Fall 11-17-2021

Secondary Mathematics Teachers' Experiences with Technology Integration in a One-to-One School District During Face-to-Face and Remote Instruction: A Phenomenography

Safna Kalariparambil
skalarip@students.kennesaw.edu

Secondary Mathematics Teachers' Experiences with Technology Integration in a One-to-One School District During Face-to-Face and Remote Instruction: A Phenomenography

A Dissertation

Submitted in partial fulfillment for the requirements for the degree of

Doctor of Education

Kennesaw State University

Doctoral Committee:

Chair: Dr. Laurie Dias

Committee Member: Dr. David Glassmeyer

Committee Member: Dr. Anissa Vega

Safna Kalariparambil
November 2021

Acknowledgements

To my participants, thank you for your support and generosity in sharing your experiences with me for this study. Despite the pandemic related challenges, you agreed to participate in this study, and that means a lot to me.

To my dissertation chair Dr. Laurie Dias, thank you for your support throughout the program. You went above and beyond to help me reach my goal. Without your guidance, I would not have made it.

To my dissertation committee members Dr. David Glassmeyer and Dr. Anissa Vega, thank you for providing me with helpful resources and valuable feedback.

To my colleagues, thank you for your encouragement and understanding.

And finally, to my family and friends, thank you for your compassion, support, and belief in me.

Dedication

To the two most important people in my life, Fathma & Sarah.

Abstract

The purpose of this phenomenographic study was to acquire a better understanding of the lived experiences of 12 secondary mathematics teachers who integrated one-to-one technology into their classrooms as part of a district-wide one-to-one technology initiative. Transcripts from semi-structured interviews were analyzed to elicit and describe different ways in which secondary mathematics teachers experienced the phenomenon. Data analysis showed teachers experienced technology integration in classrooms based on their attitude towards using technology. Those who expressed positive attitudes used technology to support modeling mathematics, differentiate learning, problem-solving, expedite grading, and provide instant feedback to students. Those who did not have positive attitudes refrained from using technology unless they had to. The results will be useful for educators, teacher educators, instructional and technology coaches, administrators, and district leaders to understand the phenomenon of one-to-one technology integration through the actual experiences of the secondary mathematics teachers, improve instructional technology practices in the classrooms, identify the need for effective professional development based on the teachers' experiences specific to the content area they work with, and to develop district-wide policies regarding technology integration in the classrooms. Recommendations for future research suggested including larger sample size across different grade levels and content areas and looking more closely into how the external variables affected the teachers' acceptance to one-to-one technology.

Keywords: [One-to-one, Phenomenography, Technology Integration]

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Chapter One: Introduction

School districts in the United States are increasingly adopting educational goals to promote 21st century skills such as collaboration, communication, creativity, digital literacy, and self-directed learning. One approach to meeting these goals has involved aggressive integration of technology, including initiatives like one-to-one computing (Varier et al., 2017). In the context of education, one-to-one initiatives refer to providing every student and educator with their own personal wireless computing device, such as a laptop, Chromebook, or iPad, with up-to-date software and access to the internet (Penuel, 2006). This is different from the Bring Your Own Device (BYOD) initiatives which allows the students to use their own personal devices to access the internet and course materials. Recently, one-to-one computing has emerged as a technology-rich educational reform where access to technology is not shared—but where all teachers and students have ubiquitous access to laptop computers (Bebell & O'Dwyer, 2010). One-to-one initiatives aim to transform the quality of the teaching and learning process by providing one computer for every student and making sure that the students have consistent access to the internet throughout the day.

Background

One-to-one initiatives in K-12 have been around for almost two decades. In 2002, Maine became the first state in the United States to implement a statewide one-to-one initiative by providing a personal portable computer to each seventh and eighth grade student and teacher, along with the software, wireless networks, technical support, and professional development needed to effectively use technology for teaching and learning. The Maine Learning and Technology Initiative (MLTI) became the template for many of these initiatives across the United States. Led by the federal government, the country was in the midst of a massive effort to make affordable high-speed internet and teaching resources available to even the most rural and remote schools (Herold, 2016). Recognizing the potential value of technology in education, the U.S. federal government launched a series of initiatives in recent years urging school leaders and educators to adopt a 21st century model for education that encompasses technology. To support these initiatives, the U.S. federal government has made significant progress in connecting students to next-generation broadband and high-speed internet access, with the percentage of school districts with high-speed broadband access increasing from 30% in 2013 to 99% in 2019 (Education Superhighway, 2019). Herold (2016) noted that the public schools in the United States spend more than $3 billion per year on digital content.

Despite all the potential benefits such as personalizing the learning for students and empowering the students to do more creative work using digital tools, many districts have run into trouble when attempting to implement one-to-one computing initiatives (Herold, 2016). The most significant problem for schools trying to go one-to-one has been “lack of educational vision” (Herold, 2016, p.4). The COVID-19 pandemic has made the digital technology play a more tremendous role in public education and has accelerated the process of schools moving towards one-to-one technology.

Problem Statement and Rationale

School districts continue to invest in one-to-one initiatives with the goal of improving student achievement, but many teachers lack the technological proficiency needed to take advantage of these new technologies (Mundy, Kupczynski, & Kee, 2012), and many teachers lack the training needed to use technology effectively in the classroom (DeNisco, 2014). Typically, one-to-one initiatives focus on providing the teachers and students with access to technology, but “say nothing about actual educational practices” (Bebell & O’Dwyer, 2010, p.6).

A number of prior studies show that even when technology is present in classrooms, teachers have been slow to transform their practice (Cuban, Kirkpatrick, & Peck, 2001; Herold, 2016) and often failed to make the most powerful uses of the new tools at their students' fingertips (Herold & Kazi, 2016). While access to technology tools and resources have increased, teachers' positive beliefs about technology use, training for technology integration, and technical support have declined over time (Francom, 2020).

According to Thornburg (1999), "Learning does not take place better or faster simply by replacing one instructional medium with another" (p.1). In fact, teachers play an essential role in the effective implementation of one-to-one initiatives (Bebell & O'Dwyer, 2010). Despite the growing number of one-to-one initiatives across the nation, there is a lack of research that focuses on teachers' experiences specific to their content area and their acceptance of one-to-one technology in their classrooms (Hughes, Yujung Ko, & Boklage, 2017; McCulloch et al., 2018). Rich descriptions of these experiences may add insight to the teachers' specific needs and challenges associated with using one-to-one technology in mathematics instruction. Hearing from teachers in their own words about their lived experiences with one-to-one technology in the classroom may inform the district technology leaders about making decisions regarding providing the teachers with the knowledge and support they need.

Purpose of the Study

Riverside County Public School District (RCPS, a pseudonym) launched its one-to-one technology initiative "*Learning Redefined*" (a pseudonym) in 2014. Each student in grades 3 through 12 received a personal laptop, and students in grades K through 2nd classrooms were provided with classroom sets of iPads. Prior to the distribution of student devices, all teachers at RCPS received professional development on using technology in the classrooms. During these trainings, teachers were introduced to Technological Pedagogical and Content Knowledge (TPACK), a framework that allows the educators to see pedagogy, content, and technology as overlapping and intersecting domains, and not as separate entities (Koehlr & Mishra, 2009). Teachers were also introduced to the Substitution, Augmentation, Modification, and Redefinition (SAMR), a four-level, taxonomy-based approach for selecting, using, and evaluating technology in K-12 settings (Puentedura, 2015). Afterwards, this training became part of the district's new teacher orientation. In addition to this mandatory initial training, the district also offered a one-day optional technology conference every summer where innovative teachers from across the district shared their successful technology implementation strategies with other educators in the district who were interested in learning more.

Due to the unprecedented challenges posed by the COVID-19 public health crisis, RCPS decided to implement a 100% virtual instruction for the first semester of 2020-2021 school year. Teachers used the district's learning management system "*itsLearning*" in combination with *Microsoft Teams* to deliver virtual instruction on a daily basis. For students who did not have internet facilities at home, RCPS deployed WiFiRanger mobile hotspots on parked RCPS school buses in key locations throughout the district for the students to use with their school-issued devices. The student devices within the 300-feet range automatically connected to the signal from these buses. The district technology office provided both online and in-person technical support in each school building for students and teachers who experienced issues with their school devices. In addition, the district's technology department published how-to videos and documents specifically designed to provide technology support for staff, students, and parents during this challenging time.

Even though the global pandemic exposed a significant gap in teacher preparation and training for emergency remote teaching (Trust & Whalen, 2020), RCPS had been preparing its teachers for an emergency remote situation for the past few years. Since the one-to-one implementation in 2014, the district had included independent learning days (ILD) in the academic calendar where students stayed at home, and teachers reported to the building for a workday and provided remote learning experiences for the students. These experiences should have helped the teachers and students at RCPS prepare for the transition to emergency remote teaching. However, online distance education and emergency remote teaching are not the same things (Bozkurt & Sharma, 2020). Emergency remote teaching involves the use of fully remote teaching solutions for instruction or education that would otherwise be delivered face-to-face or as blended or hybrid courses and that will return to that format once the crisis or emergency has abated (Hodges et al., 2020).

The purpose of this study was to acquire a better understanding of the lived experiences of secondary mathematics teachers who integrated one-to-one technology into their classrooms as part of a district-wide one-to-one technology initiative during face-to-face instruction as well as during the remote teaching. The study examined how teachers experienced, conceptualized, realized, and understood various aspects of the phenomenon (one-to-one technology) in the world around them (their classrooms and during remote teaching).

Research Questions

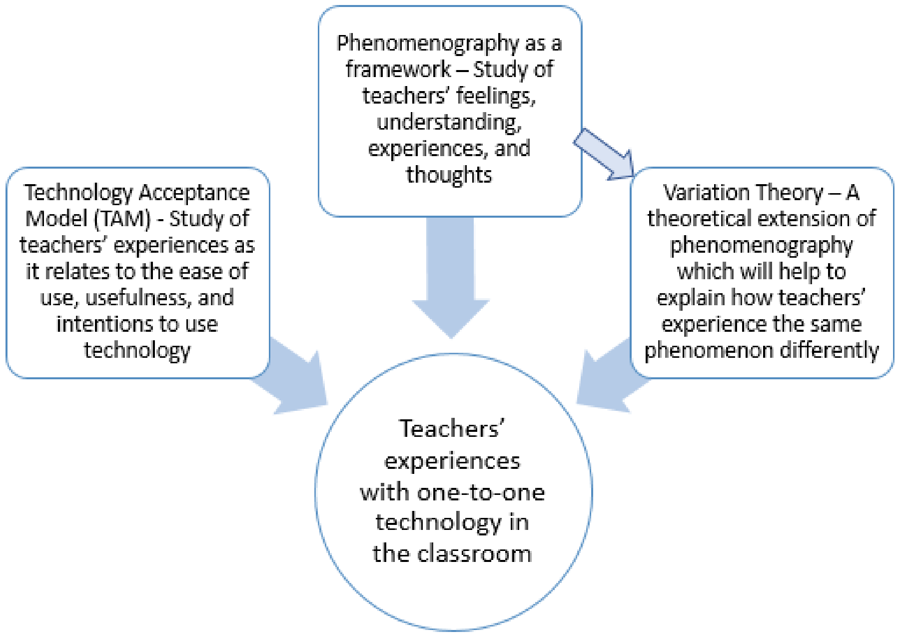
- How do secondary mathematics teachers describe their experiences of using one-to-one technology in their classrooms?
    - How do they describe the experiences during face-to-face instruction?
    - How do they describe the experiences during remote instruction?
- What kind of variation exists between the teachers' experiences?

Theoretical Framework Overview

This study is designed to investigate the different ways in which secondary mathematics teachers experience or understand the one-to-one initiative at RCPS. This study is situated in the existing principle of constructivism that all knowledge is personal, which means each individual participant has a distinctive point of view based on existing knowledge and values. The use of qualitative methods in phenomenography helped to carry out a detailed study of RCPS teachers' feelings, understanding, experiences, and thoughts related to one-to-one technology in their classrooms. Use of Technology Acceptance Model (Davis, 1989) helped the researcher understand the teachers' experiences with the one-to-one technology in the classroom as it relates to the ease of use, usefulness, and intentions to use technology. Variation theory was used to explain the variations in how teachers experienced the same phenomenon differently. Figure 1 shows pieces of each framework that were used to focus the study.

Figure 1

Theoretical Framework Overview



Phenomenography as a Framework

Phenomenography, developed by Marton (1986), is a qualitative research theoretical framework (Ornek, 2008). 'Phenomenography' originates from the Greek words 'phainemenon,' which means appearance, and 'graphein,' which means description. Phenomenographic approach uses a second-order perspective which is helpful to explore participants' conceptions from their viewpoint. Through this perspective, the researcher is oriented towards describing people's ways of seeing, understanding and experiencing the world around them. Marton & Booth (1997) called this a second-order perspective because phenomenography is aimed at people's conceptions of a certain phenomenon, and the phenomenon is investigated through the experiences of the participants rather than the experience of the researcher (Marton & Pong, 2005).

Phenomenography as a research approach is not very well known compared to phenomenology which is familiar to most qualitative researchers. In phenomenography, the words ‘phenomena’ and ‘graph’ describe the variation of people’s experience towards the phenomenon. Phenomenology aims to understand meaning of a phenomenon through the exploration of the lived experience towards the phenomenon. Phenomenology focuses on studying the phenomenon by exploring the participants’ lived experience of the phenomenon. This is called a first-order perspective. Phenomenography studies the participants’ understanding of the phenomenon by exploring the conception of the experiences. Phenomenography does not focus on the phenomenon but on the variation of experiences in the participants’ understanding of the phenomenon. This is called a second-order perspective (Jobin & Turale, 2019). Phenomenography leads to a better understanding of the perceptions and experiences of a phenomenon while phenomenology leads to a better understanding of the phenomenon itself.

According to Marton and Booth (1997), “phenomenography is not a method in itself, although there are methodical elements associated with it, nor is it a theory of experience, although there are theoretical elements to be derived from it” (p.111). Phenomenography is rather a way of identifying, formulating, and tackling certain sort of research questions. Phenomenographic research focuses on unpacking the variation in holistic understandings of a concept and how different patterns of awareness and nonawareness of component parts leads to variation in holistic understandings (Akerlind, 2018). Michael Prosser, one of the pioneer phenomemographers, perceived this research approach as an appropriate research method to study teachers’ and students’ conceptions of teaching and learning, their approaches to teaching and learning, and along with the outcome of teaching and learning activities (as cited in Khan, 2014).

The theoretical framework developed by Marton and Booth (1997) provided the basis for in-depth analysis of teachers’ experiences with one-to-one technology initiative at RCPS. The focal point of phenomenography can be represented by the word ‘conception’ (Marton & Pong, 2005), which refers to participants’ perceived understanding of a given phenomenon. Marton & Pong (2005) define ‘conception’ as the basic unit of description in phenomenographic research, and various names have been used to represent the word ‘conception’ such as ‘ways of conceptualizing,’ ‘ways of experiencing,’ ‘ways of seeing,’ ‘ways of apprehending,’ ‘ways of understanding,’ and so on. Traditional phenomenographic research aims to investigate the qualitatively different ways in which people understand a particular phenomenon or an aspect of the world around them. These ‘different ways of understanding,’ or conceptions, are typically represented in the form of categories of description, which are further analyzed with regard to their logical relations in forming an outcome space (Marton & Pong, 2005).

Marton and Booth (1997) describe a framework for analyzing the experience of learning about a phenomenon. This framework undertakes two aspects of conception, the referential aspect and the structural aspect. The referential aspect is known as the ‘what’ aspect (what is being experienced, what it means) and the structural aspect is known as the ‘how’ aspect (how is the phenomenon experienced). The referential aspect relates the content while the structural aspect considers ways in learning the phenomenon.

Variation Theory

The variation theory, sometimes referred to as “new phenomenography” (Tan, 2009), stems from the concept of phenomenography. As a theory of learning, variation theory “focuses upon guiding learners to an awareness of the different aspects of the learning object” (Miller, 2012). According to variation theory, someone truly learns something when he or she experiences the content in a new way. Variation theory and phenomenography recognize the influence of the existing knowledge, previous experiences, and perceptions of teachers upon learning (Miller, 2012). Variation theory reflects a shift within the phenomenographic research tradition that occurred in the 1990s. Phenomenography was criticized during that time because even though it could be used to identify and describe the range of experiences a particular group of people had with a given phenomenon, it could not explain why that variation in experience existed. Variation theory can be considered as a theoretical extension of phenomenography because it attempts to explain how people, teachers in this case, can experience the same phenomenon differently and how that knowledge can be used to improve district-wide technology initiatives such as RCPS's *Learning Redefined*. By exploring the variation in teachers' conceptions regarding one-to-one technology, technology leaders at RCPS can design professional learning to address the learning needs.

Theories that Focus on Teachers' Technology Use

Even though variation theory provided a framework for examining mathematics teachers' perceptions of technology, other theories were investigated in order to help the researcher inform the type of data that would be collected and analyzed. There are several theories that aim to understand the processes underlying an individual's decision to adopt or accept an innovation, such as a one-to-one initiative. These theories include but not limited to Rogers' innovation diffusion theory, Concerns-Based Adoption Model (CBAM), Theory of Reasoned Action (TRA), and Technology Acceptance Model (TAM). It is necessary to distinguish the terms adoption and acceptance. Technology adoption is a process in which a person first becomes aware of the technology, then embraces it and finally makes full use of it (Wong, 2015). In contrast, technology acceptance is an attitude towards technology influenced by various factors (Wong, 2015). TAM was the most appropriate framework for this study because it helped the researcher to analyze the teachers' experiences based on perceived ease of use, perceived usefulness, and intention to use technology.

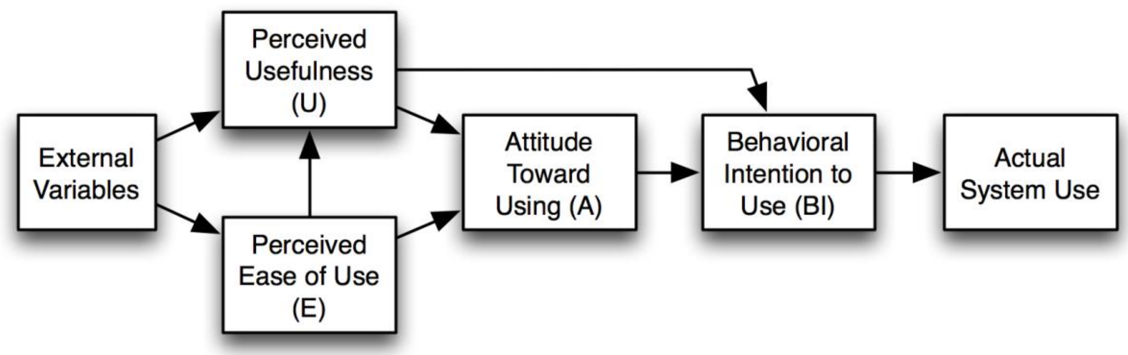
Technology Acceptance Model (TAM)

TAM posits that users' acceptance of a new technology is determined by two key dimensions, namely 'ease of use' and 'perceived usefulness' (Venkatesh, Morris, Davis, & Davis, 2003). Building on the Theory of Reasoned Action (Ajzen & Fishbein, 1977) and the Theory of Planned Behavior (Ajzen, 1991), TAM postulates that the behavioral intention (BI) to use a technology depends on the potential user's attitude towards the technology, which in turns depends on the perceived usefulness and perceived ease of use (Wong, 2015). TAM was first published by Fred Davis in 1989, and since then multiple studies (Fan, 2014; Hidayanto & Setyady, 2014; Yuan et al., 2017) have validated the relationship between the perceived usefulness and ease of use of a particular innovation and one's behavioral intention towards its use. Additional factors related to perceived ease of use and perceived usefulness have been identified by Venkatesh and Davis (2000).

Figure 2 shows the diagram of TAM. Attitude (A) refers to an individual's personal affection towards the technology (that is, whether it is a good idea, interesting, and fun). Perceived usefulness (U) is the perception of how useful the technology may be in terms of the increase in productivity and accomplishment that it will bring. Perceived ease of use (E) refers to whether or not the technology is clear and understandable from the individual's perspective when learning or using the technology (Wong, 2015). External variables such as computer self-efficacy, subjective norms, and facilitating conditions have also been cited as indirect factors affecting behavioral intention. Computer self-efficacy, which is different from the perceived ease of use, is the person's perception of how well he/she can handle the difficulties in using technology (Wong, 2015). Subjective norm is measured by how strongly a person thinks that others want him/her to use technology. Facilitating conditions refer to the perception of availability of resources, knowledge, and technical support that could facilitate the use of technology (Wong, 2015).

Figure 2

Technology Acceptance Model (Davis, Bagozzi, & Warshaw, 1989)



Nature of the Study

Phenomenography aims to discover the different ways in which people experience, conceptualize, realize, and understand various aspects of phenomenon in the world around them (Marton, 1986). The phenomenon being investigated is the teachers' technology integration in the classroom as part of a school district's one-to-one initiative. Data was collected from 12 secondary mathematics teachers at RCPS who had at least one year of experience with the school district's *Learning Redefined* initiative. To collect the data, I used open-ended interviews, which is the preferred method of data collection for phenomenographic studies (Larsson & Homström, 2007). Data was analyzed using Atlas.ti by forming codes and grouping them into categories of descriptions.

Definitions/Terms

1. Actual Use – The genuine utilization of a specific technology a person exhibits based on the person's perceived ease of use, perceived usefulness, and intent towards using. Actual use is the actual computer adoption behavior (Davis, Bagozzi, & Warsaw, 1989).
2. Categories of description – Categories of description are a form of expressing conceptions of the phenomena under investigation as they are expressed by respondents in the context of the study, that may, or may not, describe the entire range of possible conceptions of a phenomenon (Barnard et al., 1999).
3. Emergency Remote Teaching – A temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances. It involves the use of fully remote teaching solutions for instruction or education that would otherwise be delivered face-to-face or as blended or hybrid courses and that will return to that format once the crisis or emergency has abated (Hodges et al., 2020).
4. Facilitating Conditions – Facilitating conditions refer to the perception of availability of resources, knowledge, and technical support that could assist or facilitate the use of the technology.
5. Intent to Use – Based on perceived ease of use and perceived usefulness, intent to use is the calculated goal a person has towards technology application. (Davis, Bagozzi, & Warsaw, 1989).
6. *itsLearning* – A learning management system.

7. *Learning Redefined* – A pseudonym used for the one-to-one technology initiative in the school district that is being studied. The school district has launched the initiative aimed at transforming teaching and learning.
8. *Microsoft Teams* – A workspace for real-time collaboration and communication, and meetings.
9. One-to-one – an initiative designed to provide every student and educator with their own personal wireless computing device with up-to-date software and access to the internet (Penuel, 2006).
10. Outcome Space – The outcome space is a diagrammatic representation of the logical relationships between conceptions (Barnard et al., 1999).
11. Perceived ease of use – Perceived ease of use (EOU) refers to the degree to which the prospective user expects the target system to be free of effort (Davis, Bagozzi, & Warshaw, 1989).
12. Perceived usefulness – Perceived usefulness is defined as the prospective user's subjective probability that using a specific application system will increase his or her job performance within an organizational context (Davis, Bagozzi, & Warshaw, 1989).
13. Phenomenography – A qualitative research method intended to gather and analyze the perceptions of participants in relation to an identified phenomenon (Marton, 1981).
14. Technology Acceptance – An attitude towards technology influenced by various factors (Wong, 2015)
15. Technology Adoption – A process in which a person first becomes aware of the technology, then embraces it and finally makes full use of it (Wong, 2015).

16. Technology Acceptance Model (TAM) – A model introduced by Davis (1989) based on the theory of reasoned action (TRA). TAM provides information regarding a person's perception of technology use (Davis, Bagozzi, & Warshaw, 1989).
17. Variation Theory: A theory that explains that individuals see, understand, and experience the world from their own perspectives (Cheng, 2016).

Assumptions

A major assumption of this study was that the integration of technology in education is a valuable, necessary, and inevitable process. State standards now require teachers to include a technological component in their instruction (Georgia Standards of Excellence, 2020). Teachers are often required to have technology skills, but are not given proper training (Herold, 2015, Kafyulilo, Fisser, & Voogt, 2016). The participants in this study were provided with mandatory initial technology trainings, and optional ongoing professional development sessions. The study assumed the quality and effectiveness of these professional development sessions in addition to the quality of administrative and technical support contributed towards the teachers' varied experiences with integrating technology into their classrooms.

