must be a high school math student in the 2022-2023 school year. Taking part in this research project is voluntary.

Please take time to read this entire form and ask questions before deciding whether to take part in this research.

What is the study about and why is it being done?

The purpose of the study is to determine if there is a difference between the attitudes of students taking math online and those taking math in a face-to-face setting toward math and computers. This information can be used to inform instructional choices in the future.

What will happen if you take part in this study?

If you agree to be in this study, I will ask you to do the following:

- Complete an online survey that should take about ten minutes. There are two questions that gather demographic information followed by 32 questions where you rank your opinion to a statement on a scale of one to five.

How could you or others benefit from this study?

Participants should not expect to receive a direct benefit from taking part in this study.

Benefits to society include a contribution to the field of education in informing teachers about student attitudes toward mathematics and computers in a post Covid-19 world.

What risks might you experience from being in this study?

The expected risks from participating in this study are minimal, which means they are equal to the risks you would encounter in everyday life.

How will personal information be protected?

The records of this study will be kept private. Research records will be stored securely, and only the researcher, the district math coordinator, and the associate superintendent will have access to the records.

- Participant responses will be anonymous. Responses collected in the survey will not include any identifying information.
- Data will be stored on a password-locked computer and may be used in future presentations. After three years, all electronic records will be deleted.

Is the researcher in a position of authority over participants, or does the researcher have a financial conflict of interest?

The researcher serves as a teacher at [redacted]. To limit potential or perceived conflicts the study will be anonymous, so the researcher will not know who participated. This disclosure is made so that you can decide if this relationship will affect your willingness to participate in this study. No action will be taken against an individual based on her or his decision to participate in this study.

Is study participation voluntary?

Participation in this study is voluntary. Your decision whether to participate will not affect your current or future relations with Liberty University or [redacted]. If you decide to participate, you are free to not answer any question or withdraw at any time prior to submitting the survey without affecting those relationships.

What should you do if you decide to withdraw from the study?

If you choose to withdraw from the study, please exit the survey and close your internet browser. Your responses will not be recorded or included in the study.

Whom do you contact if you have questions or concerns about the study?

The researcher conducting this study is Rebecca J. Martin Philyaw. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact her at rmartinphilyaw@liberty.edu or [redacted] You may also contact the researcher's faculty sponsor, Dr. Nathan Putney, at [redacted].

Whom do you contact if you have questions about your rights as a research participant?

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the IRB. Our physical address is Institutional Review Board, 1971 University Blvd., Green Hall Ste. 2845, Lynchburg, VA, 24515; our phone number is 434-592-5530, and our email address is irb@liberty.edu.

Disclaimer: The Institutional Review Board (IRB) is tasked with ensuring that human subjects research will be conducted in an ethical manner as defined and required by federal regulations. The topics covered and viewpoints expressed or alluded to by student and faculty researchers are those of the researchers and do not necessarily reflect the official policies or positions of Liberty University.

Your Consent

Before agreeing to be part of the research, please be sure that you understand what the study is about. You can print a copy of the document for your records. If you have any questions about the study later, you can contact the researcher using the information provided above.

By continuing to the survey questions, you are giving consent to participate in this research.

If you choose NOT to participate, you may exit this survey and close your browser.