Scope and Delimitations

The focus of this study was to explore the experiences of secondary mathematics teachers with the one-to-one technology in their classrooms as well as during the remote teaching. The study only included secondary mathematics teachers, and their responses could only reflect experiences related to using one-to-one technology specifically in a mathematics teaching environment. Students and other educational support staff such as administrators and instructional coaches did not play any role in this study. The study was also delimited to public schools that made one-to-one technology available for their classrooms.

Limitations

Limitations included teachers' willingness to participate in the study, and their willingness to share information. If teachers did not honestly share the information, it would result in limitations within the data. Teachers with unfavorable views of one-to-one technology in the classroom may decline the invitation to participate in the research. Out of the 61 invitations sent out, only 12 teachers volunteered to participate in the study. Another limitation of phenomenography is that it only captures the participants' experience at a specific point of time. If the study is conducted again at later time with the same participants, the responses might be completely different as their responses are shaped by their own experiences with the given phenomenon. The study focused on the experiences of teachers related to one-to-one technology integration and did not measure academic achievement which limits the understanding of how variation in the teachers' experiences of one-to-one technology integration relate to academic achievement. The study was conducted within one school district and focused on high school math teachers' experiences with using technology in their classrooms. The population may not be representative of other school districts because the teachers in this study had access to one-to-one technology and a variety of resources, and hence the results may not be transferable to other school districts.

Significance

Even though the teacher perceptions are often overlooked as a resource for school improvement, their perceptions and views can offer a valuable perspective on education. This study contributed to the field of education by exploring the experiences and perceptions of twelve secondary school mathematics teachers. The teachers who participated in this study had various experiences and perceptions regarding the one-to-one technology integration in their classrooms. Teachers' experiences confirmed that the digital tools strengthen the activity of doing mathematics (Hegedus et al., 2017), enables the students visualize the concepts better (Wachira & Keengwe, 2011), provide instant feedback, and differentiate the learning based on the needs (Maeng, 2017). Participants expressed willingness to learn and grow and preferred personalized professional development models. School districts considering one-to-one initiatives can use these understandings to address possible challenges involved in one-to-one initiatives. The findings showed both successful factors and challenges that the mathematics teachers experienced with one-to-one technology in the classrooms. The findings may be a significant benefit to mathematics teacher educators, who in turn can better prepare pre-service teachers and equip them with the tools needed to successfully teach mathematics with technology. Teachers can use the findings of this study to understand the significance of taking advantage of the one-to-one technology to transition from traditional teacher-centered classrooms to student-centered structures. Also, being aware of the challenges will help the teachers develop the skills and strategies needed to overcome different types of barriers (Ertmer, 1999). The findings also have a significant impact on students as the district leaders and technology leaders gain a better understanding of the phenomenon and develop plans for appropriate professional development to support the teachers.

Summary

Chapter One provided the foundation for a phenomenographic study that explored secondary mathematics teachers' experiences with a district-initiated one-to-one initiative in the context of their classrooms. Using Technology Acceptance Model and Phenomenography as a framework, this study examined the different ways in which participants experienced and understood various aspects of the phenomenon. Chapter Two will provide a detailed overview of the literature search strategy, literature related to key concepts, and the theoretical foundations.

Chapter Two: Literature Review

One-to-one computing was initially referred to as ubiquitous computing– a term coined by Mark Weiser – describes technology that is always present (Chang, 2016). Bebell and O'Dwyer (2010) state that one-to-one computing "refers to the level at which access to technology is available to students and teachers," and "having a robust access ration of one computer to one student would seemingly provide an optimal setting for the study of how educational technology can impact teaching and learning"(p.7). According to Lawrence et al. (2018), one-to-one computing or technology refers to "the movement towards a classroom environment where each student in the classroom or school has a laptop, tablet or device to use individually in the classroom as a tool" (p.206). A one-to-one initiative does not simply mean handing out a personal computing device to each student. In fact, handing out a personal device to each student is just the first of the many steps involved in a one-to-one initiative.

One-to-one computing initiatives were first introduced to K-12 schools in the United States in the late 1990s. The general goal of one-to-one computing initiatives in K-12 is to enable the teachers to deliver more personalized content to meet each student's need, and to empower the students to boost their technology skills to produce authentic and creative work. As technology continues to be implemented in school systems across the United States, policy makers and administrators often fail to realize that physical availability of technology is not enough to bring about the change they advocate for (Cuban, 2001). It depends on how teachers and students use technology and how they envision technology as a part of their teaching and learning process that can make a difference. The proponents of educational technology and one-to-one programs believe that there is a potential to radically change the teaching and learning practices (and even classroom structure) via the adoption and use of one-to-one computing similar to how technology has transformed other areas of our culture such as communication and entertainment (Bebell & Kay, 2010). The purpose of this study was to acquire a better understanding of the lived experiences of secondary mathematics teachers who integrated one-to-one technology in their classrooms as part of a district-wide one-to-one technology initiative.

In addition to discussing the literature search strategy and the theoretical framework, this chapter also covers a review of the literature that addresses four major areas of the research that inform this study: the role of technology in schools, the role of teachers in a one-to-one classroom, technology in mathematics education, and barriers in technology integration. The first section, the role of technology in schools, provides literature related to how schools are incorporating technology in the classrooms. The second section, the role of teachers in a one-to-one classroom, focuses on the changing role of teachers as they integrate technology into their classrooms. The third section looks at literature related to the use of technology in mathematics education, and the fourth section describes the barriers in technology integration. The gaps in the literature and how the study will fill these gaps are discussed in the summary section.

Literature Search Strategy

The literature search for current and peer-reviewed articles was conducted mainly via the Kennesaw State University online library. The databases used were ERIC, JSTOR, Education Source, and IEEE Xplore Digital Library. Several journals including *Journal of Computers in Mathematics and Science Teaching* (JCMST), *The Journal of Technology, Learning, and Assessment* (JTLA), and *Journal of Mathematics Teacher Education* (JMTE) were referenced to look at the current trends in technology use in the mathematics classrooms. Google Scholar was utilized to locate open access articles that were not available in the university's online library. The following keywords were used to locate articles specific to this study: one-to-one technology in classrooms, one-to-one initiatives in k-12, teacher experiences with one-to-one technology, one-to-one technology in mathematics classrooms, role of technology in mathematics education, and barriers to technology integration. Variations of these terms were used to ensure thorough search results. The results were narrowed down based on relevance to the topic of study.

Theoretical Foundation

This study will use components of Technology Acceptance Model (TAM) and Variation Theory. The Technology Acceptance Model is a theory that attempts to predict the likelihood of an individual or organization successfully adopting a new system of technology (Dziak, 2017). Variation theory, an extension of phenomenography, explains that individuals see, understand, and experience the world from their own perspectives (Cheng, 2016). Variation theory recognizes the qualitative variations of people's experience and interpretation of a phenomenon.

Fred Davis, in his 1985 doctoral thesis, proposed the Technology Acceptance Model in an attempt to create an equation by which analysis could predict whether a particular technological system would be accepted. TAM is based on the Theory of Reasoned Action (Ajzen & Fishbein, 1977) and the Theory of Planned Behavior (Ajzen, 1991). According to Theory of Reasoned Action (TRA), beliefs influence attitudes, which in turn lead to intentions, which then guide or generate behaviors (Ajzen & Fishbein, 1977). TAM adapts this relationship between the attitudes, intentions, and behaviors to explain user acceptance of technology. Theory of Planned Behavior (TPB) extends from TRA and incorporates the notion of perceived behavioral control as an independent influence on behavior, independent of perceived outcomes (Ajzen, 1991).

Davis developed TAM with two major objectives in mind. First, the theoretical model should improve the understanding of user acceptance processes providing new theoretical insights into the successful design and implementation of information systems. Second, the model should provide a methodology that would enable system designers and implementors evaluate proposed new system prior to their implementation. TAM was selected for this study with the hope that the data analysis would improve our understanding of user acceptance processes related to one-to-one technology initiative at RCPS and provide insights to successful implementation of technology use in the classrooms and aid in the development of professional learning sessions for teachers.

The interest in the implementation of one-to-one initiatives in schools across the country means that the user acceptance of technology is also becoming a key factor in these initiatives. Technology Acceptance Model offers a powerful explanation for user acceptance of technology implementation in schools. According to Davis (1989), “aside from their theoretical value, better measures for predicting and explaining system use would have great practical value, both for vendors who would like to assess user demand for new design ideas, and for information systems managers within user organizations who would like to evaluate these vendor offerings” (p.319). A couple of previous studies that adopted and expanded the Technology Acceptance Model have proven the validity of this model (Adams et al., 1992; Mathieson, 1991). TAM application in education broadly consists of studies aimed at measuring either the intention to use or the actual use or acceptance of technologies in schools (Dele-Ajayi, et al., 2019). Nair & Das (2012) found TAM to be a useful model to understand the attitude of teachers to use technology in teaching. Dele-Ajayi et al. (2019) used TAM to explore the factors that affect teachers’ intentions to use digital educational games in the classroom. A meta-analysis conducted on studies that use TAM shows that the results have been generally consistent (Legris, Ingham, & Collerette, n.d).

The four constructs of TAM are perceived ease of use, perceived usefulness, intent to use, and actual use. Perceived usefulness and perceived ease of use are two important determinants among the many variables that may influence technology use (DeNisco, 2014). The use of technology is highly likely if the users believe that the system improves their job performance (perceived usefulness) and also if they believe that the system is effortless to use (perceived ease of use) (Davis 1989). The validity and reliability of perceived ease of use determines the user acceptance (Moses et al., 2013). In education, the degree to which technology is integrated into teaching and learning depends on teacher acceptance of technology. In a research study about attitudes towards laptop use among science and mathematics teachers, Moses et al. (2013) found that perceived ease of use was a significant predictor of perceived usefulness of technology.

Differences and contradictions in understanding education initiatives such as *Learning Redefined*, the initiative contained within this study, may cause confusion between the intended use and the actual implementation. Approaches to understand these initiatives should highlight those differences, and variation theory offers a way to examine the variation within experiences. Variation theory is a theory of learning and experience that explains how a learner might come to see, understand, or experience a given phenomenon in a certain way and why two students sitting in the same class might come to understand a concept differently (Bussey et al., 2013). Tan (2009) argues that variation theory is useful for describing educational policy from the perspective of how it is experienced, and that these different ways of experiencing a policy may in turn be understood and utilized in theoretical, analytical, and pedagogical ways. The presence of variation creates a potentially noticeable contrast within or between one or more features of the phenomenon (Bussey et al., 2013).

The following section addresses four major areas of the research that inform this study: the role of technology in schools, role of teachers in a one-to-one classsroom, technology in mathematics education, and barriers in technology integration.

Role of Technology in Schools

The first provider of one-to-one computer access for teachers and students was Apple Classrooms of Tomorrow (ACOT). ACOT’s research has demonstrated that the introduction of technology to classrooms can significantly increase the potential for learning, especially when it is used to support collaboration, information access, and the expression and representation of students’ thoughts and ideas (Dwyer et al., 1994). With the goal of promoting change in the context of education, ACOT has encouraged instructional innovation, emphasis on the potential of computers, access to multiple resources, cooperative learning, and instructional guidance rather than stand-up teaching. Teachers reported increases in classroom organizations and teaching methods that support student initiative and independence, decreases in traditional stand-up teaching and reliance upon published teachers' guides, and changes in their uses of technology toward less frequent use of published instructional software and more frequent use of applications as well as computer-supported activities of their own design (Baker et al., 1993). Dwyer (1990) labeled the stages of teacher evolution in ACOT classrooms as Entry, Adoption, Adaptation, Appropriation, and Invention. These stages represent the developmental phases the teachers went through as they replaced their traditional beliefs and practices with new ones (Dwyer et al., 1994). Ringstaff et al. (1996) examined the role shifts that occurred for both teachers and students in ACOT classrooms and found that the technology served as a symbol of change as teachers re-examined their beliefs about teaching and learning and their traditional role shifted from knowledge dispensers to facilitators of learning.

Another similar initiative was Microsoft's Anytime Anywhere Learning (AAL) program. Reports from Rockman (1998) showed that students participated in the AAL program were more creative, more collaborative, and better writers. The report also showed that teachers who participated in the program improved their teaching methods and demonstrated greater confidence in using technology in their lessons. Programs such as ACOT and AAL from the 1980s and 1990s provided awareness on how the appropriate integration of technology could positively impact the teaching and learning process in schools.

Technology integration means incorporating technology and technology-based practices into all aspects of teaching and learning specifically, incorporating appropriate technology in objectives, lessons, and assessment of learning outcomes (Wachira & Keengwe, 2011). When carefully designed and thoughtfully applied, technology has the potential to accelerate, amplify, and expand the impact of powerful principles of learning (Office of Educational Technology, 2016). The integration of technology into pedagogical practices may be categorized in three ways (Collins, 1990; Hughes et al., 2006) namely Replacement, Amplification, or Transformation (RAT). Replacement refers to the use of technology as a substitution for a traditional practice, such as displaying a PowerPoint slide instead of writing on the board. Amplification refers to using the technology to enhance an existing task without any functional improvements, such as creating a spreadsheet to calculate statistical values. Transformation refers to using technology to create innovative tasks that was previously inconceivable, such as having the students create a collaborative mind map or a digital portfolio. In order for the technology integration to be effective, transformation need to take place. Hughes et al. (2017) used the RAT framework to analyze the developing technology-supported practices in the classrooms and found that the teachers in elective STEM courses experienced more personal control of integration efforts than teachers of core subjects.

Technology use in classrooms contributes to better reading, mathematics, and other academic skills (O'Neal et al., 2017) as well as assists the at-risk students to develop their literacy skills, such as language, mathematics, and thinking skills, in an engaging and supportive environment (Hasselbring & Goin, 2004). ISTE (2012) has identified skills commonly referred to as 21st century skills and has developed a set of standards to guide teachers and students in the use of instructional technology in the classrooms. While the previous versions of ISTE standards focused on teaching and learning with technology, their latest version adds a focus on collaboration, advocacy, digital literacy, media literacy, computational thinking, privacy and student data, student empowerment, data-based decision making, feedback, and teaching colleagues (Trust, 2018). Dondlinger et al. (2016) explored the links between student experiences with technology-rich mathematics instruction and the ISTE standards for students and found that the student work involved with technology led to some level of attainment of each of the ISTE standards. Most of the research conducted on one-to-one technology in schools focus on student engagement, teacher implementation, or student achievement (Bebell & Kay, 2010; Bebell & O'Dwyer, 2010; Dowens & Bishop, 2015; Swallow, 2015).

In an effort to determine the impact of one-to-one initiatives in K-12 education, Zheng and her colleagues (2016) reviewed 96 journal articles and doctoral dissertations published between 2001 and 2015. They found out that "a disproportionate amount of the research to date on this topic consists of small case studies in one or a handful of schools" (p.1076). Bebell and O'Dwyer (2010) synthesized four empirical studies of one-to-one initiatives in K-12 and concluded that more studies should focus on how technology can be used to support educational processes. Common problems associated with one-to-one technology in K-12 classrooms includes digital knowledge gaps related to practical knowledge of using computers, online security practices, rights and responsibilities, and policies and laws (Moon, 2018).

Although there is an increased interest in implementing one-to-one computing initiatives in schools, there is little empirical evidence that shows its outcomes (Bebell & O'Dwyer, 2010). Despite the limited research base, schools are increasingly moving towards providing students with their own laptop computer (Herold, 2016). A majority of the research in this area focuses on the impact of such programs on student achievement (Kirkpatrick et al., 2018; Lee et al., 2017; Robinson, 2016), teacher beliefs (Tondeur et al., 2017), and the barriers to teacher adoption (Ertmer, 1999; Hsu, 2016; Khodabandelou et al., 2016). A thorough understanding of how the teachers conceive or come to understand the process of designing learning for the one-to-one environment is essential to the success of one-to-one initiatives. The current global pandemic has forced the teachers to transform their classrooms to a virtual learning environment. Investigating the teachers' experiences with the remote teaching will be beneficial for planning and preparing for future emergency situations (Hodges et al., 2020).

The use of technology allows teachers to truly differentiate and tailor instruction to meet the needs of their students. When teachers know how to design and implement proactively planned, flexible, engaging instructional activities in response to students' learning needs, technology can play an integral role in planning and implementing differentiated lessons (Maeng, 2017). Strategies such as flipping the classroom can be an effective instructional strategy for differentiating instruction for gifted and talented students (Siegle, 2014). Research indicates technology may facilitate teachers' use of formative assessment to inform the design of instruction that meets the students' needs (Maeng, 2017). Since differentiated instruction emphasizes students' interests and since today's students usually prefer working in an environment with technology rather than working in one without it, differentiating instruction with digital resources is an ideal approach (Morgan, 2017).

Bebell & Kay (2010) examined the educational impacts of the Berkshire Wireless Learning Initiative, a three-year pilot program that provided one-to-one technology access to all students and teachers in five middle schools in western Massachusetts. The study aimed to document how successfully the initiative achieved the target outcomes. The target outcomes included enhanced student achievement, improved student engagement, fundamental changes in teaching strategies, curriculum delivery, and classroom management; and enhance capabilities among students to conduct independent research and collaborate with peers. The results of the study reflected the fundamental changes in teaching practices as well as enhanced student engagement and student achievement.

The role of technology in education became very important recently when the COVID-19 pandemic challenged the schools and districts with maintaining the continuity of teaching and learning while facing the threat of extended school closures. According to COSN (2020), a successful effort to move school outside of traditional classroom requires a close cross-collaboration between instructional, content, and technology teams. According to UNESCO, nearly 16 billion students in up to 194 countries were impacted by school closures resulted from the global pandemic. COVID-19 pandemic has given us massive insights on how the role of technology can radically shift to reach the students and how to adapt learning processes in challenging times. The use of technology in the classrooms, whether it be face-to-face or virtual, does not automatically translate into better instructional outcomes. The role of technology has evolved since the 1980s one-to-one initiatives, and the current technology initiatives focus more on digital literacy and student empowerment rather than just using technology in the classrooms.

Role of Teachers in a One-to-One Classroom

“The role of the teacher is to create the conditions for invention rather than provide ready-made knowledge.” -Seymour Papert

A teacher’s primary role in any classroom is to deliver instruction and to help the students learn. A teacher’s role in traditional mathematics classrooms has been to “provide clear, step-by-step demonstrations of each procedure, restate steps in response to student questions, provide adequate opportunities for students to practice the procedures, and offer specific corrective support when necessary,” and the ultimate mathematical authority is the textbook from where “the answers to all mathematical problems are known and found” (Smith, 1996, 390-391). The introduction of computers encourages the teacher to play the role of a coach or a facilitator (Collins, 1990; Varier et al, 2017) rather than providing ready-made knowledge in the form of direct instruction. In today’s technology driven world, teachers are no longer the sole keepers of information in the classroom. Much of the learning is meant to take place between the student and the computer, so the teacher becomes a guide who ensures that those interactions are beneficial to the student’s learning (Collins, 1990). Teachers must adapt to the new role of a facilitator and provide resources, monitor progress, and encourage students to get involved in their own learning. It is critically important to appreciate the pivotal role that classroom teachers play in the success of one-to-one computing initiatives.

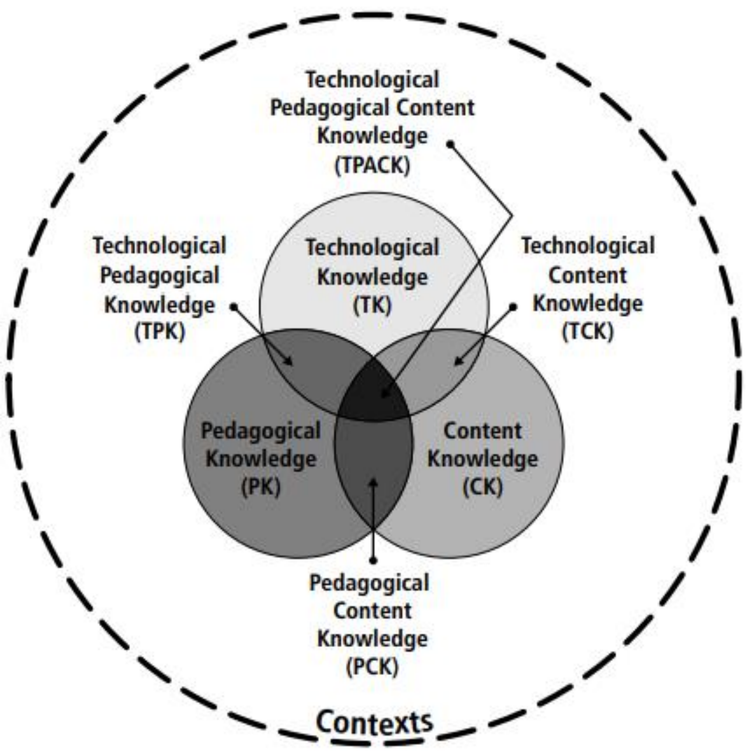
Ertmer and colleagues (2012) used a case study design with 12 award-winning teachers and found that teachers used technology to reinforce skills, transform their teaching, and enhance their curriculum. Teachers must be willing to spend time and make efforts to adapt their teaching materials and practices to make the one-to-one environment effective and relevant (Bebell & Kay, 2010). The challenge of changing practices greatly affects the teachers. Of all the stakeholders involved in education, no other experiences the daily details of technology integration like teachers" (Lawrence et al., 2018, p.206). In any one-to-one initiative, the experiences are not going to be the same for all teachers, and there could be a small number of teachers who are reluctant to change their traditional teaching practices.

Teaching is a complicated process that requires an interweaving of many kinds of specialized knowledge (Koehler et al., 2013). Technology holds part of the answer to improving teaching, but it must be combined with sharp and thoughtful changes in how teachers design curriculum and how students learn (Martinez & McGrath, 2014). Teachers not only have to understand clearly why computers should be used in their classes but how computers can be integrated into the existing school curriculum to facilitate active learning (Lai, 1993). The growth of technology will necessitate that teachers change their role and pedagogy for learning to become relevant and meaningful for students to acquire the necessary knowledge and skills to be productive citizens in the 21st century.

Teacher's knowledge for teaching with technologies require a strong pedagogical knowledge merged with the knowledge of teaching the subject matter using a vast array of technological innovations (Niess & Roschelle, 2018). Teaching with technology requires teachers to expand their knowledge of pedagogical practices across multiple aspects of the planning, implementation, and evaluation processes (Ertmer & Ottenbreit-Leftwich, 2010). In their Technological Pedagogical and Content Knowledge (TPACK) framework, Koehler et al. (2013) argue that for technology integration to occur, teachers must be competent in technological, pedagogical, and content knowledge, and more importantly, they must be able to integrate all three forms of knowledge into their instructional practices. TPACK was developed as a conceptual framework for inclusion of technological knowledge into Shulman's (1986) framework of Pedagogical Content Knowledge (PCK). Figure 3 shows the main components of TPACK and the interactions between and among these components.

Figure 3

The TPACK Framework (Koehler, Mishra, & Cain, 2013)



Content Knowledge (CK) represents the teachers' knowledge about the subject matter to be learned or taught while Pedagogical Knowledge (PK) represents the teachers' deep knowledge about the processes and practices or methods of teaching and learning. Considering the goal of engaging students in mathematical problem solving, a mathematics teacher's TPACK must focus on thinking strategically in planning, organizing, implementing, critiquing results and abstracting plans for specific mathematics content and diverse student needs (Niess, 2008). The professional development must guide the development of their knowledge and thinking in a manner that considers the knowledge they need for planning and organizing student learning in mathematics (Niess, 2008).

A teacher's role in a one-to-one classroom is considered to be important for implementing effective pedagogical activities, and hence examining the teacher-perceived advantages and challenges (Kim et al., 2019) are important in designing effective professional development opportunities for teachers. The teacher perceptions regarding technology integration can be improved through professional development (Kopcha, 2012). Educational preparation programs where technology use is ubiquitous better prepare the teacher candidates for technology-rich classrooms (Donovan et al., 2011). Traditional models of professional development, such as workshops and courses, may not be successful in preparing the teachers to integrate technology into their teaching. Research conducted over the past two decades indicates that to be effective, professional development must be personalized, ongoing, and must provide feedback on teachers' individual classroom practices (Schachter & Gerde, 2019).

Technology offers the teachers with the ability to transform the quality of instruction. Many of the initiatives focused on transforming teaching seek specifically to make instruction more student-centered, more differentiated, problem or project-based, and demanding of higher-order thinking skills (Penuel, 2006). Providing opportunities for teachers to both experiment and to succeed is important. Schools can support this by creating a culture that allows teachers to try out new practices, while making technical and pedagogical support readily available (Ertmer & Ottenbreit-Leftwich, 2010). The successfulness of the one-to-one technology integration is not limited to the device in use, but it is how well the teacher is able to incorporate the technology into the classroom and provide outlets for student exploration (Lawrence et al., 2018).

The COVID-19 outbreak exposed a significant variation in teachers' readiness to use technology to support learners at a distance. While teachers who used technology frequently in their practice reported an easier transition to emergency remote teaching for themselves and their students, most teachers seemed to be learning remote teaching strategies and tools while teaching remotely (Trust & Whalen, 2020). Khlaif et al (2021) noted several factors that could negatively influence student engagement in an emergency remote teaching environment such as cultural factors, infrastructure factors, digital privacy, and digital inequality. For future research, Trust & Whalen (2020) suggested looking at how teachers used technology for emergency remote teaching, for example, did they try to replicate their in-person teaching strategies with digital tools, or did they design authentic, technology-rich learning activities with new digital tools and apps.

Technology in Mathematics Education

Technology integration in the context of teaching and learning mathematics includes several components such as computers with appropriate mathematical software that allows interactivity, online discussion boards, applets that allow the students to interact with mathematical problems, graphing calculators, handheld devices that allow for real time data collection, analysis, and representation, and applications such as spreadsheets that allow for algebra and data analysis (Wachira & Keengwe, 2011). One-to-one technology also allow mathematics teachers to provide personalized instruction to the students by providing additional resources such as video tutorials and digital practice assignments that are not only personalized for the students based on previous work, but also automatically checked for accuracy including instant feedback provided when students submit answers. For mathematics education, technology integration should go beyond general education technology usage to also include mathematics-specific technologies such as GeoGebra, Geometer's Sketchpad (interactive math applications), Desmos (an online graphing calculator with a collection of technology-enchanced activities), graphing calculators, and other mathematics-specific technologies (Stohlman & Acquah, 2020).

Mathematics teaching and learning is a complex process for which it involves the teacher, students and the content (mathematics). The three vertices in the didactic triangle come with its unique characteristics and yield complex interactions (Ratnasari et al., 2018). In order to add another vertex to this triangle, which is technology, mathematics teachers will need to play a central role in orchestrating the classroom practices so that the mathematics can be learned effectively through the support of technology. Digital tools are not only a pedagogical medium for organizing processes in education, in particular, they strengthen the activity of doing mathematics, such as experimenting, visualizing, and applying (Hegedus etal., 2017). Technology tools can help students to extend the range and quality of their mathematical investigations and to encounter mathematical ideas in more realistic settings (Wachira & Keengwe, 2011). Technology tools provide powerful capabilities for computation, construction, and visual representations offering students access to mathematical content and contexts that would otherwise be too complex for them to explore (Wachira & Keengwe, 2011).

The use of digital technologies seems to have been particularly challenging in the case of mathematics, especially when it comes to actively engaging students using technology as a learning tool (Niess & Roschelle, 2018). Digital technology is less common in mathematics classrooms than we might expect, given the growing development of digital tools for mathematical learning (Utterberg, et al., 2019, Wachira & Keengwe, 2011). Deciding when a particular form of technology may be appropriate for a specific mathematics topic can be difficult (Hodges & Conner, 2011). Teachers need to decide what, how, when, and where technology will be used, and if it will enhance or hinder student understandings (Raines & Clark, 2011). Many mathematics teachers (and their students) primarily use technology as a simple calculational tool, or for data storage, or for the display of static materials, methods which are unlikely to develop student understanding, stimulate their interests, or increase their proficiency in mathematics (McCulloch et al., 2018). Scholars have attributed the under-use of technology in mathematics teaching to a lack of emphasis on computer skills training in teacher preparation and professional development programs (Bennison & Goos, 2010; Wachira & Keengwe, 2011). Joubert (2013) found that teachers' attitudes, their understanding of the uptake and use of technologies, and changes in mathematics education in light of new technologies have had a huge effect on the use of computer in the mathematics education community.

National Council of Teachers of Mathematics (NCTM), in its position statement, claims that "Strategic use of technology in the teaching and learning of mathematics is the use of digital and physical tools by students and teachers in thoughtfully designed ways and at carefully determined times so that the capabilities of the technology enhance how students and educators learn, experience, communicate, and do mathematics" (National Council of Teachers of Mathematics, 2015). With strategic integration of both content-specific and content-neutral technology, students and teachers can construct their learning together in authentic ways that elevate mathematics learning (Picha, 2018). Technology must be integrated in a way that is pedagogically appropriate for mathematics instruction. When planning to integrate technology into a lesson, teachers need to consider the technology knowledge the students will need, the mathematics content knowledge they will need, and the best practices for teaching both the technology and the math (Picha, 2018). Using technology in the math classrooms can increase student engagement, increase motivation to learning, allow for better teacher-student interaction, support student collaboration, assist in the accuracy of mathematical computation, and help students not only feel more comfortable with learning mathematics but also allow for a deeper understanding of the mathematical concepts (Murphy, 2016). Frameworks such as TPACK (Koehler & Mishra, 2009) allows the mathematics educators to see pedagogy, content, and technology as overlapping and intersecting domains, and not as separate entities. Research shows that content-specific apps and online content that focus on mathematics with the use of virtual manipulatives are highly effective (Polly, 2016). The positive effect of using technology throughout the curriculum can assist student learning mathematics to higher-order thinking that can help students even beyond the classroom. Therefore, the use of technology within the curriculum from elementary to high school is necessary for the betterment of learning mathematics (Murphy, 2016).

TPACK has been widely used in Mathematics education research (Agyei & Voogt, 2015; Bowers & Stephens, 2011; Muir et, al., 2016). According to Bowers & Stephens (2011), “the goal of modern mathematics instruction should not be to use classroom-based technologies solely for drill and practice. Instead, our vision of TPACK is to help teachers develop a technological habit of mind oriented toward using advanced computation and communication tools to help students understand the underlying concepts and their relation to the larger world outside of school” (p.286). Alongside the need to develop their knowledge and skills, teachers’ attitudes towards technology integration also need to be understood to appropriately determine competencies which mathematics teachers need to integrate technology into their lessons (Agyei & Voogt, 2015). Muir et, al. (2016) demonstrated that the TPACK framework can be useful in considering the mathematics knowledge required for teaching and helpful for describing teaching practices that incorporate technology. The study also showed that the use of interactive whiteboards and virtual manipulatives can have a beneficial influence on students' learning. There is limited evidence in the literature of research that looks at how this framework can be used to interpret the teaching of a mathematical topic.

After examining how elementary school teachers integrated technology into their mathematics teaching in classroom settings that were one-to-one environments, Urbina & Polly (2017) found that despite being in a one-to-one environment, students only used technology on rare occasions or if they finished activities early. Letwinsky (2017) examined the relationship between variables that may support or inhibit a secondary mathematics teacher's decision to integrate technology and found that the teachers' level of self-efficacy did not contribute to technology integration. The data indicated high teacher self-efficacy is directly correlated with more positive attitude towards technology, yet actual implementation of technology was low. The results of this study indicated the need to continuously explore how teachers are using technology in meaningful ways to teach mathematics, and this information is important for school leaders because positive attitude toward technology supported with targeted professional development opportunities may help increase the level of technology integration in mathematics. Hill & Uribe-Florez (2020) found that most mathematics teachers have a positive attitude toward technology integration and a willingness to learn and grow.

Majority of the technology professional development provided for teachers are not content-specific. Learning subject matter with technology is different from learning to teach that subject matter with technology (Niess, 2005). Strategically integrating technology into instruction requires a unique knowledge base, and teachers need mathematics-specific professional development opportunities to develop this knowledge (Fuentes & Ma, 2018). Hill & Uribe-Florez (2020) indicated that schools and districts should focus on providing professional development for teachers to learn strategies for effectively using the technology to enhance student learning. As mathematics teachers consider integrating technologies into their instruction, they must not only determine how the technologies support learning the mathematics, but they must also consider which pedagogical strategies effectively engage students in learning the mathematics. Teachers must identify, orchestrate, and manage different pedagogical strategies and learning tasks for integrating the technologies in new and perhaps different mathematical topics (Niess & Roschelle, 2018). Professional development that is content-specific may provide a clear vision for appropriate technology use thus helping address teachers' questions and misconceptions on whether and how technology-based activities address educational objectives (Wachira & Keengwe, 2011).

Urbina and Polly (2017) pointed out that the technology-based activities used by the teachers are low-level review of math computations and emphasized the need to provide effective support to teachers about integrating technology in meaningful ways. When designing mathematics lessons, meaningful technology integration may include focusing on student skills such as decision making, refection, reasoning, and problem solving (Raines & Clark, 2011). Changes in classroom practice are often associated with participation in professional development as teachers try a new teaching approach such as the integration of technology into their classroom practice. Teachers perceive technology professional development as ineffective, particularly when it does not address individual needs (Karlin et al., 2018). Instead of the traditional workshops that introduce them to a new technology, teachers want to know "how to teach specific mathematics topics using technology, with an emphasis on their personal management of the technology in the classroom and its impact on student learning" (Bennison & Goos, 2010, p.36). Integration of dynamic technologies into mathematics education is bringing transformative changes to mathematics teaching, but it is perceived as a lcomplex process for individual teachers (Prodromou & Lavicza, 2017). All of these literature point toward the need to study the teachers' experiences with one-to-one technology further and the need to provide content-based technology professional development.

Barriers in Technology Integration

In order to understand teachers' experiences using one-to-one technology in the classroom, it is important to consider the barriers that teachers have when integrating technology. Teachers are now expected to better equip students with 21st-century skills, making it important to understand teachers' beliefs about the role of technology in teaching and learning (O'Neal et al., 2017). Teachers' use of technology in the classroom seems to be influenced by several factors. Beliefs about students' learning abilities and learning styles, concerns regarding meeting curriculum requirements, limited opportunities for professional development, and low levels of knowledge and skills for computer integration have all been found to impact classroom technology integration (O'Neal et al., 2017). Mathematics teachers who participated in a study conducted by Hill & Uribe-Florez (2020) mentioned access, resources, and time as the main barriers to using technology in the classroom. In many cases, teacher opinions and attitudes have helped to form, implement, and maintain school policy regarding technology implementation programs (Lawrence et al., 2018).

Many research studies have looked at the barriers to technology integration (Ertmer, 1999, Hsu, 2016, & Khodabandelou et al., 2016). According to Ertmer (1996), being aware of the various types of barriers will help teachers develop the skills and strategies needed to overcome each of the different types of barriers. Ertmer (1999) proposed the first order and second-order barriers that can hinder technology integration in classroom. The first order barriers are external such as lack of adequate access to resources such as devices, internet connection, time, training, and instructional support. Schools have experienced increased access to technology tools and resources over time which reduced the significance of first order barrier to technology integration (Ertmer & Ottenbreit-Leftwich, 2010). Though access to technology tools and resources is necessary for technology integration, experience has shown that access may not be sufficient for effective teaching and learning with technology, and teachers may still maintain traditional teaching practices that are not consistent with technology (Francom, 2020). Teachers need to be provided with opportunities to become knowledgeable regarding the various technologies that are available and to dispel any misconceptions or doubts regarding the use of technology (Raines & Clark, 2011).

The second-order barrier also known as internal barriers includes teachers' beliefs related to pedagogy and technology, and willingness to change. Technology use is often impacted by teachers' beliefs and attitudes regarding the role of technology in teaching and learning (O'Neal et al., 2017). Teacher beliefs associated with technology integration practices includes value beliefs and ability beliefs (Vongkulluksn et al., 2018). Value beliefs about technology include a conviction that important instructional goals can be met with the help of technology, while ability beliefs have to do with the self-efficacy of the teacher for using educational technology tools and resources (Ertmer et al., 2012; Vongkulluksn et al., 2018). Vongkulluksn et al. (2018) compared value and ability beliefs among teachers and found that a teacher who believes technology can assist in meeting important instructional goals (value belief) is more likely to integrate technology effectively than a teacher who has confidence in using technologies for teaching and learning (ability belief). The results also indicated that teachers' value beliefs predicted how well teachers integrated technology in their classrooms, including how much they used technology to foster student-centered instruction and higher-order tasks.

Tsai & Chai (2012) argue that lack of design thinking by teachers may be the third-order barrier for technology integration in classrooms. Design thinking is a teacher's ability to "create learning materials and activities, adapting to the instructional needs for different contexts or varying groups of learners" (Tsai & Chai, 2012). Tsai & Chai (2012) believe that through reducing this third-order barrier, teachers can undertake technology integration actively and fluently. Chambers (2019) defines third-order barriers as school culture and institutional structure and how a teacher negotiates physical resources and pedagogical beliefs within the school environment. According to Chambers (2019), third-order barriers are "those that are related to the organization and its structure such as the bell schedule, class length, insufficient planning time, lack of peer collaboration, no technology plan, and no technology component in the teacher evaluation system" (p. 41).

Classroom technology is integrated into content and pedagogical practices at the teacher's discretion; not all teachers will integrate technology into their practice, and those who do use technology adopt the technology in varying degrees of integration (Minshew & Anderson, 2015). Teachers' attitudes and beliefs regarding technology are crucial factors in determining the effectiveness of technology in classroom. Teacher beliefs have been shown to be heavily influenced by the subject and school culture in which they participate (Ertmer & Ottenbreit-Leftwich, 2010). Most of the times, the internal barriers related to technology integration are personal, and vary greatly from teacher to teacher even within the same environment. Most teachers believe that technology is valuable in educational settings because it contributes to meaningful learning; however, they have not necessarily outweighed the obstacles (Machado & Laverick, 2015).

The ability of teachers to overcome what they perceive as barriers may be dependent upon the value they place on using technology to build necessary skills as well as how they are already using technology in the classroom (O'Neal et al., 2017). Barriers to training, resources, and support must be addressed for technology integration to be impactful to teaching and learning. Research has shown that teachers need both in-service training and ongoing curriculum support in order to be able to incorporate technology into their curriculum in meaningful ways (Barbour et al., 2017). Professional development sessions and professional learning communities will increase the effective use of technology in the classroom. Therefore, it is imperative that the educators collaborate to improve experiences and engage in ongoing professional development. Improvements in these areas should contribute to more positive beliefs regarding the role of technology in teaching and learning, resulting in more teachers integrating technology across the curriculum and helping the students develop the skills necessary for the 21st century (O'Neal et al., 2017).

Summary

This chapter included a review of the literature related to one-to-one technology integration in classrooms, role of technology and teachers, and the barriers in technology integration. While the literature reviewed provided insight on the efficacy of various one-to-one initiatives, they provided very little guidance for educators on designing learning environments for learning that leverage technology to support content specific knowledge and skills. The role of technology in 21st century teaching and learning as well as the role of teachers have yet to be solidified in our K-12 classrooms. Since teachers play a very important role in integrating technology into classrooms, a detailed study that examines the teachers' experiences with integrating technology is crucial. This study will provide and in-depth analysis of the teacher experiences with integrating one-to-one technology in secondary mathematics classrooms.

Chapter 3: Methodology

As stated in chapter 1, the purpose of this study was to acquire a better understanding of the lived experiences of secondary mathematics teachers who integrated one-to-one technology into their classrooms as part of a district-wide one-to-one technology initiative. This chapter begins with a description of the research design of the study with supporting rationale for its use. The role of the researcher is discussed to explain the researcher’s role as well as any personal or professional relationships between the researcher and the participants. The methods used for participant selection, data collection, and data analysis are also included. Additional information such as the issues of trustworthiness and ethical procedures will conclude the chapter.

Research Design and Rationale

Since the purpose of the study was to acquire a deeper understanding of how high school mathematics teachers experienced technology integration in their one-to-one classrooms as well as during the remote teaching, a qualitative research approach was deemed to be the most appropriate methodology to provide a detailed picture of the teachers’ experiences. Phenomenography, a qualitative methodology that focuses on collecting different and varied accounts of experiencing a phenomenon (Marton, 1986), fulfilled the purpose of this research. This phenomenographic study explored the experiences of secondary mathematics teachers on how they were using and experiencing one-to-one technology in their classrooms as well as during remote teaching. According to Herold & Kazi (2016), teachers had been slow to transform their practice and often needed support to make use of the new tools and resources provided by the one-to-one technology initiatives. In order to understand the actual experiences of teachers in a one-to-one learning environment and the variations between their experiences, the following research questions were used:

- How do teachers describe their experiences of using one-to-one technology in secondary mathematics classrooms?
    - How do they describe the experiences during face-to-face instruction?
    - How do they describe the experiences during remote instruction?
- What kind of variation exists between the teachers' experiences?

A qualitative research design allows the researcher to directly interact with the participants in the study and acquire a detailed understanding of the issue or phenomenon. According to Creswell & Poth (2016), a qualitative research design is helpful when there is "a need to study a group or population, identify variables that can be measured, or hear silenced voices" (p.40). Phenomenography is an innovative qualitative research design that aims at identifying and interrogating the range of different ways in which people perceive or experience specific phenomena (Tight, 2016). Phenomenography aims at description, analysis, and understanding of experiences (Marton, 1981).

> Phenomenographers adopt a particular (albeit with some variations) methodological strategy for data collection and analysis. This typically involves the use of interviews as a method for collecting data on the phenomenon of current interest; though other forms of data, such as written responses, may also be used. All of the data collected is then treated collectively for the purposes of analysis, such that the focus is on the variations in understanding across the whole sample, rather than on the characteristics of individuals' responses (Tight, 2016).

Phenomenography is an educational research tradition that is exploratory and descriptive, and it maps the different ways the participants experience, conceptualize, perceive, and understand various aspects of a phenomenon around them. Phenomenography was developed from an empirical educational framework by Ference Marton and coworkers in the 1970s. In phenomenography, the aim is to study the variation of peoples' conceptions of a given phenomenon in the surrounding world (Larsson & Holmström, 2007). Whereas the conceptions are understood to be a way of experiencing or understanding the phenomenon in terms of individual awareness, categories of description are used by researchers to denote them, and are understood as the qualitatively different ways a phenomenon may appear at the collective level (Marton & Booth, 1997). The study was not directed at the phenomenon as such, but at the variation in people's ways of understanding the phenomenon. This is referred to as a second-order perspective (Marton, 1981). Through this perspective the researcher is oriented towards describing people's ways of seeing, understanding, and experiencing the world around them. Hence in the second-order perspective, phenomena are investigated through the experience of the participants rather than the experience of the researcher (Pang, 2003). This perspective was ideal for investigating the variation in which secondary mathematics teachers understood the one-to-one technology initiative in the mathematics. The researcher had to defer her own assumptions and examine the phenomenon from the participants' perspective. The researcher experienced the phenomenon by asking questions to learn more intensely about the phenomenon through the participant (Bowden, 2000).

The results of a phenomenographic study most often include a detailed elaboration of the categories of description, a detailed analysis of the relationships within and between categories, and an outcome space (Åkerlind et al., 2005). Categories of description are a form of expressing conceptions of the phenomena under investigation as they are expressed by participants in the context of the study, that may, or may not, describe the entire range of possible conceptions of a phenomenon (Barnard et al., 1999). Categories of description provide "possible ways of viewing various aspects of the world, the aggregate of basic conceptions underlying not only different, but even alternate and contradictory forms of propositional knowledge, irrespective of whether these forms are deemed right or wrong" (Marton, 1981, p.197). Categories of description are formed from analyzing the data abstracted from interview transcripts or any other forms of communication with the participants (Barnard et al., 1999).

The outcome space is a diagrammatic or structural representation of the logical relationships between identified categories. Marton (1981) refers to this system as a collective intellect (p.198) which is a structured pool of ideas, beliefs, facts, and so forth that underlie interpretation and the construction of reality. The outcome space has two essential elements: descriptions of each category and selections of illustrative statements (Bowden, 2000) and can be represented in various formats, such as in tables, diagrams, or figures (Yates et al., 2012). The outcome space provides a map of the qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of the world around them (Marton, 1986). The outcome space also provides a way of looking at collective human experience of phenomena holistically, despite the fact that the same phenomena may be perceived differently by different people and under different circumstances (Akerlind, 2005). Outcome space represents the full range of possible ways of experiencing the phenomenon in question, at this particular point in time, for the population represented by the sample group collectively (Akerlind, 2005).

Role of the Researcher

In my current position as a distance learning educator at the district's virtual campus, as well as the previous positions as a digital learning specialist at the district level, and a high school mathematics teacher, there have been many opportunities to integrate one-to-one technology in the classrooms and to support the teachers as they are integrating one-to-one technology in their classrooms. As a high school mathematics teacher, I had the opportunity to integrate one-to-one technology in the classroom as well as to train the students in using technology to enhance their learning process. As a digital learning specialist, I worked alongside with the mathematics and science teachers and provided support in their attempts to integrate technology into their classrooms. During this time, I also had the opportunity to train the teachers on using instructional technology tools and applications as well as on a variety of best practices in instructional technology.

I have been working with the school district for over eight years and witnessed how the *Learning Redefined* one-to-one initiative evolved over time. I was always willing to embrace new technologies and was excited about assisting the students and colleagues with the integration of one-to-one technology as the initiative rolled out. When the one-to-one technology initiative first rolled out in the district, I did not see the same level of excitement among teachers in my professional learning community. For most of my colleagues, it was a “distraction” in the classroom, and they believed that students did not learn using technology, especially in a mathematics classroom. I routinely encountered a wide range of variations in teacher perceptions and experiences related to using technology in the classroom. The various perspectives of teachers about the one-to-one technology in the classrooms, both positive and negative, motivated me to study the teachers’ experiences further. These encounters and experiences led me to recognize the increasing need to study teacher technology acceptance, technology integration in the classrooms, and effective instructional technology professional development. I understood that there are obstacles to achieving both acceptance and usage of technology in the classrooms. By using phenomenography, I was able to come to a deeper and broader understanding of teachers’ experiences in a one-to-one classroom. This study was conducted in a school district where I have been employed as an educator for the past eight years. I had worked together with many of the participants on a daily basis in the same building, or occasionally during district collaborative planning days.

Research Context

Riverside County Public Schools (RCPS) was a public-school district outside of a metropolitan area in the southeast. RCPS had 11 elementary schools, four middle schools, three high schools, and four non-traditional schools including a Career Academy and STEM Magnet School, one virtual campus, and 14 Specialty and Choice programs. RCPS served approximately 17,000 students – approximately 65% African American, 15% Hispanic, 15% White, 3% Multi-racial, and 2% Asian. Approximately 73% of the students were eligible for free and reduced lunch. The mission of RCPS was to ensure student success for all through a world-class education with advanced opportunities and personalized support. The school district's one-to-one initiative *Learning Redefined* strived to transform teaching and learning throughout the district by using technology as a tool. *Learning Redefined* launched in 2013-2014 school year where each student in grades 3 through 12 received a personal laptop and grades K through 2 classrooms received classroom sets of iPads. Since then, all teachers had received numerous professional development opportunities in technology integration practices. This phenomenographic study focused on the lived experiences of 12 secondary mathematics teachers at RCPS during the one-to-one technology implementation.

According to the district's three-year technology plan, there had been growth in both the utilization and quality of instructional technology in RCPS schools over the past several years. Teachers were provided with the opportunity to attend or teach technology workshops during the district's yearly technology conference. In addition, teachers had access to the service of digital learning specialists where they could schedule individual or group coaching sessions to learn more about technology integration in classrooms. The technology plan identified keeping up with the emerging technology as one of the major barriers for staff.

The school district had been one-to-one since 2015 and implemented independent virtual learning days at least 4 times a year since 2016. The district used virtual learning days for inclement weather as well as for professional learning days. For these virtual learning days, the teachers prepared asynchronous lessons and activities for students and delivered them via *itsLearning*, the district's learning management system. During the professional learning days, the students were expected to review and complete the work from home while the teachers attended professional learning sessions provided by the district. Given their experience with virtual learning, I expected that the teachers would have a seamless transition to the remote teaching situation caused by the COVID-19 pandemic. Being one-to-one for many years, this experience should have helped the students and teachers to effortlessly transition to the new learning environment. Teachers were given a given a short training a day before the school closure on how to use *Microsoft Teams* to meet with their classes. Teachers used *Microsoft Teams* to and regularly met with their classes during the scheduled class times. In addition, teachers continued to use *itsLearning*, the district's learning management system, as well as *Schoolnet*, the district's assessment system, to provide course materials and assess the students.

The original intention of the researcher was to explore the teacher experiences with one-to-one technology in the classroom. However, when the schools across the nation were forced to close its doors during the second week of March 2020 due to the COVID-19 pandemic, RCPS staff and students also had to move to an emergency remote teaching and learning environment. Due to the pandemic, I had to rethink the intention of the study and make necessary modifications as the teachers were no longer in their classrooms. I speculated that their experiences may be different in their new environments. For teachers, it was not just a move from classrooms to computer screens; it tested basic ideas about planning instruction and assessments, managing the virtual learning environment, and the role of technology. To address this, I added additional interview questions related to teachers' remote teaching experiences. Also, I decided to conduct online interviews using *Microsoft Teams* following the COVID-19 protocols.

Participant Selection Logic

The participants of this study included 12 secondary mathematics teachers from the three high schools at RCPS as well as the two non-traditional high schools who had at least one year of experience with the district's *Learning Redefined* initiative prior to the pandemic. Additional information about the participants is provided in chapter 4. As a way of narrowing down the study to a specific content area to see the variations of teacher experiences existed within that content area, math was selected based on the researcher's content area expertise in that subject. To capture the detailed experiences of the participants, the researcher asked follow-up questions during the interview based on the guidelines provided in Appendix A. The researcher's experience with teaching mathematics using technology was useful in asking meaningful follow-up questions during the interview.

Permission to perform the study in the district was obtained from the Director of Assessment and Accountability. The researcher compiled a list of all secondary mathematics teachers at RCPS. The researcher then contacted each school's principal for additional permission to interview their teachers. Once the principal permissions were obtained, a group email was sent to each school's math department seeking their interest in participating in the study. 12 teachers, at least one teacher from each high school, volunteered to participate in the study. Purposive sampling was used to identify participants who met the criteria. This sampling strategy was appropriate for a phenomenographic study as representative sampling might have limited the exploration of the different ways people experienced one-to-one initiative at RCPS. Marton & Booth (1997) suggested taking a small sample purposively from a particular large population. Variation in participants' experience is an important aspect in phenomenographic research approach. Therefore, it is necessary to choose participants from different levels of experience and features such as age, gender, grade level taught, and so on, for maximum variation in the outcome space (Åkerlind, 2005). Once the participants were identified, they were asked to review the informed consent (Appendix B) and to complete a Research Participation Interest & Informed Consent Acceptance form (Appendix C) to participate in the study. The informed consent (Appendix B) included detailed information regarding the specifications of the study, timeline, methodology, and procedures. The participants also used an online sign up tool that allowed them to choose the day and time for their interview.

Data Collection

Phenomenographic interviews are not intended to bring out attitudes or ready answers held by interviewees. Instead, the interview is seen as a means for the interviewee to think about, reflect on, and formulate ways of experiencing a particular phenomenon (Limberg, 2008). Thus, the data collection method heavily relied on in-depth open-ended interviews. According to Larsson & Holmström (2007), researchers can get information about people's conceptions of a given phenomenon through their speech and actions. I developed approximately 20 interview questions that focused on the phenomenon of one-to-one technology and various components of the Technology Acceptance Model such as perceived ease of use, perceived usefulness, attitude towards using, and external variables (see Appendix A).

I conducted interviews in January 2021 and February 2021. Participants were provided with the opportunity to preview the interview questions prior to the scheduled interview and two participants took advantage of this opportunity. During the interviews, every effort was taken to ensure that the interviewer's own experiences of one-to-one technology in the classroom were bracketed so as not to influence the responses of the interviewees. The informants were encouraged to speak freely about their experiences, giving concrete examples to avoid superficial descriptions about how things should be or ought to be (Larsson & Holmström, 2007). The aim of the interview was to have the participant reflect on his/her experiences and then relate those experiences to the interviewer in such a way that the two come to a mutual understanding about the meanings of the experiences (as cited in Ornek, 2008). The questions provided a progression within the interview, moving from discussing the experiences when they first taught in a one-to-one environment to their experiences in their classrooms prior to the pandemic, and then the experiences with the transition to the remote teaching during the pandemic. Each of the questions helped to develop a rich picture of how the interviewees experienced one-to-one technology in their classrooms. Interviews lasted an average of 45 minutes to 75 minutes depending on the amount of experiences participants had to share.

Due to the pandemic, all interviews were conducted online, and recorded using *Microsoft Teams*. For transcript and closed caption purposes, Microsoft Stream automatically generates WebVTT files from what was spoken in the videos. These files include time codes, metadata, and extra lines. To remove the time codes, metadata, and additional lines from the transcripts, a web service called Microsoft Stream transcript VTT file cleaner was used. After cleaning up, the transcript text was copied and pasted into individual Microsoft Word files.

Green (2005) recommends that "unlike naturalists' inquiry where follow-up interviews are often used, phenomenography normally relies on one interview per participant" (p.40). I anticipated that a follow-up interview might be necessary in case there were any clarification questions, however in this case, one interview per participant was sufficient as Green (2005) suggested. As a mathematics educator, I had a genuine interest in what the participants had to say, and I was able to keep the interview style relaxed and friendly for my participants (Stenfors-Hayes et al., 2013). The recordings of the interviews were used for a complete and accurate transcription. I reviewed the data from the interviews to determine themes and patterns and looked for commonalities and differences experienced by the participants during their one-to-one technology integration process.

Data Analysis Plan

The objective of phenomenographic analysis is to identify and describe variation in ways of experiencing the phenomenon (Limberg, 2008). The interviews were recorded using *Microsoft Teams*, and then uploaded to *Microsoft Stream*. *Microsoft Stream* automatically generated captions using Automatic Speech Recognition technology. Once the captions were generated, the transcripts were saved for further analysis. Atlas.ti was used to generate codes. I used phenomenographic analysis—an iterative, multi-stage coding process that involves sorting participant descriptions into explicit categories that represent distinct ways of experiencing the phenomenon of interest, identifying suitability of responses within the current categorization, redefining the categories, describing the relationships between categories, and subjecting the categories and relationships to collaborative internal and external critique (Zoltowski et al., 2017). In a phenomenographic research methodology, there is not a single technique for data analysis (Marton, 1986). The goal is to look for qualitatively different conceptions of the phenomenon of interest collectively rather than the conceptions of individual participants (Sin, 2010). In order to achieve this, the data analysis was guided by the research questions.

Phenomenographic research aims to explore the range of meanings within a sample group, not the range of meanings for each individual within the group. This means that no one interview transcript (interviews represent the most common data source for phenomenograpic analysis), for example, can be understood in isolation from the others. Every transcript, or expression of meaning, is interpreted within the context of the group of transcripts or meanings as a whole, in terms of similarities to and differences from other transcripts or meanings (Akerlind, 2005). While determining the steps for data analysis, González's (2010) five-step method and the seven steps outlined by Sjostrom and Dahlgren (2002) were considered. The following steps guided the data analysis for this research study:

1) Read and re-read the transcripts. Take notes.
2) Compile answers from all respondents to a certain question. Identify most significant elements in the answer given by each participant.
3) Use Atlas.ti to form codes (open coding) to condense data into identifiable categories (axial coding).
4) Focused reading to identify similarities and differences between and within relevant sections of interviews.
5) Generate a list of categories of description.
6) Read again in relation to categories of description.
7) Build the final outcome space.

The analysis began with a search for meaning, or variation in meaning, across interview transcripts, followed by a search for structural relationships between meanings. Open coding allowed the researcher to break up the data and label them with codes. This was obtained by labeling pieces of data such as quotes with a particular code. Phenomenographic analysis requires a series of iterations to refine the categories through repeated reading of the transcripts (Akerlind, 2005). The transcripts or selected quotes were grouped and regrouped according to perceived similarities and differences along varying criteria. Axial coding allowed the researcher to read over the codes created during open coding to find how the codes could be grouped into categories. In phenomenography, categories of description emerge from the analysis of transcripts rather than the researcher fitting the data into a predetermined model (Herbert & Pierce, 2013). Interview transcripts were examined to find ways of grouping the participants' responses into categories of descriptions according to the features held in common. These features are referred to as *dimensions of variation* (Herbert & Pierce, 2013). To answer the research questions, the researcher ensured that the categories of description generated would describe different ways of experiencing the phenomenon.

Phenomenographic findings are reported in an outcome space that describes the categories of qualitatively different conceptions of the phenomenon (Sin, 2010) and the structural relationships among them (Zoltowski et al., 2017). The outcome space allows the researcher to examine participant experiences from a variety of perspectives because the phenomena can be understood differently by various participants in the study (Akerlind, 2005). Marton and Booth (1997) suggest the following criteria to judge the quality of an outcome space:

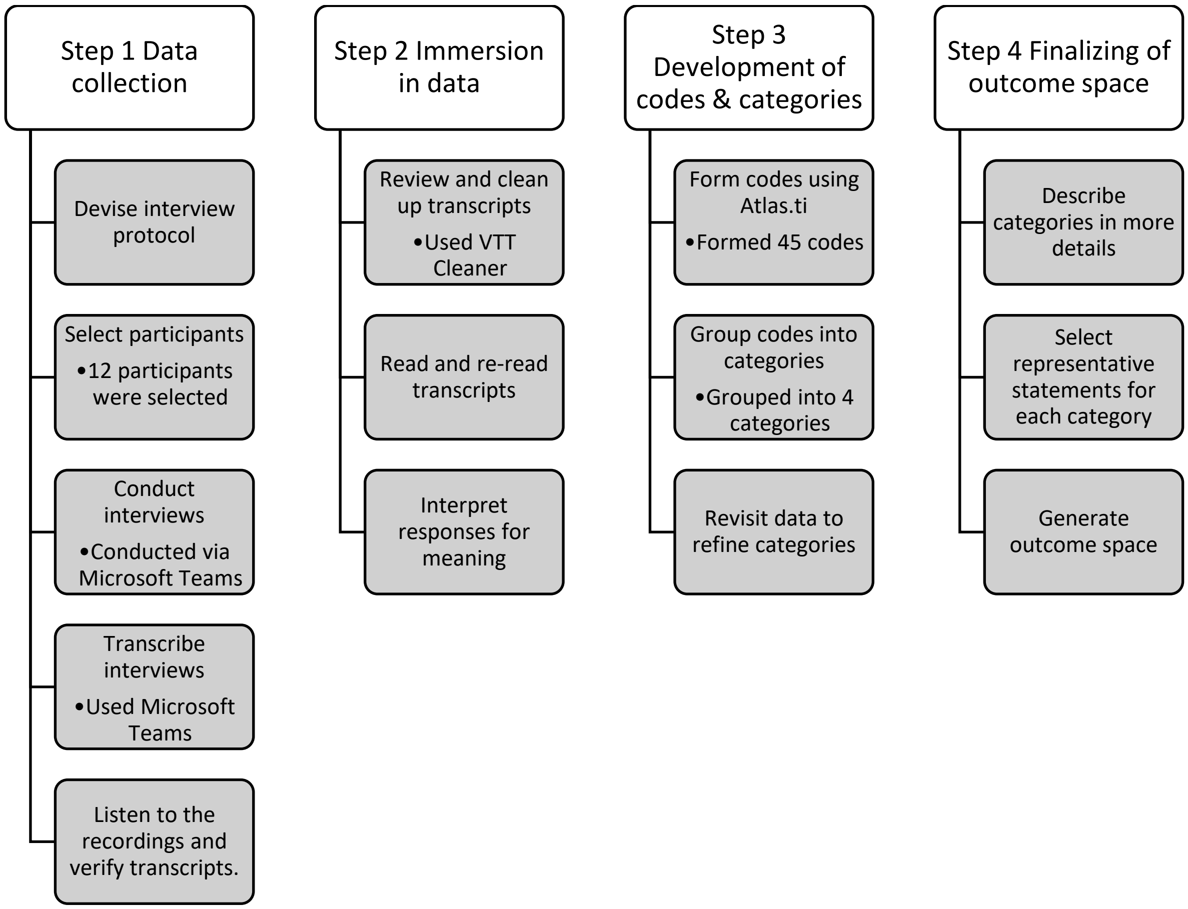
a) Categories of description must stand in clear relation to the phenomenon.
b) Categories must stand in a logical relationship with one another.

c) The categories are optimal and parsimonious, that is, as few categories should be explicated as is feasible and reasonable for capturing the critical variation in the data (Yates et al., 2012).

The outcome space in a phenomenographic study usually includes a set of logically related categories, in this case, categories were related to the teacher experiences of one-to-one technology integration in terms of the components of Technology Acceptance Model (TAM). Each category should stand distinctly to reflect the variation of the experiences rather than singular experience (Bowden, 2000). Selective coding in phenomenography refers to naming and describing the categories in detail. While the outcome space serves as a vehicle for communicating the ways in which people experience a particular phenomenon, it is not feasible to suggest that it captures all possible ways in which this may be experienced or conceived (Marton & Booth, 1997). The phenomenographic data collection and data analysis processes are summarized in Figure 4.

Figure 4

Phenomenographic Data Collection & Data Analysis (Adapted from Herbert & Pierce, 2013)



During step 3 of the data analysis, I developed 24 codes and additional codes were developed as the data analysis progressed for a total of 45 codes (Appendix D). The codes were then grouped into code clusters and then to four categories. While categories one and two considered the teachers’ experiences with one-to-one technology, categories three and investigated teachers’ attitude toward using technology and the external variables that affect the use of technology. The categories were used to describe the range of different ways in which 12 secondary school math teachers understood and described their experiences with the one-to-one integration in their classrooms. An outcome space table was formed based on the work of Han and Ellis (2019) to include descriptions of each category and selections of representative statements (Appendix E).

Issues of Trustworthiness

Credibility: In order to establish proper analysis of the phenomenon and to ensure value of the findings, credibility has to be established. According to Sjostrom and Dahlgren (2002), the researcher has to show that a chosen way of describing differences and similarities is well supported by the empirical material. I have provided excerpts from the interview to support the relevance of the categories. The credibility of this study is based on precise description of each part of the research process, explicit presentation of interview questions and procedures, and a careful description of the analyses and conclusions that will make it possible for the readers to replicate the study. In addition, member checks of the transcripts were completed to ensure that the findings represent the perception of the participants, and the information is as accurate as possible. Participants' experiences with the one-to-one technology is presented in the participants' own words using quotations from the interviews.

Transferability: To allow transferability, researchers provide sufficient detail of the context of the fieldwork for a reader to be able to decide whether the prevailing environment is similar to another situation with which he or she is familiar and whether the findings can justifiably be applied to the other setting (Shenton, 2004). The goal of this study was to acquire a better understanding of the lived experiences of secondary mathematics teachers who integrated one-to-one technology into their classrooms as part of a district-wide one-to-one technology initiative. The interviews were designed to provide rich examples of the participants' perceptions and experiences with the district's one-to-one initiative in their classrooms. Since the perceptions are not predictable prior to the study, it is impossible to know if the knowledge gained through this study is transferable or not.

Dependability: In order to address dependability, the process within the study is reported in detail using in-depth methodological description (Shenton, 2004). This enables other researchers interested in the work to replicate the process implemented in the study. To enable the readers of the research report to develop a thorough understanding of the methods and their effectiveness, the text includes a thick description of the research design and its implementation. The details coming from the interviews regarding the experiences of teachers with the one-to-one initiative can be compared with other educators in similar situation.

Confirmability: To achieve confirmability, researchers must take steps to demonstrate that findings emerge from the data and not their own predispositions (Shenton, 2004). The concept of confirmability is determined by the degree to which the findings are influenced by the participants and not the biases of the researcher (Shenton, 2004). The participants had the opportunity to preview the interview questions a few days prior to the scheduled interview. This ensured that they had enough time to reflect on their past experiences and jot down notes if needed. To ensure the findings of the study are the result of the experiences of the participants, the researcher incorporated triangulation through interviews, interview notes, and member checks. Admission of the researcher's beliefs and assumptions are explained in the Role of the Researcher section.

Ethical Considerations

In order to maintain the confidentiality of the participants and the institution, and to preserve the anonymity of the participants, pseudonyms were used. Participants were given an informed consent form (Appendix C) to provide sufficient information so that they can make an informed decision about whether or not to enroll in the study or to continue participation. The researcher ensured that the participants were not coerced, that they had voluntarily agreed to participate in the research, and they knew they were free to withdraw from the study at any time. All IRB protocols and procedures were followed to ensure the confidentiality of each individual participant who had volunteered to participate in this study.

The following ethical principles are defined to drive this study (Ravitch & Carl, 2021):

1. Be honest.
2. Respect the privacy and anonymity of the participants.
3. Keep the data confidential.
4. Keep the participants informed.
5. Provide the correct information.
6. Be aware of the researcher bias.
7. Develop professional rapport with the participants.
8. Avoid sharing the researcher's experiences with the participants.
9. Provide professional feedback to the participants.
10. Be honest in reporting the results.

Summary

This chapter described the approach chosen to answer the research questions for this study. Data was collected using open-ended interviews via *Microsoft Teams* and analyzed using *Atlas.ti*. 45 codes were grouped into five categories of description which described the different ways in which the participants understood and experienced one-to-one technology. The quality of the study is addressed by describing ethical considerations as well as trustworthiness, credibility, and dependability of the findings.

Chapter 4: Findings

The purpose of this study was to acquire a better understanding of the experiences of secondary mathematics teachers who integrated one-to-one technology into their classrooms as part of a district-wide one-to-one technology initiative, and thus contribute to the field of education by offering educators and school districts a deeper understanding of how teachers experience one-to-one technology in their classrooms.

The questions driving this research study were:

1) How do secondary mathematics teachers describe their experiences of using one-to-one technology in their classrooms?
    - How do they describe the experiences during face-to-face instruction?
    - How do they describe the experiences during remote instruction?
2) What kind of variation exists between the teachers' experiences?

This phenomenographic investigation sought to describe the collective experiences of the participants with one-to-one technology in the classroom. Since the classroom experiences of the teachers have been affected by the COVID-19 pandemic, the first question also examined the teachers' experiences with remote teaching.

This chapter begins with an overview of the participants, and the findings are then presented in four Categories of Description. The Categories of Description include the teachers' experiences with using one-to-one technology in the face-to-face classroom, experiences with remote teaching, attitude toward the use of one-to-one, and external variables (factors that lead teachers to use one-to-one technology).

Participants and School Contexts

The study included 12 participants from the three high schools in the district as well as from two non-traditional high schools. Seven participants were female, and five were male. Their ages ranged from mid 20s to early 50s. The school names were replaced with pseudonyms. The three high schools in the district were Horizon High School, Sunshine High School, and Riverside High School. Edgewater High School and Riverside Open Campus were classified as the non-traditional high schools. Edgewater High School, the district's magnet school, provided options for students who were interested in leadership, science, and technology. Riverside Open Campus served high school students who dropped out or were at-risk of dropping out of school.

The participants' experience with one-to-one technology varied as did their teaching experience. All participants were currently teaching high school math courses at the time of the interview, and seven participants also had background experiences in other disciplines in addition to math as shown in Table 1. Several of these participants were part of the school district's one-to-one initiative when it first rolled out in 2015. To ensure confidentiality, a pseudonym was assigned to each participant. To easily identify the participants, each participant's pseudonym is hyphenated with the school's pseudonym. See Table 1 for participant profiles. A short narrative of each school and each participant is provided after Table 1.

Table 1

Participant Profiles

School Pseudonym	Participant Pseudonym	Degree	Discipline	Teaching experience	Experience with one-to-one	Courses Taught
Edgewater High School (EHS)	Carter-EHS	Doctor	Math, Computer Science	26 years	5 years	AP Calculus Multivariable Calculus, Advanced Finite Math, Math of Industry & Government, History of Math
	Jacob-EHS	Doctor	Math, Economics	18 years	5 years	Pre-Calculus, AP Calculus
	Jane-EHS	Masters	Math, Social Science	8 years	5 years	Analytic Geometry, Advanced Algebra, SAT Prep
Horizon High School (HHS)	Beth-HHS	Masters	Math, Psychology	9 years	3 years	AP Statistics, AP Psychology, Analytic Geometry
	Jessica-HHS	Masters	Math	6 years	5 years	Coordinate Algebra
	Weston-HHS	Bachelor’s	Math	19 years	4 years	Coordinate Algebra, Analytic Geometry
Riverside High School (RHS)	Ann-RHS	Specialist	Math, Science, Public Health	4 years	1 year	Coordinate Algebra
Riverside Open Campus (ROC)	Emma-ROC	Bachelor’s	Math, Film Industry	2 years	2 years	Analytic Geometry, Advanced Algebra
	Mason-ROC	Masters	Math	16 years	5 years	College Readiness Math
Sunshine High School (SHS)	Celia-SHS	Doctor	Math	15 years	5 years	Analytic Geometry, Advanced Algebra
	Charles-SHS	Masters	Math	22 years	5 years	Analytic Geometry
	Tiffany-SHS	Specialist	Math, Curriculum & Instruction	22 years	5 years	Coordinate Algebra

Edgewater High School (EHS): EHS was opened in 2000. The school provided a unique learning environment designed for high achieving students with an interest in mathematics, science, and technology. The school had an enrollment of approximately 308 students in grades 9-12 and employed approximately 25 teachers at the time of this study. Carter-EHS, Jacob-EHS, and Jane-EHS were the participants from EHS.

The most experienced participant was Carter-EHS. He was in his mid-50s and had been teaching since 1994. He remembered the graphing calculator as the only technology tool back then, and he still believed that the graphing calculator was the most useful technology tool in a math classroom at the time of this study. He taught AP Calculus and preferred to restrict the use of technology in his classroom to graphing calculators since the College Board did not allow any other technology on their exams. He found technology to be useful when it came to formatively assessing his students and providing feedback. He did not get too excited when the school district rolled out one-to-one technology in the classroom, but he was willing to try it out.

Jacob-EHS had been teaching since 2002. He was in his late 40s and had taught in various programs including Governor's Honors program which was a summer educational program in the state of Georgia designed for intellectually gifted high school students. He described his first experiences with the one-to-one technology as a "*natural progression*" to what he had been doing already with the limited access to technology. He stated that the availability of one-to-one technology in the classroom opened up possibilities for him.

Jane-EHS was a teacher in her mid-30s. When one-to-one technology first rolled out in her school district, she described her thoughts as not being very positive about it. She thought student laptops were not useful in a math classroom. She said, "*they are just going to be paperweights in my classroom.*" As the years passed by, she learned how to integrate technology in her classroom by trial and error, and through the professional learning provided from the district. She was selected as the technology teacher of the year for her school for being a role model on how to effectively integrate technology in the classroom.

Horizon High School (HHS): HHS was founded in 1976. The school had an enrollment of approximately 1800 students in grades 9-12 and employed approximately 120 teachers at the time of this study. Beth-HHS, Jessica-HHS, and Weston-HHS were the participants from HHS.

Beth-HHS had been teaching for 9 years and was in her early 30s. She was "*nervous, uneasy, and excited at the same time*" when she realized she would be teaching in a one-to-one classroom. She did not have one-to-one technology in her previous school, so she said she felt uneasy about having to convert all the lessons she had already designed to fit in a one-to-one classroom. She recalled that initially she did not have a lot of guidance when it came to utilizing one-to-one technology in the classroom to its maximum potential.

Jessica-HHS was a teacher in her early 30s. She stated that she found herself very "*overwhelmed*" when she found out that she would be teaching in a one-to-one classroom because it was also her first year of teaching. When she got her master's in Education, she did not have the opportunity to learn how to integrate technology in the classroom. She learned to integrate technology through trial and error and through observing her peers.

Weston-HHS was in his late 30s and had been teaching for 19 years. He spent his first several years of teaching in a different state in the early 2000s and he recalled the school being "*very forward-thinking*" in terms of using technology in the classroom. He had access to laptop carts and classroom sets of tablets, so he was able to incorporate some technology into his classroom during that time. He remembered being "*excited and nervous*" at the same time when he realized he would be teaching in a one-to-one classroom where each student would have a laptop.

Riverside High School (RHS): RHS was founded in 1954 and was the oldest high school in the district. The school had an enrollment of approximately 1900 students in grades 9-12 and employed approximately 120 teachers at the time of this study. Even though there were 16 math teachers at RHS, Ann-RHS was the only teacher who volunteered to participate in the study.

Ann-RHS was in her late 20s. She had access to one-to-one technology in her previous school district as well, but the students were not allowed to take the devices home. She stated that she "*had a great feeling*" when she started working in this school district because students were allowed to take their devices home, and she had the opportunity to do more with her students. She learned to integrate technology in her classroom through school trainings and through her own trial and error experiments.

Riverside Open Campus (ROC): ROC was opened in 2000. The school had an enrollment of approximately 150 students in grades 9-12 and employed approximately 12 teachers at the time of this study. Emma-ROC and Mason-ROC were the participants from ROC.

Emma-ROC switched careers from the film industry to teaching. She was in her late 20s and considered herself to be fluent when it comes to using technology. However, one-to-one technology, where each student has a laptop, was new to her and she expressed feeling "*excited, daunted, and overwhelmed.*" She learned math the old-fashioned way using paper and pencil and could not think much about using technology to teach math. She mentioned that she had evolved more post-pandemic compared to her pre-pandemic experiences in the classroom with using technology.

Mason-ROC was in his late 40s and was in the Army Reserves. He had been in the field of education on and off for 16 years. When he took time off from the Army, he taught. At the time of the study, he had taught in three different states. He preferred to use technology to supplement the learning that takes place in a traditional classroom. His thoughts regarding one-to-one technology in the classroom included the concerns regarding whether the students will take care of their devices.

Sunshine High School (SHS): SHS was founded in 1991. The school had an enrollment of approximately 1100 students in grades 9-12 and employed approximately 90 teachers at the time of this study. Celia-SHS, Charles-SHS, and Tiffany-SHS were the participants from SHS.

Celia-SHS was in her late 30s and had been teaching for 15 years. In addition to teaching, she also coached the high school math teachers in the district. In her previous school district, she had the opportunity to use laptop carts and her use of technology in the classroom was limited to implementing paperless Fridays where students had a change from their normal worksheet routine and worked on computer activities instead. She was excited about teaching in a one-to-one classroom, but her biggest concern was figuring it out because of the lack of guidance in the beginning. She did a lot of trial and error and experimented with different resources to figure out what was best for her students.

Charles-SHS was in his mid-50s and had been teaching for 22 years. He stated that even though he had used smart boards and promethean boards in the classroom before, he had never used any apps or programs to teach until the current year. His experiences were limited to using online gradebooks and excel spreadsheets to keep data. When the one-to-one technology first rolled out in the district, his thoughts were "*are we going to still do the math or are we going to* *sit in front of the computer and play on the apps.*" He stated that he struggled when incorporating technology in the classroom and preferred the old-fashioned way of teaching from books.

Tiffany-SHS was in her late 40s and had 22 years of teaching experience. She had experience working in several school districts with various levels of technology use in each. She said she was "*very excited*" when the school district decided to implement one-to-one because she had been "*using technology in the classroom for a while and never had the luxury of each student having their own laptop.*"

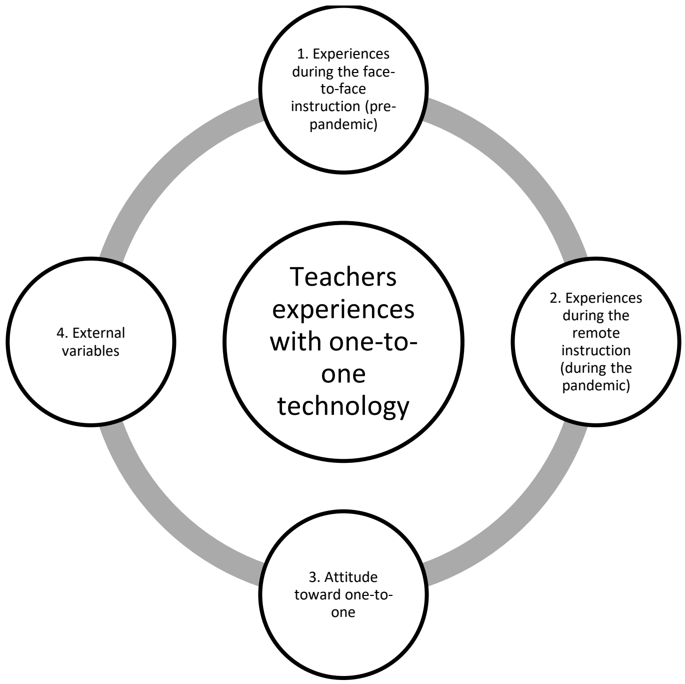
Data Analysis

During the first round of analysis, the researcher used open coding to develop 24 codes to describe the teachers' perceptions and experiences in various areas of using technology in the classroom. As the data analysis progressed, additional codes were developed to a total of 45 codes. The codes were assigned to 329 quotations from the 12 interview transcripts. A quotation was either a complete sentence or a partial sentence and represented the participant's thought. The codes were divided into four categories as shown in Figure 5 to address the first research question. A complete list of codes is provided in Appendix D.

Phenomenographic data analysis groups perceptions which emerge from the data collected into specific categories of description (Akerlind, 2005, Marton, 1981, & Marton, 1986). The four categories of description (Figure 5) are described in detail below. These four categories of description along with the selections of representative statements accompanying each category that is used to describe the phenomenon was used to develop an outcome space table which is shared with the results of the study (Appendix E).

Figure 5

Categories



Category One: Experiences during the Face-to-face Instruction

Category one examined the teacher's experiences with one-to-one technology when they were in the classroom prior to the pandemic. Since the classroom experiences of the teachers were affected by the pandemic, it was necessary to examine the experiences in two different categories. Therefore, category two will address the teachers' experiences during remote teaching. The main codes for category one included the teachers' feelings and initial reactions towards one-to-one, experiences with learning how to use technology in the classroom, and the experiences specific to technology use in the classroom. Table 2 illustrates how the qualitative coding process rendered category one as well as the code clusters that are integral to the category.

Table 2

Category One Coding

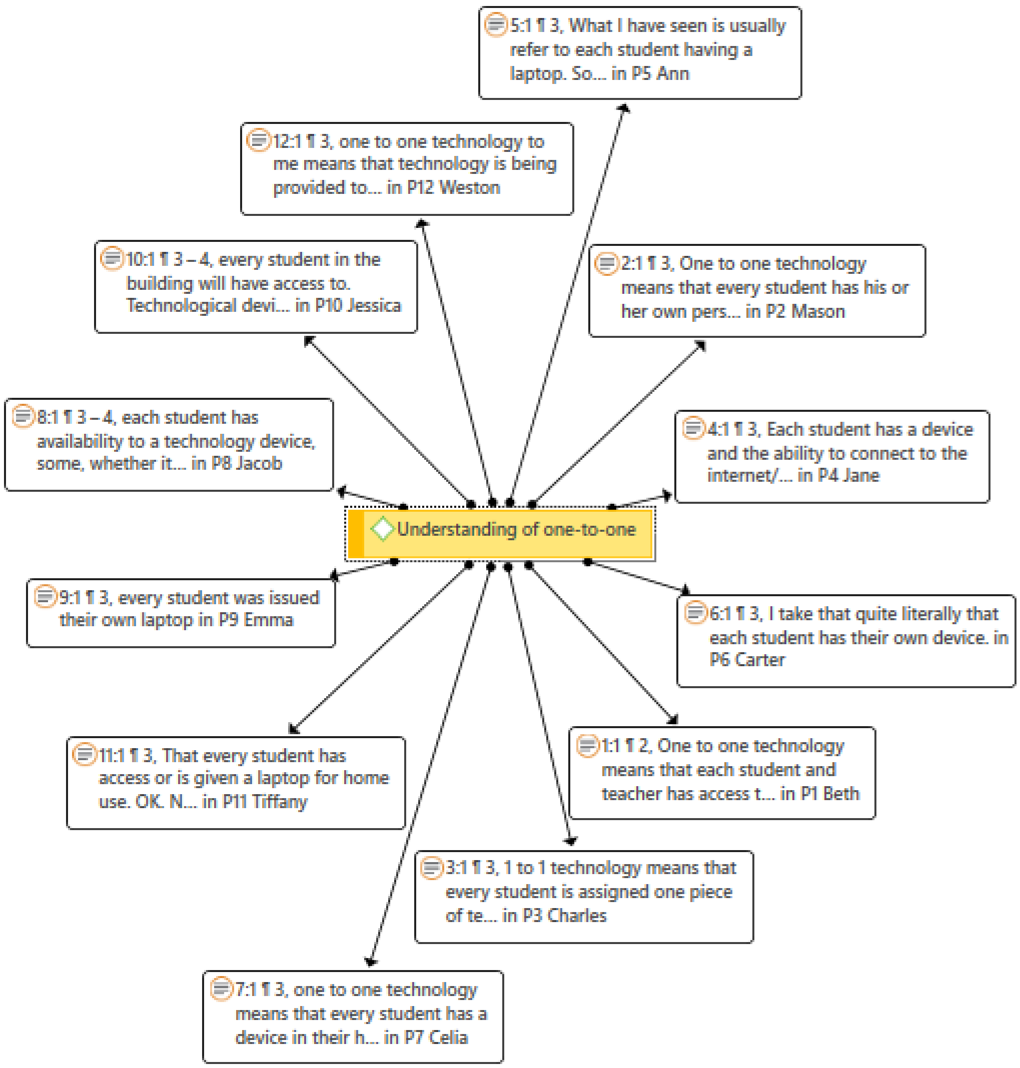
Category	Code Clusters	Codes
Experiences during the face-to-face instruction	Understanding of one-to-one	
	Initial reactions to one-to-one	Feelings about one-to-one
	Experience with learning to use technology	Self-learning
		Learning from peers
		Learning from PLC
	Experience with IL days	Planning for IL days
	Successful experiences	Success factors
	Challenging experiences	Experience dealing with challenges
	Technology & teacher responsibilities	Classroom management
		Grading
		Providing feedback to students
	Technology & instruction	Designing lessons
		Differentiating using technology
		Real life connections
		Visual experiences

Understanding of One-to-One

All participants described one-to-one technology as each student having a school-issued device. Participants also described that the students were allowed to take these devices home and use as a resource to complete schoolwork. Students were able to connect to the internet to access educational resources. Students were responsible to keep up with and take care of their devices. One-to-one technology allowed the students to access educational materials without having to carry different textbooks and other resources in their backpacks. Figure 6 shows a list of quotations showing the participants' understanding of one-to-one technology in the classroom.

Figure 6

Network of Quotations - Understanding of one-to-one



Initial Reactions to One-to-one

One-to-one program at RCPS (School district pseudonym) allowed all students with an opportunity to enhance their learning through access to a technology device both in the classroom and at home within the guidelines of the policies, regulations, and procedures set forth by the school system. Laptops were distributed to all high school students during the year 2015-2016 and students in grades 3-8 received their laptops the following year.

Participants described their initial reaction to one-to-one implementation in the classroom using the words “nervous,” “overwhelmed,” “uneasy,” “excited,” “daunting,” and “leery.” Charles-SHS did not think one-to-one technology would be very useful in teaching or learning math:

> Math, in my opinion, is ancient. I don’t think the average student is going to go to Khan academy on their own and watch some videos. So, my first impression was are we going to play with the math, or are we going to still do the math? Because in the end, the learning happens when we are doing it, not when we are setting up a computer or playing on an app.

He believed that the learning happens when students do the math by generating and applying strategies for solving problems and checking to see if the answers made sense. He did not think that the technology would facilitate this learning process, or his students would take the initiative to explore the possibilities of learning using their laptops.

Similarly, Carter-EHS did not believe at the time of one-to-one implementation, and still did not believe at the time of this study that technology enhanced the way his students learned math. He described why he thought technology does not promote the learning process in the math class:

> They need to know how to factor. They need to know how to solve an equation. They need to know how to find antiderivatives. They need to know how to solve a differential equation. They need to put a pencil in their hand and the pencil on the paper and they need to actually do things. So, the technology in my experience does not promote that

> because it's so easy to find the answer without having to do that work. So the skills that the students need, they're not getting because of technology.

Carter-EHS thought that the students could easily find the answers using technology by using programs such as *PhotoMath* (a mobile application that provides the students with the step-by-step solution to a math problem) or *Wolframalpha* (an online service that computes the answers for students). He was concerned about the students misusing these programs rather than using it as a tool to enhance their learning. Both Charles-SHS and Carter-EHS had over 20 years of teaching experience in the classroom, and it was not surprising that they preferred the traditional ways of using paper and pencil to teach and learn math.

Tiffany-SHS is another participant who had over 20 years of teaching experience. She had a specialist degree in Curriculum, Instruction, and Technology, and she had attended several trainings geared towards technology throughout her teaching career. She recalled that she was "excited" when she learned that she was going to teach in a one-to-one classroom. Even though she had similar number of years of teaching experience as Charles-SHS and Carter-EHS, Tiffany-SHS's initial reaction to one-to-one was different, and she was excited to look into the possibilities of using one-to-one devices to enhance the learning process of her students.

Of the nine participants who were unsure about the one-to-one implementation in the beginning, seven of them eventually started liking it as they began experiencing the one-to-one technology in their classrooms. Jane-EHS stated that her initial reaction was totally against students using the laptops in her classroom. She thought, "I'm literally never going to use these laptops in my classroom. They're just going to be a paperweight in my class. You don't need a laptop for math. You need a calculator and paper." But over the years, her thinking changed, and she became a leader who trains other math teachers on how to effectively integrate technology in their instruction. She was selected as the Technology Teacher of the Year in 2018 for her outstanding use of technology in the classroom.

A few other participants Beth-HHS, Celia-SHS, Jessica-HHS, and Weston-HHS seemed excited about the idea of one-to-one implementation but expressed that they were nervous about not knowing how to integrate technology in their classrooms. Beth-HHS shared her feelings toward one-to-one implementation and referenced the need for guidance on how to effectively integrate technology in the classroom:

> I was a little uneasy first, because I felt like I was going to start from ground zero. I have all these activities and lessons I have built over the years, so now I have to take all those resources and make them digital. So, I was really uneasy about that. To be honest, I didn’t know exactly what to expect when they told me I am going to be one-to-one. I didn’t have a lot of guidance when it came to really utilizing one-to-one to its maximum potential. So, to me, it was like I was thrown in there. That’s when I took it upon myself to learn these things.

She stated that she also felt “a bit nervous” because she relied on paper and pencil to teach math, but she was “very excited to try something new.” Her major concern was that she would have to spend a lot of time re-designing her lessons to work with the one-to-one technology in the classroom.

Celia-SHS shared similar feelings as Beth-HHS about the initial excitement of having one-to-one and referenced the need for guidance. She stated that she was excited because she was thinking about how amazing it was “that each student will have a device in my classroom” and “how much the kids can do with the laptops.” At the same time, she was also concerned that “so now that we got these computers for students, am I expected to just kind of figure it out? I waited on the district to give us some guidance." Jessica-HHS stated that she was overwhelmed because it was her first year of teaching and she was teaching in a one-to-one classroom. She stated that she "didn't have any training on using one-to-one in the classroom. I got my master's degree in teaching, but there was never a course that taught how to use technology in the classroom." However, she tried to "use it sparingly." She added that "It scared me that I didn't have a way to use technology effectively with my students." Weston-HHS said he "was excited," but he was "also nervous of the [unfamiliarity] of it all and trying to figure how to transition to a one-to-one classroom."

Participants' initial experiences show that 10 out of the 12 participants were eager about the one-to-one initiative. Even though the teachers had basic training prior to the one-to-one implementation, they expected more guidance at the time of implementation on what to do with the one-to-one technology in the classroom. The district had embedded more professional learning opportunities for teachers in the years that followed, but at the time of implementation teachers felt the need for more guidance. Next, we will look at the participants' experiences with learning to use technology in the classroom.

Experiences with Learning to Use Technology

When it comes to learning how to use technology in the classroom, six participants admitted that they learned by trial and error. Three participants mentioned that the trainings provided by the district were sometimes helpful. Five participants reported learning from their peers.

Beth-HHS shared her excitement about learning to "integrate technology in the classroom by trial and error." She also referenced district provided resources such as access to experienced professionals and professional development opportunities.

> We have mandated professional development. Sometimes it's useful, sometimes it's not. I am pretty much the type of person that likes to figure things out on my own. So, I don't usually try to put myself in a professional development unless they require us to do it.

Mandated technology professional development provided during pre- and post-planning every year were not always useful for all teachers, and hence teachers seemed to prefer learning what they need by trial and error at their own pace. Ann-RHS, Celia-SHS, and Jessica-HHS shared similar feelings regarding learning by trial and error. Ann-RHS said "I learned how to integrate technology in the classroom through school trainings and by my own trial and error. I'm trying out different things with the students and learning on my own time." Celia-SHS stated that she learned by "trial and error" as well. She added that "We have professional development, but I am the type of person, even if I go to a professional development, until I'm ready to actually use it, it really doesn't mean anything to me." Jessica-HHS shared that she "learned how to integrate technology in the classroom by trial and error, and through my mentor teacher who helped me a lot with integrating technology in the classroom".

Mason-ROC thought that the PLC meetings were not very beneficial to him "because in PLC, they only highlight the things that are important to them. Everybody has their own interest, so I just have to do a lot of experiments to learn the things I need for my classroom." He preferred to learn on his own through experiences. Most teachers seemed to depend on learning by trial and error, and through experimenting when it comes to integrating technology in their classrooms. This approach provided the teachers with the opportunity to practice something new in the comfort of their own classroom and make improvements by learning from their mistakes.

Weston-HHS recalled how much the support from his peers helped him with learning how to use technology in his classroom. When he started working in the one-to-one classroom, he remembered having a colleague who mentored him regarding the use of technology, and he was able to become familiar with the one-to-one technology because of that interaction he had with his colleague. He added that the support from his peers helped him with the transition to a one-to-one classroom even though he was nervous at first:

> I had great support from my peers in the math department who constantly helped me to improve my own learning process as far as how to implement technology in the classroom. And the trial and error that came with it was not as dreadful as it could have been because I had a lot of peer support.

He recommended that kind of peer support is vital to anyone who is new to a one-to-one classroom. Learning from peers has the potential to provide teachers with the support they need to improve their comfort with using technology in their classrooms. The experiences of Weston-HHS and Jessica-HHS emphasize the need for promoting peer coaching as a way of supporting the teachers.

Even though the district offered technology-related professional development opportunities for the teachers every year during the pre- and post-planning days, it was evident that the teachers did not find it useful until they were ready to use it in the classroom. And when they were ready to implement it, they relied on trial and error and learning from peers. The actual learning happened when the teachers were willing to experiment, take risks and learn from their mistakes. The support from peers and knowledgeable professionals was valuable in this learning process. Beth-HHS suggested that optional trainings were needed based on teachers' needs rather than requiring the teachers to attend:

> What works in Science may not work in Math. So, don't force everybody to learn, but provide optional trainings based on the needs of each department. I feel like you are

> going to get more people to learn that way. And sometimes that means showing one eager person and having that eager person go back to their department and share what he or she learned.

As Beth-HHS suggested, training programs based on the needs of individual subject area might be more beneficial for the teachers because the trainers could focus on how a specific technology could be used in a particular subject area. Teachers might be able relate more if the training is focused on their subject area rather than it being general. This could also promote small learning groups within each department supporting each other as they learn something new. The next section looks at the teachers' experiences with the Independent Learning days that were embedded in the district's academic calendar.

Experiences with the Independent Learning (IL) Days

The IL days were implemented in the school district since 2016. Teachers were asked to design lessons for their students to complete from home. Seven out of the 12 participants did not have any productive experiences to share about those days. They recalled assigning students with busy work or additional practice on something they have already learned in class. Teachers did not think that students would be able to learn new material on their own from home. However, Beth-HHS, Ann-RHS, and Jessica-HHS admitted that the experiences with the IL days helped them and their students with their transition to emergency remote teaching caused by COVID-19. Beth-HHS thought that both teachers and students in this school district were "more prepared than anyone else in the state" for such a precedented time since they had access to one-to-one technology since 2015. Ann-RHS was glad that "our district had that in place because it made the transition much smoother." Jessica-HHS thought that "it's helped the students acclimate themselves to at least looking for assignments online and completing them online and knowing where things are."

Tiffany-SHS used the IL days as practice days for students to work on additional practice or for completing missing assignments. Beth-HHS said that she would not ask the students to learn something new during the IL days prior to the pandemic. She stated she "would probably give something simple for the kids to complete about content that I have already gone over in class, not really asking them to go out of their way to learn something on their own".

Charles-SHS and Carter-EHS shared similar experiences related to IL days. Charles-SHS stated that his students did not take those IL days seriously, and they did not do their assigned work. Carter-EHS stated that IL days were not useful for his students since he could not get his students to do any work on those days. He thought the IL days were "kind of useless" and he ignored them as if they were off days. He stated that he "didn't use the IL days to introduce new content because honestly, I didn't trust that that they would do it or understand it well enough." The teachers did not feel comfortable assigning the students with independent learning material and instead, used the IL days for additional practice work on something they had already taught.

Jane-EHS had similar experiences in the beginning when the district first started IL days, but eventually she moved on to where she created flipped lessons for her students to complete at home during the IL days. She was excited to share that she "actually created a whole flipped math lesson where the students answered practice questions, then they completed an enrichment or remediation assignment based on their score from the practice questions." She added that a lot of people did not know how to handle the IL days and did not have any experience.

Jacob-EHS noted that he was concerned about students' internet access at home, so he tried not to assign them anything important. He thought, "Just because you have a computer doesn't mean that you have reliable internet access at home, so I tended to give assignments that's more of a guided exploration of what they have already learned in class." The access issue was addressed during the remote teaching due to the COVID-19 pandemic. The school district deployed mobile hotspots on parked RCPS school buses in key locations throughout the district and the students were able to connect to a reliable network if they did not have internet at home.

The IL days were developed and implemented by the district to get the students and teachers accustomed to a remote independent learning environment in case of an extended school closure such as inclement weather. These days were asynchronous in nature where the teachers created and posted lessons and activities to *itsLearning*, the learning management system, and the students accessed the activities and completed them from home. Due to the lack of motivation from the students' side, most teachers considered these as additional practice days and did not feel comfortable assigning any new content to the students. The next section will highlight the participants' successful experiences with one-to-one technology in the classroom.

Successful Experiences in the Classroom

Participants attributed their successful experiences to a variety of factors. For Beth-HHS, it was being able to provide her students with visual experiences to understand math in a better way:

> Giving students like actual simulations so that they could see what's going on real time. For example, when teaching cross sections of 3-dimensional figures, you can provide students with the simulation showing a plane going through a cone and having them see what the cross-section shape is in real time. I think that is very important because it makes something that is so, like this spatial reasoning there happened for them and make it more concrete for them.

Mathematics is often presented to students as a set of steps to be followed in a particular order. Mathematical modeling, such as the simulations described by Beth-HHS, can help the students understand and explore the meanings of complex mathematical concepts.

For Ann-RHS, it was the ability to engage students and provide them with instant feedback. She described her experience using *Nearpod*, a web-based tool for creating and delivering interactive presentations as well as formative or summative assessments. She stated "You can see if the students are on task and provide them instant feedback. Nearpod even has games built in so I can incorporate games into my lesson. Students really like that, and they are very engaged." Jacob-EHS had similar thoughts about student engagement and referenced that the success depends on the student engagement. He recollected creating a task similar to a *WebQuest* where students would click on to find links to practice on sites such as *Khan Academy* or *Deltamath*, and his students were very engaged with that. He "found that those experiences were very valuable, very engaging, interactive and the students got instant feedback as they were working through problems."

For Jessica-HHS, it was about how the technology helped her facilitate student discussions. She shared her experience with using *Desmos* in the classroom, an online tool that can be used in a variety of ways ranging from a short learning assessment to a full class length interactive activity:

> I used a *Desmos* activity to work on the line of best fit. It allowed the students to watch a video, collect data, and create a table. Then they were able to manipulate the line to see what the line of best fit was. *Desmos* has some great features, and I was able to snip some of the students' work for all students to see, and they were able to judge and have a rich discussion on which one of those lines was a good fit for the data.

Jessica-HHS's experience suggested that technology can be used to take the learning to the next level by providing the students with interactive lessons and using live examples of student work to facilitate discussions.

Weston-HHS noted that the level of student engagement along with some fun element really make an activity successful. He remembered how his students enjoyed using old fashioned card sorts in the classroom, and he appreciated the ability to create digital card sorts using apps such as *Desmos* or *Nearpod*. He pointed out that "the success with that has been the connections that I have been able to make with the students to make the learning fun and challenging." Weston-HHS's experience suggested that incorporating fun element in teaching and learning math could lead to increased student motivation and engagement.

Emma-ROC served high school students who have dropped out or are at-risk of dropping out of school. She described her experiences with personalizing the learning for students using the *IXL*, a website that provided in-depth content to help students master complex topics and help them take charge of their learning. Emma-ROC stated that her first real successful experience in the classroom was with *IXL*. She really loved that "I could have all my students take the diagnostic test, and then I could use that to directly assign them the skills they need." She added that "a lot of students are coming to us with gaps in knowledge" so this was a useful tool for her and her students. One-to-one technology made it easier for Emma-ROC to personalize the learning and address the needs of students who struggle with math. The technology and IXL enabled her to focus on the deficits of each student and provide personalized practice.

One-to-one technology in the classroom enables the teachers with numerous benefits. Technology can be a very good motivator for the students, but as with everything else in the classroom, it was important for the teachers to establish rules and routines for the use of technology in the classroom. Teachers found that it was much easier to provide personalized instruction that addressed the gaps and needs of each individual student. Providing resources and information to students becomes an easier process when you teach in a one-to-one classroom. One-to-one technology also enabled the teachers to provide instant feedback to students, facilitate student discussions, and make the learning process fun and engaging. At the same time, teachers also experienced challenges as they tried to incorporate technology in their classrooms. Next section focuses on the participants' challenging experiences involved with the one-to-one technology in the classrooms.

Challenging Experiences in the Classroom

Participants described the challenges associated with using one-to-one technology in the classroom mostly happens when the internet goes out, when the firewall blocks sites on student computers, or when the devices are not working. Participant responses indicated that in such situations, it would be important to have a back-up plan to keep the learning uninterrupted.

Mason-ROC, Jacob-EHS, and Beth-HHS shared similar experiences about feeling disappointed when the network went down. Mason-ROC noted "when you design a lesson around technology, the Wi-Fi goes out and you are stuck with what you were trying to do." He said he liked to keep books in the classroom as a backup resource to use when technology is not working. Jacob-EHS expressed his frustration and described his experience with network going down while he was trying to present an activity on the computer. "You planned this activity, and the network goes down… Those are the things that are frustrating. Sometimes you spent 10 minutes trying to get it to work, and you realize, you just wasted 10 minutes. Those are disappointing times." Beth-HHS pointed out that the situation could be out of control when the network goes down or when the sites not loading correctly. She said, "when that happens, I try to move on to a different lesson until I can figure out what’s going on.” Network going down and pages not loading correctly were issues that the teachers and students had no control over. As the participants had figured out, it would be best to have a back-up plan to use in such situations so that the student learning can continue.

Emma-ROC mentioned that it is challenging to decide what technology to incorporate in her lessons. “There is so much stuff out there and figuring out what to incorporate is hard.” She admitted that her challenging experience “would have been creating structure.” She noted that “with so many different technologies offered to me, but also just a myriad of platforms and not streamlining it into any kind of pattern like that the students could easily follow” had been challenging for her. Providing professional development based on the needs of each subject area as Beth-HHS suggested previously, could address this issue. Doing so would streamline the technology use specific to each content area, and teachers would not be as overwhelmed with deciding what is best for their classroom and for their students.

Teachers also referenced students getting distracted with technology in a one-to-one classroom. Charles-SHS, Celia-SHS, Jane-EHS, and Jessica-HHS referenced how technology could become a distraction and classroom management in a one-to-one classroom could be challenging. Charles-SHS noted students browsing other non-instructional websites while they are supposed to be learning. He said, “You always have that person who was watching basketball or football on their computer while we are trying to find the zeros of a quadratic.” Celia-SHS thought students sometimes got distracted because of all the other things they could do with their laptops. She added that students “don't see them as learning tools like we see them as learning tools. The students just see them as their way to get into stuff and see stuff.” Jane-EHS shared that technology is sometimes a “distraction” in her class as well. Jessica-HHS noted that students can be “wandering around and get lost in the world of internet.” The fact that technology was sometimes a distraction in the classroom could not be denied. A teacher’s classroom management procedures might need to be modified when there are student devices in the classroom. Jessica-HHS emphasized that the classroom management in a one-to-one classroom is really important because teachers need to make sure “that the students are on task, and they're focused on what they're supposed to be doing versus wandering around on their laptop in the world of the Internet.”

Teaching in a one-to-one school district where each student has a school-issued device opened up possibilities for teachers to enhance their teaching practices; however, teachers still faced challenges associated with using one-to-one technology in the classroom. The major challenges were the network going down in the middle of a lesson and the student distraction caused by the devices. Though there was nothing a teacher could do to control the network, establishing procedures in the classroom helped to decrease the distractions in the classroom. Next, we will look at the teachers’ perceptions on how technology contributed to the teachers’ responsibilities.

Technology and Teacher Responsibilities

Of the 12 participants, four participants mentioned that the one-to-one technology had made them more efficient in the area of grading, and seven participants mentioned that they found technology very useful in providing the students with instant feedback. In a one-to-one classroom, teacher experiences with technology can be slightly different since the student devices can help or hinder the teachers’ responsibilities. Even though the normal teacher responsibilities include planning and delivering the lessons, managing the classroom, evaluating the students, communicating with the parents etc., the participants’ responses were more geared towards how technology was helping them in the area of grading and providing feedback to the students.

Beth-HHS referenced how the one-to-one technology has made her “more efficient” and “more organized” in executing her responsibilities as a teacher. She added that the one-to-one technology had made her provide more enriching and engaging lessons for her students. Tiffany-SHS discussed how teachers spend a lot of time grading assignments and noted how one-to-one technology had made the grading process easy for her:

> As teachers, we spend so much time, particularly on grading. So, a lot of the platforms, like *Deltamath*, *IXL*, *Boomcards* etc. can self-grade. We used to spend a lot of our time on the weekend, bringing home papers to grade. Now there are several quality platforms that can ease our grading responsibilities. It’s allowed me more time to do other stuff such as differentiating or research more stuff instead of just grading all day and night. It’s fast on the kids’ side too. They get that instant feedback without having to wait for you to take it home and bring it back.

As Tiffany-SHS pointed out, automatic grading using technology can provide the teachers with more time to focus on individual student needs and provide assistance based on student needs.

Also, participants found the ability to give instant feedback to students using one-to-one technology very valuable. Jane-EHS mentioned she used websites such as *Deltamath* (an online practice website for math skills) and *USA Test Prep* (a web-based tool that is designed for test preparation and provides the students with instructional resources and assessments) because it provides her students instant feedback while they are doing homework.

> It immediately tells them if they're right or wrong. It explains how to do it if they got it wrong, and that's something I cannot provide for them at home. So, I like to use sites like *Deltamath* and *USA Test Prep* for homework because you know it gives them that immediate feedback. It's much better than them turning in something that I'm going to grade a week later.

Jacob-EHS used websites such as *Khan Academy* (a website that provides short lessons in the form of videos and supplementary practice exercises) and *Deltamath* to provide his students with immediate feedback. He found "that those experiences were very valuable, very engaging, interactive, and the students got instant feedback as they were working through problems on *Deltamath* or *Khan Academy*." Ann-RHS discussed it is almost impossible to provide instant feedback when you are not using technology.

> When you're not using technology, there's no way to give instant feedback to students. Some of these online platforms can even provide them extensive feedback. You know, provide videos and all as soon as they submit their answer, versus I am walking around trying to provide that feedback in person. Sometimes I use *GoFormative* and I'm able to see them work out problems on my screen and I can even correct them before they finish. So yeah, one-to-one technology definitely helps the way we give feedback to our students.

Some websites provided the students not only instant feedback on if they are right or wrong but provided on-spot remediation as well. This was a very useful aspect of one-to-one technology in the math classroom because students did not have to rely on the teacher or wait for the teacher.

Beth-HHS referenced the ability to provide feedback to both individual students and to the whole group without exposing the student names using *Desmos*:

> Giving students individual and sometimes instant feedback using the one-to-one technology with them still being anonymous in their own way. If you can hide students' names and then provide some feedback on certain problems that they did. That's definitely one of the skills I think I have improved upon is giving feedback using technology.

Desmos allowed the teachers to discuss student work with a group of students without exposing the student names to the whole class. Hiding the student names helped to protect the privacy of the students and made the students feel comfortable discussing their work in a whole group.

In this section, teachers shared their experiences with how one-to-one technology is useful for them in executing their teacher responsibilities such as grading and providing feedback to students. The ability of being able to give students instant feedback was referenced by many participants as one of the most useful benefits of one-to-one technology in the math classroom. Teachers' perception of how useful the technology may be in terms of the increase in productivity and accomplishment that it will bring (Perceived usefulness) is intended to influence their use of one-to-one technology in the classroom. Next section highlights teachers' experiences with using technology to plan instruction.

Technology and Instruction

When it comes to planning lessons using technology, three participants mentioned the importance of filtering through the available resources to identify what is best for them, two participants mentioned changing the way of assessing to address assessment security issues, four participants indicated differentiating using technology, and seven participants mentioned using technology to improve the teaching of math by providing the students with simulations and visual experiences.

Beth-HHS mentioned the importance of filtering through the available resources to identify what is going to be the best for your students. She stated “You need to first filter what's going to be the best, what's going to maximize your students' learning, what's going to minimize your workload. So, you always have to do that kind of planning.” School districts provided the teachers with many resources in addition to the free and paid resources that were available on the internet. Filtering through all the resources to identify what works for the students appeared to be a skill that the teachers needed to master.

Jane-EHS discussed security as an issue that need to be considered and addressed when planning lessons and assessments. She mentioned “Security is obviously a lot more of an issue than it was previously, so you have to build your questions around things that just can't be Googled. Like you can't ask as many just straightforward questions.” Jacob-EHS elaborated on the issue of security and discussed that he had to change the way of questioning to make sure his assessments more authentic:

> Some of the apps actually do the work for the students, so I've had to change my questioning. I used to be able to put together a good multiple choice or short answer question and feel somewhat justified with that as long as I change the numbers on the problems. But now they've got *PhotoMath* and they just take a picture, it shows them how to do the problem and they copy it.

Participants agreed that one-to-one technology makes it easy for them to differentiate the learning process and personalize the learning for students with specific needs. Weston-HHS referenced that technology helps him to provide remediation and additional practice to those students who need it. He said, “technology helps me to personalize and differentiate the education that is happening in my classroom, specifically using resources like Deltamath etc. gives me an opportunity to give additional practice to the students who need it.” Emma-ROC added that the one-to-one technology enables her to provide both remediation and enrichment effortlessly. She had students at completely different levels of learning. She said she “can easily use technology to identify kids in different groups and provide practice based on their levels”. Beth-HHS added that one-to-one technology helps her to “...differentiate a lot easier and unnoticeably” in her classroom. Tiffany-SHS mentioned that technology provide “...another means to reach students that learn differently.” Teachers had always worked hard to identify the gaps in student learning and provide remediation based on those gaps. One-to-one technology took this process to new heights as it helped the teachers to use programs such as *IXL* to identify the gaps and provide personalized practice based on those gaps.

Seven participants believed that technology helped their students to visually see the math and make connections with the math they are learning. Beth-HHS shared her experience with giving students actual simulations so that they could see what's going on in real time:

> For example, today I taught about cross sections of 3 dimensional figures, and you can provide students with the simulation showing a plane going through a cone and having them see in real time like what is the cross-section shape. I think that is very important because it provides the spatial reasoning for them and make it more concrete for them.

Mason-ROC agreed that technology helped his students visualize things that were hard for him to explain. He stated, “Math is hard to see in your mind unless you just have a math mind. For those folks that doesn't have a math mind, technology helps them see it.” Charles-SHS admitted that the manipulation that he could do with technology using a smartboard took "...Geometry to the next level." He added:

> It shows, and it allows you to see things, especially when, for instance, when you talk about magnifications and reductions, you can just click and drag and see the thing betting bigger and on certain programs, it will have the scale factor up there and then you can click and drag… so it can lead to a better experiences in discovering mathematics.

Charles-SHS agreed that some of these things were impossible on a piece of paper, or it might take a long time for students to see and experience the math. Technology enabled the students to visualize and experience the math in seconds. Jane-EHS thought some of the *Desmos* activities that she used with her students made "connections in a way that I never could without it, like there's no way on paper or on PowerPoint that I could explain it the way that Desmos does." Emma-ROC's thoughts were similar, and she said "it is definitely better than doing it on paper. They won't be able to manipulate the way that they can online, so I think having that visual, you get more of that with technology than you do with paper."

While sharing their experiences with designing lessons to use in a one-to-one classroom, teachers' perceptions continued to reflect the usefulness that technology brings for them (Perceived Usefulness). Teachers found that the one-to-one technology improved their ability to provide visual simulations to students. Having access to one-to-one technology also improved their ability to easily identify gaps in learning, differentiate the learning, and provide enrichment and remediation based on the student needs. Designing assignment questions seemed to be an issue; however, teachers have realized that they needed to change the way of questioning and provide the students with authentic opportunities for demonstrating mastery of the learning concepts to prevent them from misusing the available resources.

Summary of Category One

Category 1 focused on the participants' experiences using one-to-one technology in the classroom. Even though the teachers started out feeling a little bit nervous and overwhelmed with the one-to-one technology in the classroom, most teachers seem to have evolved and engaged in the learning process on utilizing the one-to-one technology to its maximum potential. Teachers have access to district and school provided professional learning opportunities, but the actual learning took place when the teachers found the technology useful for them and for their students and started learning by trial and error. Barriers that used to exist in the past such as access and resources availability were not mentioned by the participants. The new challenges include filtering through all the available resources to decide what is best for the students, having a proper back up plan when technology fails in the middle of a lesson, assessment security, and managing the student use of computers.

Charles-SHS and Carter-EHS were the only two participants that did not find the one-to-one technology in the classroom very exciting. Charles-SHS admitted that he preferred books and traditional teaching methods because of his age, but he pointed out that technology helped to manipulate geometrical concepts much easier than doing it on paper. He was not against those who used technology in their classrooms, but he was comfortable with the traditional ways of teaching using books and whiteboard. Carter-EHS's reasoning was that he taught AP classes, and the college board only allowed the use of a graphing calculator on their exams. This held him back from spending time on researching other available technologies and resources for his students. Overall, most participants described their experiences with one-to-one technology as positive and useful.

Category Two: Experiences during the Remote Instruction

Category Two focused on the teachers' experiences during the remote instruction due to COVID-19. The main codes included the teachers' feelings about the remote teaching, preparedness for the remote teaching, and experiences during the transition to remote teaching as well as during the remote teaching. Table 3 illustrates how the qualitative coding process rendered category two as well as the code clusters that are integral to the category.

Table 3

Category Two Coding

Category	Code Clusters	Codes
Experiences during the remote instruction	Understanding of remote teaching	Online teaching background
	Preparedness for remote teaching	Feelings about transition
		Impact of IL days on transition
	Transition to remote teaching	
	Experiences with the student engagement during remote teaching	Feelings about remote teaching
		Remote teaching challenges
		Student motivation to remote teaching

Understanding of Remote Teaching

During the middle of March 2020, teachers experienced a temporary shift of classroom instructional delivery to an alternate remote teaching mode due to COVID-19. What started out as a two-weeks of emergency remote teaching ended up being an extended period of remote teaching which lasted almost 16 months. The unprecedented circumstances teachers and the students faced due to the pandemic prevented them from making a normal transition to remote teaching. 10 out of the 12 participants had no previous experiences with online teaching and the district did not have time to provide enough training on how to teach online.

Carter-EHS and Jessica-HHS were the only two participants who had some online teaching experiences. Carter-EHS had been teaching online in the evenings for an organization called the Art of Problem Solving. He had taught about 20 courses online for them so far. Jessica-HHS had been teaching English language online for students in other countries which gave her the experiences for being in front of the camera and convey information to kids online. Tiffany-SHS, Weston-HHS, Beth-HHS, and Jane-EHS had some experience being an online student. However, the experiences with the district's IL days made it easy for most of the participants to adjust and adapt to the situation easier.

Beth-HHS referenced the importance of being "flexible in how we teach our students" in a situation like this. Mason-ROC noted how he had to learn how to teach online within a short period of time. He said: "You come to school on a Friday, and they said you are not coming back for two weeks. Everything now is online. So, you had to learn real quick to be successful at teaching students." Jane-EHS and Carter-EHS thought that they needed to keep the learning going and get the information to the kids as the best as they could. Jane-EHS said, "It wasn't meant to be long time, but unfortunately it lasted forever." Carter-EHS said, "Keep going somehow. Let's just keep trying and do the best we can with what we got." Despite the fact that the whole nation was going through a state of unprecedented, teachers tried and did their best trying to get information to their students.

There were challenges involved in teaching math virtually. Charles-SHS believed teaching and learning math would not be possible in an online platform.

> I tell people, before the pandemic, I would not take a math class online at any university. Period. I didn't think it would work that way. It is just the absorption rate for me would be just so different. So, it is so tangible, the interaction, the instant ability for a math

> teacher to walk down the aisle and say that should be a negative, not a positive, oh you forgot to divide on this formula. You can catch it, but when you are remote, it becomes impossible.

The interactions between the teacher and the students are very important in a math classroom. As Charles-SHS pointed out, to replicate the presence and support from a teacher when the students are engaged in problem-solving is challenging. To meet the demands of online teaching, teachers explored different ideas. Ann-RHS suggested that the remote teaching should be engaging and interactive. She added, “It should be an actual lesson. It should be a teacher and students coming online and interacting with each other.” Weston-HHS mentioned about the need to “modify our current practices and objectives to accommodate a unique circumstance.” Teachers realized that the lessons needed to be modified to make it work in the online learning environment.

Teacher perceptions regarding remote teaching included the need to be flexible during the pandemic, the need to make modifications in their plans to provide continuing learning experiences for the students and making it engaging and interactive as possible for the students.

Preparedness for Remote Teaching

Even though there was uncertainty about how it would look, all participants indicated positive feelings towards the transition to remote teaching. The school district in this study was more prepared than most other school districts in the state of Georgia because it was already a one-to-one school district. Each student and teacher had a school-issued device, teachers had some training on using technology in the classroom, and teachers and students knew how to use a learning management system.

Charles-SHS believed that the district's IL days prepared him for a situation like this, and he also appreciated the support from his colleagues, and the math coach. Jane-EHS thought she was more prepared because of her experiences with doing flip model in the classroom. Also, she mentioned that being one-to-one for a long time also made her feel prepared for the situation.

> I thought that I was going to be more prepared because I had been teaching a few units flip model. Our district was more prepared because we were already one-to-one. I watched some districts scramble in April to rollout student devices. So, I think we were in a better position because we had already been one-to-one.

Beth-HHS remained positive about the circumstances. She stated that she was not scared to teach online. She stated, "It felt like okay, I am just going to go home, and I am going to do exactly what I have been doing in the classroom, but online. I was pretty cool with it." Emma-ROC said she went out of her way to teach herself how to teach online. She said, "I was excited for the opportunity. And this forced me to learn how to teach online. I don't think I would have spent hours and hours going out of my way to learn how to teach most effectively online". Celia-SHS explained how she and a colleague worked together to figure it all out.

> I had to figure it out, so me and another teacher friend of mine, we got together that Saturday. I went over to her house, and we actually played with it, her being a teacher and I being in her class and vice versa to try to figure out the little nuances of *Teams*…I know the situation was pretty much same for everybody in the district.

The COVID-19 situation forced the teachers to go out of their comfort zone and learn something new.

Mason-ROC was concerned about the students who were "unmotivated" in the classroom. He said his "first impression was how are we going to get these kids through…How are we going to successfully teach these students, especially the ones that struggle with school?" Jacob-EHS was concerned about the assessment security in the online teaching environment.

> I was concerned about assessments. And I was concerned about integrity into the classroom. Like how do I assess a kid? I can't watch them while they're taking quiz, so I've had to change my assessment protocols, but that was hard for me to think how that is going to work.

The teachers' experiences showed that the IL days prepared some of the participants for remote teaching to an extent. The IL days were not designed to be synchronous or interactive. In the remote teaching environment, teachers also had to learn about synchronous teaching and live interactions. Teachers took the initiative to learn the basics of online teaching by experimenting and through the help from their peers.

Transition to Remote Teaching:

Of the 12 participants, eight participants indicated that their experiences with the district's IL days helped them with the transition to remote teaching. From the comfort zone of their own classrooms, teachers were forced to transition to two weeks of emergency remote teaching from home, and then to continue to an extended period of remote teaching. As Weston-HHS pointed out, it was not an easy transition for the teachers.

> It is not simply a transition from classroom practices being done virtually. I think it needs to be a modified schedule. It needs to be a modified curriculum and modified planning and instruction. And the expectations have to be adjusted for your virtual learners because in this emergency remote situation there are a lot of different challenges that they may be dealing with at home that have nothing to do with school. So, I think we have to be cognizant of that prior to assigning students work in a virtual environment.

The IL days were helpful for some participants as they transitioned from classroom to online teaching. Prior to the pandemic, IL days were asynchronous in nature and teachers did not have to meet with their students. Meeting students online and engaging them in the learning process was new to most of the teachers. Charles-SHS mentioned that the IL days helped him get familiar with the district's LMS. The IL days allowed him "to manipulate and navigate the *itsLearning* site. So, when we went into the remote teaching mode, it wasn't a matter of familiarity. I was already familiar with it." Ann-RHS agreed that her experiences with the IL days prior to the pandemic made her transition to online learning much smoother. She said when the district laid out the plans for remote teaching, she realized that it was basically IL days. She added, "And listening to teachers from the other districts, I was really glad that we had that in place because it made the transition much smoother." Jessica-HHS perceived that the IL days made the students' transition to online learning easier. She thought that "the IL days have helped the students acclimate themselves to at least knowing where things are, looking for assignments online, and completing them online." The IL days appeared to have made the transition to remote learning smoother for both the teachers and the students.

Experiences with Student Engagement during Remote Teaching

Online teaching came with some benefits to the teachers. Beth-HHS was already comfortable with the idea of teaching online, so unlike many other teachers, she did not have to spend time figuring out how to teach online. She mentioned she was getting more time to look more into student progress and provide what they needed. "I am getting more time to personalize the learning. You know you get to look at each student because we have all that time because we don't have to manage the behavior in the classroom." She added that she was able to successfully engage most of her students in the new remote teaching environment. "I am still getting hand raises, and still getting the feedback from them. They are still answering questions and they are all following along with me for the most part." Beth-HHS was overall excited about using technology in the classroom and had easily figured out how to engage students in an online learning environment.

Jane-EHS did not think a lot had changed because she was still meeting with her students every class period. "We're still doing 70-minute block and we still have *Teams* meetings with the students every class period. So, I feel like we're still doing a lot of face-to-face even though we're not physically there." She thought, "My laptop screen has taken the place of my smartboard." However, she missed the interaction between the students. "I cannot watch them do their work though. I think the big thing that is missing is the students talking to each other. My classroom was never silent. There were always live discussions going on." She said most of her students did not feel comfortable turning their microphone on to talk even though they were very active in the classroom so she was unable to replicate the live discussions.

Ann-RHS shared positive experiences but mentioned that she needed to improve on engaging the students in the remote teaching atmosphere. "I feel very comfortable using all the technology that we are required to use. Maybe the area I can improve on is probably the student engagement because in some of my classes, students are not engaged." Jessica-HHS pointed out that the student engagement in the remote environment as an issue, and she struggled with it. "Making sure they are actually in front of their laptop when I am teaching because I know some of my students log in and then they walk away… I'm trying to implement things that make them interact as much as possible." Tiffany-SHS started using *Nearpod* to increase student engagement in her online class.

> The most frustrating thing is the students not logging in to the meeting on time. And it has been the same students. I have learned to use *Nearpod* so now I can monitor the students in real-time like what the students are doing and control what they can see. Every few slides, they need to do an activity, and I can see who is engaged and who has stopped. I can also go through their work and give immediate feedback. So that has been going well since I started using *Nearpod*.

Teachers had to try different programs to find what worked best to engage their students in the online learning environment.

While the other participants discussed their experiences with the student engagement in the online learning environment, Mason-ROC perceived that the parent engagement had become easier since parents can easily access the online classrooms and see what their children are doing.

> I give them my meeting links and invite them to come in anytime. I have had students whose parents wanted to visit the classroom before, so now that became a little easy. They can see how they are being taught, and how their child is doing and all that.

He used the remote teaching as an opportunity to invite parents to his online classroom and to increase parental engagement.

Summary of Category Two

Teachers appreciated the opportunity to stay home and continue teaching rather than being out during a pandemic. Teachers' experiences with the remote teaching showed that teachers had a somewhat smooth transition to the emergency remote teaching and then to the extended remote teaching. The one-to-one technology that had been available in the district, and their previous experiences with the IL days seemed to have helped all the participants with their smooth transition to online teaching. Teachers were in the process of getting acclimated to the online teaching at the time of the data collection for this study and described that they were concerned about the lack of student motivation, student engagement, and assessment security in the online learning environment.

Category Three: Attitude toward One-to-one

Category Three examined the participants' attitude toward one-to-one technology in the classroom. Teachers' attitude can have significant influences on their perceptions and judgements regarding technology, which in turn influences the actions that they perform in the classroom. Therefore, it is important to examine their attitude along with their experiences. Despite of the minor challenges that existed, 10 out of the 12 participants expressed positive attitude towards the use of one-to-one technology in the classroom. Table 4 illustrates how the qualitative coding process rendered category three as well as the codes that are integral to the category.

Table 4

Ca*tegory Three Coding*

Category	Code Clusters	Codes
Attitude toward one-to-one	Attitude toward using	Post-pandemic thoughts
		Beliefs about the needed skills and knowledge
		Deciding factor
	Change in approach over time	
	Suggestions for implementation	

Attitude toward Using

According to TAM, perceived ease of use and perceived usefulness are believed to directly affect a person's attitude (Wong, 2015) toward using technology. Perceived ease of use is based on the thought that if technology is easier to integrate, then it is convenient. Teachers described one-to-one technology as a useful tool when it came to providing the students with visual experiences, instant feedback, and differentiated learning. Technology also allowed the teachers to stay organized and efficient.

Beth-HHS believed that if teachers had the willingness to learn and try new things, they would find it easier to learn and integrate one-to-one technology:

> I think if you are ambitious enough and you really want to try new things, you are going to learn it no matter what the barriers would be. I don't think it necessarily means like you need to have a strong background in instructional technology, you just have to have the willingness to learn.

Not all teachers believed that the technology enhanced the teaching and learning process and might not have the willingness to try and learn new technologies. This could also be related to how teachers understood the perceived ease of use and the perceived usefulness of one-to-one technology in the classroom. Seeing and experiencing that the one-to-one technology would make their teaching responsibilities easier would increase their willingness to learn.

Mason-ROC described one-to-one technology as “very helpful” when it came to providing graphing experiences for complex mathematical concepts for his students. Though not very fond of the technology in the classroom, Charles-SHS noted that technology allowed him to take his geometrical lessons to a “different level” by manipulating geometric figures and graphs using a smart board. He referenced being able to teach his students about magnifications, reductions, and scale factors using his smartboard which led to better experiences in discovering mathematics.

Technology is also useful for both teachers and students to organize the learning materials. Jessica-HHS thought some of the notetaking strategies she follows were “much more dynamic" because she used technology tools such as OneNote for notetaking. OneNote allowed her to create notebooks, sections, and pages, and incorporate graphics and multimedia within the notebook pages. Tiffany-SHS referenced that one-to-one technology was very useful for her when designing engaging lessons for her students.

> One-to-one technology has helped me reach my students, because this is a very technology-driven generation of kids that we have, so it has helped me create more interactive lessons. I am the kind of teacher who likes to do more activities with my students rather than standing in front of the classroom and just talk. Now I can make all my activities online, and they can access it from anywhere. Technology has made me even more creative in what I can do for my students.

Tiffany-SHS had always preferred doing more activities with the students and technology had made it easy for her to create rich learning experiences for her students.

The participants of this study described their experiences as positive and explained how they had been learning to effectively use technology in the classroom by experimenting with various resources, and by trial and error. This supports the Hill & Uribe-Florez (2020) finding that most mathematics teachers have a positive attitude toward technology integration and a willingness to learn and grow. Teachers see the professional learning opportunities provided by the school and district a first step in the process of learning how to effectively use one-to-one technology in the classroom. Attending these professional learning sessions does not guarantee that the teachers will implement what they learned in the session. Teachers will need to perceive the usefulness in order to actually integrate technology in the classroom.

Change in Approach over Time

Nine out of the 12 participants did not start out with a positive attitude when the one-to-one initiative was rolled out in their classrooms. Teachers did not think that the student devices would be very useful in mathematics classrooms and perceived that the laptops were going to be a distraction rather than being an instructional resource for the students. Over time, most participants started seeing the usefulness and started looking for ways to learn the effective integration of one-to-one technology to its' full potential.

Beth-HHS described it as being more conscious of what is best for her students. She thought "Just because it's out there doesn't mean it's best for your students and you don't have to throw a bunch of different things at your students to get them to understand the concept." Choosing the right educational apps and programs in the classroom can be a challenge. Mason-ROC referenced the importance of keeping yourself updated and "learn how to adapt and keep changing with time." Technology is changing every day, and it is important for a teacher to stay up to date with the changes.

Jane-EHS stated that a lot of her change of attitude towards technology use came out of necessity. She also referenced that learning about new things helped her:

> At first, laptops were a complete distraction. So, I was like, if they are going to be on it anyway, let me give them something to do on it. What can I do that will help me make my job easier? How can I use this to do some of the activities I do in class so that I don't have to grade for three hours? So, I think a lot of just spurred out of necessity, and then other parts of it spurred out of learning about new things, like learning about *Desmos* activities and stuff like that.

Jane-EHS's way of adapting to the situation suggested that she considered the perceived usefulness of using technology in the classroom. Perceived usefulness is the extent to which she believed that using one-to-one technology will enhance her job performance.

Jessica-HHS started her teaching career in a one-to-one classroom. She said, "At the beginning, it was scary, and I didn't think it was going to be effective for what I was trying to do with my students." She had vivid memories of it not going very well in her classroom. She said her attitude towards technology use improved once she became comfortable with it. As the years passed by, she remembered, "I got much better at it, finding different ways to incorporate technology. And just being comfortable with it. I feel like I am definitely much more efficient now in using technology in the classroom."

Celia-SHS stated that her attitude toward using technology changed when she saw other people using it. She remembered being "resistant" because she did not see any benefit in using technology in her classroom. She said, "It wasn't until I saw more people doing these things that just seem so amazing…Now, I am at a point where I want to learn more new things and implement it." Weston-HHS described his experiences as a continuous improvement, and he referenced that collaborating with his peers and learning from them make him a better educator:

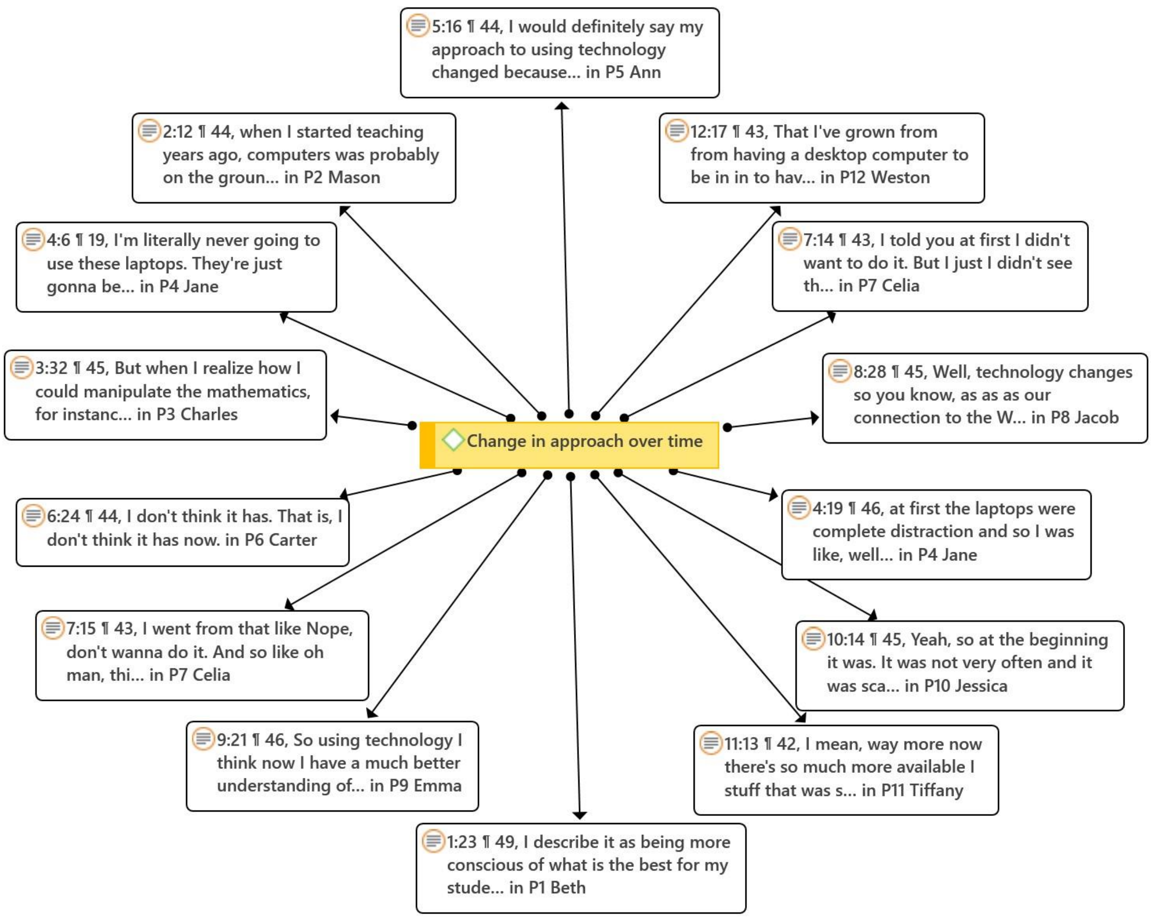
> Continuous improvement has been the change. I'm a lifelong learner and all of these technology and resources only improve me as an educator. I am constantly learning from my peers and collaborating with them in order to find out what resources they are using, or what tricks they have learned that they can pass on to me to just make me better.

Celia-SHS and Weston-HHS's experiences showed that observing the peers and learning from the peers are beneficial for the teachers to improve in technology use in the classroom.

Figure 7 shows a list of quotations showing how the participants described their change in attitude toward using technology in the classroom. While everyone described their approach has changed over time as they adapted to the situation and learned new ways to integrate technology in such a way that it is beneficial to them and their students, Carter-EHS was the only participant who commented that his attitude towards using technology has never changed.

Figure 7

Network of Quotations – Change in Attitude



Suggestions for Implementation

During the data collection process, teachers were allowed to provide suggestions or recommendations that they would like to see implemented in the district level to improve the effectiveness of one-to-one technology in the classrooms.

Emma-ROC's statement showed the importance of personalizing the professional development opportunities so that teachers are not wasting time learning something that they already knew:

> There are people who really need to be trained on how to use something, and there are people who need to be trained on how to effectively use something. I don't necessarily need to be taught how to use something because I can figure it out, but I need to be taught how to implement it in an effective way. A lot of the times, professional learning focuses on how to use something, and not quite personalized enough in the way that makes me feel like it's helping me increase my pedagogy.

Emma-ROC's statement was similar to Beth-HHS's who suggested personalizing technology use by department because what worked in one department may not work in another department. She also suggested that learning from peers is much more effective than forced professional development session.

> Don't force everybody but provide optional trainings because I feel like you are going to get more people to learn this way. I would suggest training a couple of eager folks first because it becomes popular when teachers see others using it successfully.

Beth-HHS and Emma-ROC's thoughts suggested that the professional development is better when provided based on the needs. Jane-EHS suggested that the district not spend a lot of money on resources and to get teacher input while purchasing technology for the classroom. The technology leaders were making the decisions on what software and programs to purchase. Emma-ROC thought they needed to have a list of approved programs to use because if teachers needed to use a specific technology that is not purchased by the district, they needed to go through an approval process. Sometimes this takes a long time and having a list of pre-approved programs sorted by the content area would save time.

Summary of Category Three

Category three looked at the participants' attitude toward one-to-one technology. The statements showed that all participants except Carter-EHS had developed positive attitude over time regarding the use of one-to-one technology to support the teaching and learning process in the classroom. Teachers discussed the possibilities of personalizing professional development opportunities to promote effective technology use in the classrooms. The access to one-to-one technology does not provide assurance that the teachers will use them effectively. The teacher is an integral part in determining how the technology is used in the classroom, and therefore, it is important to make sure that the teachers have the right attitude towards technology use in the classroom.

Category Four: External Variables

Category Four examined the participants' experiences with the external variables associated with the technology use in the classroom. External variables influence beliefs, attitudes, and intention to use technology. Table 5 illustrates how the qualitative coding process rendered category four as well as the codes that are integral to the category.

Table 5

Category Four Coding

Category	Code Clusters	Codes
External variables	Background	
	Professional development	Feelings about professional development
	Technology support	Resource Availability
		Admin Support
		Peer Support

Background

The classroom experiences of the informants participated in this study ranged from two to 22 years. Six of the participants first experienced one-to-one technology when they were hired to teach at this district, and the other six participants have been working for the district prior to the district's one-to-one rollout. Teachers who moved from other districts stated that they had used some technology in their previous district such as smartboards, online gradebooks, and access to computer labs, but their true one-to-one experience began when they started working for this district. Table 6 summarizes their background experience with one-to-one technology in the classroom.

Table 6

Background Experience with One-to-one in the Classroom

Participant Pseudonym	Background experience with one-to-one in the classroom		
	First experienced when hired in this district	Had some experience with technology in the classroom (but not one-to-one) prior to working in this district	Was in the district since the beginning of one-to-one implementation
Beth-HHS	✓		
Jessica-HHS			✓
Weston-HHS	✓	✓	
Charles-SHS	✓	✓	
Tiffany-SHS			✓
Celia-SHS			✓
Ann-RHS	✓		
Jane-EHS	✓	✓	
Carter-EHS			✓
Jacob-EHS			✓
Emma-ROC	✓		
Mason-ROC			✓

The participants' degree level or mathematic discipline did not seem to affect their attitude towards technology use in the classroom. Two participants had undergraduate degrees, five participants had master's degrees, two participants had specialist degree, and three participants had doctoral degrees. Despite their degree level or the courses taught, participants seemed to have positive attitude towards technology use in the classroom. The two participants who were more inclined towards traditional ways of teaching and did not prefer using technology in the classroom were the oldest among the group. The data analysis did not find any differences in technology use regarding teachers' age, background, or experience.

Professional Development

Teachers who participated in this study had access to various professional development opportunities provided by the district. However, teachers had different views on attending professional development sessions that may or may not be useful for them. Access to technology and other related resources make the teachers feel comfortable enough to experiment on their own and learn from those experiences. Teachers preferred the opportunities to collaborate with others and learn from each other.

Beth-HHS noted that she was able to "help other teachers use technology and incorporate technologies in their classrooms" and she considered it "professional development". She added that she would not put herself in a professional development unless the school required her to do so. Charles-SHS mentioned about the professional development opportunities he had in the past and admitted that he learns more from his math coach:

> I was told to go to a training where we talked about using technology in the classroom and the problems involved in it. But we do have a coach, and I spent a lot of hours with her every week, working on how to do things with technology and how to navigate the learning management system.

He preferred working one-on-one with his instructional coach in figuring what technology to use in his classroom and how to use it.

Jane-EHS stated that whenever she had the opportunity to attend technology professional development, she would choose sessions that are helpful for her content area rather than attending general sessions.

> Every year I went to the technology conference provided by the district. They were helpful because I grew up not using computer, and I needed to learn how to use computers for teaching. I also went to a state conference a few times and whenever I'm there, I try to go to technology-based sessions, especially if it has to do with my content area.

She found these opportunities valuable since she did not have a technology background and she realized it is important to learn how to integrate technology in the classroom.

In addition to the professional development opportunities provided by the district, Jacob-EHS also attended online workshops that helped him with using technology in the classroom. He had taken free online classes which introduced him to “a lot of newer apps and ways to use technology in the math classroom.” He said he was planning to take an online course about “effective virtual online teaching.” While all other participants discussed their experiences with district provided technology professional development and collaborating with peers to learn more about technology integration, Jacob-EHS was the only participant who mentioned about exploring other learning opportunities such as online workshops.

Regardless of the type of professional development offered by the district, teachers appeared to be eager to learn more about what is best for them and for their students. The plethora of resources available made it difficult for the teachers to choose what is best for them and for their students. Teachers like Beth-HHS took the initiative to try out a new technology and share the outcome with her peers. Teachers like Weston-HHS and Celia-SHS were motivated when they see others using a new technology.

Teachers seem to appreciate technology support based on the needs rather than sitting in an all-day professional learning session to learn about a new technology. Charles-SHS mentioned that working with the math coach helped learn ways to integrate technology in his instructional practices. Charles-SHS, Jane-EHS, and Emma-ROC referenced that the support from technology coaches was very helpful. Ann-RHS, being new to the district, mentioned that the new teacher training provided by the district included a session on the district’s one-to-one initiative which helped her to get started with using technology in the classroom.

Technology Support

Teachers understood that they had access to a wide variety of instructional programs and support. Jane-EHS stated:

> We have a lot. The district actually buys a lot of subscriptions and things. I don't use all of them. Everything starts in our learning management system, *itsLearning*. And it actually will do quite a bit of things. You can create assignments and assessments that will self-grade. There's a multitude of different item types you can use so it makes it interesting. I also use *Desmos*, *Deltamath*, *USA Test Prep*, *Khan Academy*, *Quizizz*, and I have access to a lot more that I don't use.

Ann-RHS referenced that she and her students had access to Microsoft Suite. "Our district is a Microsoft district, so we have the *Microsoft Suite*. We have *itsLearning* where we post everything for the students. *Deltamath* and *Desmos* are probably the two main programs that I use in the classroom." Celia-SHS mentioned several other resources that she used regularly. "Some I have never used, like *boom cards* and *Edpuzzle*, I 've heard of them, but never used them. I regularly use *Nearpod*, *Kahoot*, *Playposit*, *itsLearning*, *padlet*, *polleverywhere*, *whiteboard.fi*, *Deltamath*, *IXL*, and *Flipgrid* to engage the students."

Administrator support was another variable that helped the teachers with integrating technology in the classroom. Teachers noted that the administrators had been very supportive in finding out what type of resources teachers needed and made arrangements to provide those resources for the teachers. Jane-EHS and Celia-SHS stated that they had very supportive administrators, but they rarely received technology-specific feedback from them. Jane-EHS stated:

> I don’t think anybody looks at my *itsLearning* page to see what I have there which is kind of sad because I put a lot of effort into what I put on my *itsLearning* page. When they come to observe me, they observe what is in the classroom. I would appreciate if they looked at my virtual space and give me some feedback on that.

Celia-SHS did not think she “had a lot of administrative feedback as far as integrating technology” in the classroom. This could be related to the administrator’s background in using technology in the classroom. If they had no background in using technology in the classrooms, they probably did not know what kind of feedback to give to the teachers other than general feedback. Ann-RHS noted she sometimes received technology-specific feedback from her administrators. Jessica-HHS could not remember getting technology-specific feedback from her administrators, but she noted that they had been very supportive with getting technology resources needed for the teachers. Weston-HHS, who worked in the same school as Jessica-HHS, had similar experiences from his administrators:

> My administrator consistently checks in with us, attends our PLC meetings. She is very forward-thinking, and she brought *Study Island* to us because she went through a training and thought it would be useful for our classrooms. So, she’s hunting for things to make our jobs easier and more beneficial.

Lack of resources and support (Ertmer, 1999 & Hill & Uribe-Florez, 2020) are two major barriers teachers face when implementing technology in the classrooms. Teachers participated in this study experienced access to a variety of technology resources and technology support.

Summary of Category Four

Category Four focused on the participants’ experiences with the external variables associated with the technology use in the classroom. The participants’ background did not seem to affect their technology use in the classroom. Teachers' views regarding professional development and learning to use technology suggested that not all teachers preferred to learn the same way.

Variations

Phenomenographic study aims to identify the different ways in which a group of people experience, interpret, understand, perceive, or conceptualize a certain phenomenon or aspect of reality. To answer the second research question, the participant responses to each question were compiled into different pages in a OneNote notebook. This allowed the researcher to examine the differences in the responses. When looking for variations in the experiences, the researcher focused on the following areas:

1) Experiences using one-to-one technology during face-to-face instruction
2) Experiences during the remote instruction

During the face-to-face instruction prior to the pandemic, teachers experienced the one-to-one technology in the classroom slightly differently. Beth-HHS, Tiffany-SHS, Emma-ROC, Jane-EHS, and Weston-HHS were willing to adopt new ideas and were very appreciative of the available resources. Their experiences with using one-to-one technology focused on providing instant feedback to students, improving their efficiency as classroom teachers, staying organized, designing differentiated learning, and creating activities that promote critical thinking and creativity. They were relatively quick to embrace new technology and often took the role of a leader to support other teachers in their PLC group with technology integration. Jessica-HHS, Jacob-EHS, Celia-SHS, Mason-ROC, and Ann-RHS used technology to engage their students. They preferred using websites and self-grading programs that provided their students with additional practice. They were more willing to try out a new technology when they observed it from other teachers. Charles-SHS and Carter-EHS did not think the one-to-one technology was helpful for their students and appeared to be reluctant in trying out new things unless they had to.

While sharing their experiences with the transition to the remote teaching, all participants except Carter-EHS and Jessica-HHS indicated that they had never taught online before, and they received minimal training on how to teach online right before the school closure. Teachers noted that most of what they learned was through trial and error and from each other. All teachers responded that they had a difficult time providing quality instruction during the pandemic. The most challenging task was to hold the students accountable for their learning in a remote learning environment. As the school district changed their grading procedures to address student and parent concerns during the pandemic, teachers found it difficult to hold the students responsible for their learning. Teachers were instructed to provide extended time for students to complete their work, allowances for re-dos or retakes of assignments, and not to penalize students for missing work.

Beth-HHS, Jane-EHS, Tiffany-SHS, and Celia-SHS shared that they enjoyed teaching online and felt comfortable with the transition. Ann-RHS, Emma-ROC, Jacob-EHS, Jessica-HHS, Mason-ROC, and Weston-HHS stated their technology integration skills have improved since the transition to the online teaching, and their new skillset was going to change how they use technology in the classroom in the future.

Summary

The goal of this study was to acquire a better understanding of the lived experiences of secondary mathematics teachers who integrated one-to-one technology into their classrooms as part of a district-wide one-to-one technology initiative. This chapter analyzed different ways teachers have experiences one-to-one technology in their classroom as well as during the remote teaching. In addition to sharing their experiences with one-to-one technology, teachers also shared their attitude toward one-to-one and their experiences with the external variables that affected the technology use in the classroom.

The findings suggested that the teachers were appreciative of the one-to-one technology provided by the district. Even though the district's one-to-one technology initiative had resolved the barriers of the past such as access and availability of resources, lack of professional development etc., teachers still experienced challenges with technology in the classroom. The new challenges included filtering through all the available resources to decide what is best for the students, having a proper back up plan when technology fails in the middle of a lesson, assessment security, and managing the student use of computers. From the teachers' responses, it was evident that the teachers learned more about technology integration from their peers rather than sitting in mandated professional development sessions.

Chapter 5: Discussion and Implications

The purpose of this phenomenographic study was to acquire a better understanding of the lived experiences of secondary mathematics teachers who integrated one-to-one technology into their classrooms as part of a district-wide one-to-one technology initiative. Technology Acceptance Model, a theory that models how users come to accept and use a technology (Venkatesh et al, 2003), provided a foundation for examining the secondary mathematics teachers' experiences with the one-to-one technology in the classroom. Phenomenography emphasizes the variations in experiences and collective meaning rather than individual experience (Marton & Booth, 1997). It studies the qualitatively different ways in which people experience a phenomenon, which means it does not ask about the nature of the phenomenon (as phenomenology does) but ask about how people experience, understand, and conceptualize a phenomenon (Cossham, 2017). My overall research objective was to explore one-to-one technology in the secondary mathematics classrooms through the experiences of the mathematics teachers.

Twelve secondary mathematics teachers volunteered to participate in this study which investigated their experiences with one-to-one technology in the classroom. Considering how the COVID-19 pandemic has changed the learning environment, the study also investigated the teachers' experiences with the remote teaching environment. Using the phenomenographic perspective, I used an interview protocol to collect data on participants' experiences with one-to-one technology in the classroom as well as during the remote teaching environment. Each participant completed a semi-structured one-on-one interview, as a means of addressing the following research questions:

- How do secondary mathematics teachers describe their experiences of using one-to-one technology in their classrooms?
    - How do they describe the experiences during face-to-face instruction?
    - How do they describe the experiences during remote instruction?
- What kind of variation exists between the teachers' experiences?

Keeping the research questions in mind, I analyzed each participants' responses and identified four categories of description for their experiences with one-to-one technology: 1) experiences with one-to-one during the face-to-face instruction, 2) experiences with one-to-one during the remote teaching, 3) attitude towards one-to-one, and 4) external variables. Evidence of how the study addressed the research questions was presented in Chapter 4. To conclude, this chapter will include a discussion of the findings, implications of findings, and recommendations for future research.

Discussion of the Findings

Discussion about the findings in relation to the previous literature is organized by the research questions below:

Teachers' Experiences with One-to-one Technology in the Classroom

Even though the participants' initial reaction to the one-to-one technology indicated a mix of feelings, a majority of the participants had concerns about how one-to-one technology would impact them as teachers. Their concerns included recreating the lesson plans, beliefs that technology may not work for mathematics teaching, lack of guidance on how to effectively integrate one-to-one technology, and the management of student devices. Eventually, teachers started looking for ways to better prepare themselves to teach in a one-to-one classroom which included trying new things and learning from their mistakes, reaching out to support professionals such as an instructional coach or a technology coach, and collaborating with peers within the same department or professional learning communities.

Participants' understanding of one-to-one technology was consistent with the existing literature. Participants described one-to-one technology as each student having a device (Lawrence et al., 2018). Participants demonstrated the one-to-one technology acceptance by noting that they did not feel they needed to be technology experts to integrate technology in the classroom. Hill & Uribe-Florez (2020) found that most mathematics teachers have a positive attitude toward technology integration and a willingness to learn and grow. The participants in this study indicated they were willing to learn and adapt to the one-to-one initiative and appreciated proper guidance and support from experienced professionals during this learning process.

Digital technology was found to be less common in mathematics classrooms (Utterburg, et al., 2019; Wachira & Keengwe, 2011) probably because mathematics teaching and learning itself is a complex process and deciding when a particular form of technology maybe appropriate for a specific mathematic topic can be difficult (Hodges & Conner, 2011) for teachers. Participants referenced the plethora of resources that were available to them, both provided by the district and the free resources available on the internet, and noted that it was a challenge for them to choose the right kind of technology to incorporate in their lessons. Literature showed that the under-use of technology in the mathematics teaching can be due to the lack of emphasis on technology in teacher preparation and professional development programs (Bennison & Goose, 2010; Wachira & Keengwe, 2011). It is very critical that the teachers understand how and when to integrate what type of technology into their lessons.

Participants described that the one-to-one technology helped them become more efficient in their role as a teacher and improve their quality of instruction. Perceived usefulness was found more consistently in the participants' experiences related to the use of one-to-one technology to provide students with improved learning experiences, differentiate learning, and provide feedback to the students. Teachers were more likely to accept a technology if they believe that the new technology improves their job performance, and it is effortless to use. Jane-EHS stated that she accepted technology when she realized how technology can make her job easier especially with tasks such as grading and providing feedback to students. Teachers also saw the benefit of technology in the role that technology played in providing the students with improved learning experiences and instant feedback. Participant experiences suggested that perceived ease of use and perceived usefulness are considered to be two important determinants among many other variables that may influence the technology use (Davis, 1989; Moses et, al. 2013; DeNisco, 2014).

Digital tools are found to strengthen the activity of doing mathematics, such as visualizing, experimenting, and applying (Hegedus et, al., 2017). Beth-HHS and Charles-SHS pointed out that technology provides dynamic opportunities for teaching and learning math such as using technology to provide the students with experiences that helps to easily visualize geometric concepts. Teachers can use technology to enhance and improve the learning and make mathematical concepts come alive through interactive media. One-to-one technology enables the students to explore mathematics and make discoveries using digital tools, games, and simulations. Participants referenced programs like *Desmos* that allow the students to explore and visually experience complex mathematical content and context that would otherwise be too complex for them to explore without the technology (Wachira & Keengwe, 2011). Literature review informed us that technology integration in mathematics education should go beyond general education technology usage to include mathematics-specific technologies such as Desmos (Stohlman & Acquah, 2020). The word *Desmos* was mentioned 25 times by 9 participants in the interview transcripts. Teachers understood the perceived usefulness of using programs like *Desmos* to provide the students with a visual learning experience, and make the mathematical concepts interactive, fun, and engaging.

Technology can play an integral role in planning and implementing differentiated lessons when teachers know how to effectively use formative assessment tools to design instruction that meets the students' needs (Maeng, 2017). Beth-HHS, Emma-ROC, Tiffany-SHS, and Weston-HHS shared their experiences with using *Desmo, Deltamath,* and *IXL* to differentiate the learning for their students. Another major advantage pointed out by the teachers while describing their experiences with using one-to-one technology in the classroom was the ability to provide the students with immediate feedback and remediation. Participants in this study used various websites to accomplish this task and learning from their mistakes.

Participants' experiences pointed towards the need to develop content specific and targeted professional development (Penuel et al., 2007; Post, 2021). As Kim, Choi, and Lee (2019) stated, "a teacher's role in a one-to-one classroom is considered to be important…and hence examining the teacher-perceived advantages and challenges" are critical in designing effective professional development for teachers. The participants' experiences with learning to use technology indicated that the mandated professional development sessions provided by the district were rarely useful because they did not always meet their needs, and teachers preferred to learn based on their needs, interest, and at their own pace. The professional development provided in this district focused on products that were purchased by the district. This may be useful to expose the teachers to a new program or technology, but the teacher experiences showed that they were not willing to use it until they saw the perceived usefulness in it. Based on the experiences of the participants, some examples of preferred professional development program would include guidance on identifying and using technology to address various concepts in mathematics, how math teachers can effectively use technology to provide the students with immediate feedback and remediation, and activities focuses on different ways to integrate platforms such as Desmos in a math classroom.

Providing teachers with the opportunities to experiment and learn is important, and school districts can support this “by creating a culture that allows teachers to try out new practices while making technical and pedagogical support readily available” (Ertmer & Ottenbreit-Leftwich, 2010). Professional learning communities (PLC) such as a specific course of subject area can take the initiative to incorporate a dedicated time slot to discuss technology as part of their periodical meetings. Teachers like Beth-HHS and Jane-EHS could share their experiences with the other teachers in the group. These PLC meetings should take place weekly, bi-weekly, or monthly in order to provide personalized and ongoing learning experiences for the teachers.

Also, participants in this study did not receive much feedback on their individual classroom technology integration practices similar to how they would receive feedback from administrators on their pedagogical practices. This information adds to the existing literature which indicated that the professional development must be personalized, ongoing, and must provide feedback on teachers’ individual classroom practices (Schachter & Gerde, 2019). Instructional leaders directly and indirectly determine the success or failure of teacher competencies in instructional technology (Webb, 2011). The experiences of the participants showed that the aspect of receiving technology-specific feedback on individual classroom practices was missing. This can be attained by including technology criteria in the teacher evaluation processes and providing feedback to teachers on their individual classroom technology integration practices.

The barriers in technology integration found in the literature such as time, access, resources, and limited opportunities for professional development (O'Neal et al., 2017; Hill & Uribe-Florez, 2020) were not mentioned by the participants. Participants had access to resources and professional development opportunities. Francom (2020) found that access may not be sufficient for effective teaching and learning with technology. Participants like Charles-SHS and Carter-EHS had a different outlook on using technology in the classroom which clearly shows that having access is not sufficient for technology integration. The new barriers identified by the participants included filtering through all the available resources to decide what is best for the students, technology failure in the middle of a lesson, assessment security, and monitoring the student use of computers. Post (2021) also found that monitoring students' technology use can be difficult for teachers when students are able to access inappropriate content on their devices.

The findings also indicated that the professional development did not affect the likelihood that the teachers will accept of use the technology in the classroom. Participants credited their existing technology use in the classroom to the support from instructional coaches, peers, and their own willingness to try out different things. From the participant standpoint, support from peers and coaches had the effect of improving their perceived ease of use and perceived usefulness of one-to-one technology in the classroom. As pictured in the TAM model (Figure 2), external variables such as resource availability, peer support, administrator support, and technology support contributed towards the participants perceived ease of use and perceived usefulness. For the technology professional development programs to be effective and useful for the teachers, it must be designed specific to each content area based on the needs, and it must help the teachers see the perceived ease of use and perceived usefulness.

Teachers' Experiences during Remote Teaching

The widespread closing of schools due to COVID-19 pandemic shocked the educational community with many teachers scrambling to figure out how to shift their pedagogy to emergency remote teaching (Hodges et al., 2020; Trust & Whalen, 2020). As stated by Trust & Whalen (2020), the participants in the study reported an easier transition to emergency remote teaching because of their familiarity with the one-to-one technology in the classroom prior to the pandemic. Teachers and students knew how to use the district's learning management system. However, the participants described their actual remote teaching experience as challenging despite their previous experiences with one-to-one technology in the classroom. This is because the teachers had to use an unfamiliar platform, *Microsoft Teams,* to interact with the students and deal with other challenges involved in online teaching such as student engagement, lack of proficiency in teaching online, and assessment security that they were not familiar with before the pandemic.

Teachers had to learn the remote teaching strategies while teaching remotely. Participants in this study used *Microsoft Teams* to interact with the students and delivered the same type of instruction they would have delivered in the classroom. The expectations for online presence were unclear for the teachers and they were unable to hold the students accountable for task completion (Huck & Zhang, 2021; Trust & Whalen, 2020). However, COVID-19 pandemic was a transformative challenge for the teachers as they had to experiment and understand how to teach math through online platforms. The challenges described by the participants included student engagement in the online platform, not being able to provide meaningful learning experiences, and the inability to provide in-person teacher support when the students are engaged in problem solving.

Student engagement plays a crucial role in student learning in distance education (Martin & Bolliger, 2018). The learner-to-learner and learner-to-instructor interactions are extremely valuable for online learning and leads to increased student engagement (Martin & Bolliger, 2018). Even though the teachers knew how to use the learning management system to assign content, the interactions among the learners and between the learners and the instructor were missing in the remote teaching. As noted by Huck & Zhang (2021), teachers struggled to engage and motivate the students in the online learning environment. Roman et al., (2021) noted that the student engagement challenge was compounded by the state-wide grading policy which did not allow the students' overall course grade to drop from where it existed prior to the onset of emergency remote teaching. Teachers and students were new to *Microsoft Teams* and were not trained enough to use the interactive features of it. Selecting technology tools such as *NearPod* worked well for some teachers to engage their students and assess learning in the online platform, but majority of the participants did not know how to design quality instruction with technology for the remote learning environment to engage students.

A teacher's presence in an online classroom is important for scaffolding, facilitating, reducing distance in learning, providing more instruction about the assignments and activities, and engaging students in online learning (Khlaif et al, 2021). As noted by Lambert and Schuck (2021), "the wall" (p.289) that was created between the students and teachers in the remote teaching environment prevented the teachers from providing the support that their students needed during the learning process. Moore (2013) used the term "transactional distance" to discuss this distance between the teacher and the student. This distance made teaching mathematics online far more challenging for the participants. Challenges included supporting struggling students during mathematical problem-solving when not physically present with them (Lambert & Shuck, 2021). Gambashidze (2021) noted that if the teacher manages to establish a meaningful learning environment with the right choice of complexity and appropriate material and instills in students a sense of responsibility of their own learning, then the transactional distance diminishes.

The teachers' experiences during the remote teaching suggest the importance of establishing a shared school vision that articulates not just using the laptops in the classroom but also an understanding of how teachers can use technology to teach in such situations. As suggested by Trust & Whalen (2020), unstructured professional development such as mentoring or learner-centered activities that allow teachers to develop knowledge and skills to help them teach with technology would be ideal for preparing teachers to teach in any situation including online, remote, or blended settings. The future of education will include the online teaching and learning becoming more common in schools and teachers must be prepared in their teacher education programs to address the challenges involved in online teaching such as strategies to engage and motivate students, strategies to foster student achievement, and communicating with students and families (Huck & Zhang, 2021).

Participants' experiences with the use of technology in the classrooms prior to the pandemic was different from their experiences with remote teaching during the pandemic. Prior to the pandemic, teachers had the opportunity to learn from one another or receive support from experienced professionals when they needed support with technology integration. As Huck & Zhang (2021) noted, teachers were asked to transition to online teaching with little time to prepare, using the tools which few had fluently mastered. Online teaching requires many different skills and competencies than traditional teaching (Huck & Zhang, 2021). To address this, researchers recommended providing targeted professional development for administrators and teachers, and prioritizing time for teachers to experiment and practice with technology (Huck & Zhang, 2021; Wachira & Keengwe, 2011).

Variations in Teachers' Experiences

Variation theory, a theoretical extension of phenomenography, was used to inform how participants experienced one-to-one technology differently. Teachers' attitudes towards technology and self-efficacy play a significant role in their willingness to use technology as a tool for instruction (Letwinsky, 2017). The participants in this study can be categorized into three groups based on the variations in their experiences. As O'Neal et al, (2017) stated, the variation in their technology use could be related to their beliefs and attitudes regarding the role of technology in teaching and learning.

The first group appreciated the available resources and were very fast in adopting and implementing new ideas. They described that the one-to-one technology helped them become more efficient and create authentic learning experiences for their students. Vongkulluksn et al. (2018) found that the teachers who believed that important instructional goals can be met with the help of technology are more likely to integrate technology effectively. This "value belief" (Vongkulluksn et al., 2018) also predicted how well teachers integrated technology in their classrooms. Their experience with using technology can also be related to their beliefs regarding perceived ease of use and perceived usefulness (Davis, 1989).

The second group appreciated the availability of one-to-one technology but their use of technology in the classroom was limited to using basic programs that would self-grade and provide the students with additional practice. McCulloch et al. (2018) found that many mathematics teachers use technology as a simple calculational tool rather than using it to develop student understanding or to increase their proficiency in mathematics. The experiences of this group of teachers can also be connected to the lack of design thinking (ability to create learning materials and activities, adapting to the instructional needs for different contexts or varying groups of learners), the third-order barrier noted by Tsai and Chai (2012). Tsai and Chai (2012) believed that the teachers can undertake technology integration actively and fluently by reducing this third-order barrier.

The third group did not believe that the one-to-one technology was helpful in teaching and learning math and did not attempt to incorporate technology into their classroom unless they had to. These teachers did not find value in using technology to teach mathematics and was reluctant to use technology in their teaching. This could be attributed to the fact that technology was neither a part of their teaching when they first started to teach, and it may not have been easy for them to adjust to new ways (Batane & Ngwako, 2017). This group of teachers did not consider technology as a useful tool to do their teaching job, and they were not motivated to use it.

The variations in teachers' experiences could be related to variations in their perceptions regarding the perceived ease of use and perceived usefulness of using one-to-one technology in the classroom. Similar to what Francom (2020) stated, having access to technology and resources may not be sufficient for effective teaching and learning, and some teachers in this study still maintained traditional teaching practices. As Kopcha (2012) noted, the teacher perceptions regarding technology integration can be improved through professional development. While the exposure to professional development opportunities is important, this variation in teachers' experiences indicate several factors that play an important role in translating teachers' professional development experiences to actual classroom practices such as value beliefs, beliefs related to perceived ease of use and perceived usefulness. The same model professional development may not work for the different groups of teachers with varying perceptions regarding the technology use. The variation in teachers' perceptions and experiences suggests the importance of designing professional learning and providing learning opportunities based on the teachers' needs.

Limitations of the Study

The mathematics teachers' descriptions represent snapshots of their experiences with one-to-one technology. Teachers shared that their initial perceptions towards using one-to-one technology in the math classroom have changed since the first time they experienced one-to-one technology in their classrooms. Therefore, the teacher perceptions are limited to the duration of the study under the assumption that the teacher perceptions will continue to change as they gather more experience with using one-to-one technology in their classrooms. This study was conducted within one school district and focused on high school mathematics teachers' experiences with using technology in the classroom. The participants in this study had access to one-to-one technology and a variety of other technological resources which eliminated the access issues that may still exist in other school systems. The research population for this study may not be representative of populations in other school district, and the results may not be transferable to other school district or subject areas.

Recommendations for Future Research

This study focused on secondary mathematics teachers' experiences with one-to-one technology. Due to the phenomenographic approach used, this study had a limited number of participants. Also, the participants all taught the same content area in grades 9-12. Their participation in my study demonstrated possible perceptions in the ways one-to-one technology is used in the mathematics classroom. A study including a larger sample size and across different grade levels and content areas would be beneficial in order to see if the findings of this study will be similar or not.

The findings of this study suggested how the secondary mathematics teachers experienced the one-to-one technology in their classrooms. The following questions emerged from this study that need to be addressed:

1) Do the mathematics teachers in elementary and middle schools experience one-to-one technology similarly?
2) Do the mathematics teachers in a different school district experience one-to-one technology similarly?
3) How do teachers of other content area in the same district or in a different school district experience one-to-one technology?
4) How efficiently can the mathematics teachers use one-to-one technology to improve the students' conceptual mathematics knowledge?
5) How do the students taking secondary mathematics courses experience one-to-one technology in their math classrooms?

Future studies may also look more closely at how different elements or external variables such as teachers' backgrounds, age, or gender affected their acceptance to use one-to-one technology. It may be beneficial to investigate this subject using a quantitative approach to see the impact of various elements on teacher use of one-to-one technology.

Implications

The findings from this study have implications for school district leaders, administrators, technology coaches, and teacher educators. The findings informed the need for a professional development model that supports teachers' acceptance and use of one-to-one technology in the classrooms.

District leaders may need to rethink about spending money on professional development that may not be useful for teachers and provide personalized professional experiences based on teacher needs, and making sure teachers have a voice in the process (Hall & Trespalacios, 2019). Hall & Trespalacios (2019) also noted that personalized professional learning experiences that engage teachers in translating learning into practice are important for the success of large-scale technology implementations. School leaders may want to consider this when designing any future technology professional development programs. Rather than providing them with one or two sessions of technology professional development, as suggested by Trust & Whalen (2020), an unstructured professional development such as mentoring or learner-centered activities that allow teachers to develop knowledge and skills to help them teach with technology is recommended. Additionally, a program where teachers can learn from each other is also recommended because several participants mentioned about the support from their peers during their learning process.

Administrator support can play a key role in shaping teachers' practices (Ertmer et al., 2012). Administrators and technology coaches could provide technology-specific feedback and motivation on what teachers are doing well with the technology, and what they need to improve on. Teachers need time to gradually become comfortable with technology and slowly increase the scope of use, and feedback on their existing technology integration practices can be helpful.

Teacher educators in general may consider factors that have a determining role in teacher acceptance such as perceived ease of use and perceived usefulness. Formulating procedures and creating facilitating conditions for the maximization of technology use which involves design thinking that goes beyond the TPACK knowledge perspective will assist the teachers to take their technology use to the next level. As stated in the National Council of Teachers of Mathematics (NCTM, 2015) position statement, strategic use of technology in the teaching and learning of mathematics in thoughtfully designed ways at carefully determined times enhance how students and educators learn, experience, communicate, and do mathematics. Findings in this study indicated several ways teachers perceived the usefulness of technology in the math classroom, such as providing the students with the visual experiences, providing instant feedback to the students, and differentiating the learning based on student needs (Hegedus etal., 2017; Picha, 2018; Stohlman & Acquah, 2020). Mathematics teacher educators could consider focusing on providing strategies on how technology can be used to enhance the teaching and learning experiences.

Conclusion

Throughout this entire process of data collection and analysis, I have had the opportunity to personally reflect on my own perceptions of using technology in the math classroom. I believe that the integration of one-to-one technology in the mathematics classroom is critical to reach today's students and the significance of it is worthy of further inquiry. One-to-one technology allowed the mathematics teachers who participated in this study to improve their instructional practices, provide personalized and differentiated learning based on the student needs, and provide timely and useful feedback to their students. I further believe that the one-to-one technology has caught the attention of many educators regardless of their experience or background in using technology. As a mathematics educator, I also believe that the use of one-to-one technology in the mathematics classroom can positively impact the teacher which in turn can have a positive impact on students' learning and mathematical achievement.

Studies have shown that digital tools can strengthen the activity of doing mathematics (Hegedus et al., 2017) and provide powerful capabilities for offering students access to mathematical content and contexts that would otherwise be too complex for them (Wachira & Keengwe, 2011). Studies have also shown that the digital technologies are less common in mathematics classrooms (Utterberg, et al., 2019, Wachira & Keengwe, 2011), and have been particularly challenging in mathematics classrooms when it comes using technology as a learning tool (Niess & Roschelle, 2018). Knowing the mathematics teachers' actual experiences with the one-to-one technology is a worthwhile contribution to the literature. This knowledge provides a valuable contribution to the curriculum and instructional technology development.

One-to-one technology is becoming increasingly available for the school districts, and the COVID-19 pandemic pushed several school districts to provide each student with a device. As the National Council of Teachers of Mathematics (2015) suggested, strategic use of technology in the teaching and learning of mathematics can enhance how teachers and students learn, experience, communicate, and do mathematics. I believe that true instructional reform in the mathematics classroom is possible through the use of one-to-one technology.

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Appendix A

Phenomenographic interview protocol

Section	Questions
Opening	I would like to thank you for agreeing to participate in this interview today. My name is Safna Kalariparambil and I am a doctoral student at Kennesaw State University conducting research on the experiences of secondary mathematics teachers with our school district's one-to-one technology initiative. I would like your permission to record this interview for transcription purposes. Your responses will remain confidential and will be used only for education and research purposes. The interview will take approximately 60 minutes and will include 20 questions regarding your experiences with using technology in your classroom. The interview is divided into two parts. Part one will cover your experiences with using one-to-one technology in the classroom prior to the pandemic. Part two will cover your experiences using one-to-one technology during the remote teaching. There are no right or wrong answers to the questions I ask you. The questions are open-ended. I would appreciate if you could elaborate on your answers since my goal is to gather a detailed description of your experiences. I may ask follow-up questions so that we can arrive at a deeper understanding of your experiences with the one-to-one technology. I will be glad to repeat the questions or clarify the questions if needed. After each question, I will leave some open time if you need time to think. Do you have any questions or concerns before we begin?
Part 1	
Background & definitions	1. What does the word one-to-one technology mean to you? (Attitude) 2. Describe your background in using technology in the classroom? (External Variables) a. How did you learn how to integrate technology in the classroom? (Facilitating Conditions) b. How and in what ways have you participated in professional development activities that targets the use of technology in your content area? (External Variables) 3. What skills and knowledge do you find useful in using one-to-one technology in your math classroom? (Perceived Usefulness)
Describing experiences	4. Can you describe your first thought or impression when you learned that you will be teaching in a one-to-one classroom? (Attitude Toward Using) 5. Describe your experiences with the independent learning days prior to the global pandemic? (Perceived Ease of Use) 6. Please tell me about the types of technology that are available for you and for your students. (Facilitating Conditions). a. How do you decide what type of technology to incorporate into your lessons? 7. Describe your experience with designing and implementing a technology-rich lesson for your students? (Perceived Ease of Use)

	a. Can you tell me about a successful experience you have had with one-to-one technology in your classroom? What made it successful? (Perceived Ease of Use) b. Can you tell me about a challenging experience you have had with one-to-one technology in your classroom? What made it challenging? (Perceived Ease of Use) c. When something did not work as planned in your lessons using technology, how were the adjustments made? Could you please provide an example? (Perceived Ease of Use, Facilitating Conditions) 8. Can you describe your experience with the support from administrators in integrating technology in the classroom? (External Variables)
Comparing experiences	9. Did your approach to using technology in the classroom change over time? How do you describe the change? (Attitude Toward Using)
Beliefs	10. How have one-to-one technology in the classroom helped or hindered your daily responsibilities as a teacher? (Perceived Usefulness) 11. Did integrating technology into your mathematics teaching practices help you improve your teaching experience? (Perceived Usefulness) 12. Do you believe that the technology enhances the way your students learn mathematics?
Part 2	
Background & definitions	13. What does the word remote teaching mean to you? (Attitude) 14. What is your background in teaching online? (Facilitating Conditions)
Describing experiences	15. Can you describe your first thought or impression when you learned that the district has decided to implement 100% virtual learning for the semester? (Attitude Toward Using) 16. Can you describe your experience with teaching with technology during the remote teaching? (Perceived Ease of Use)
Comparing experiences	17. How have your experiences with independent learning days impacted your transition to remote teaching? (Perceived Usefulness) 18. When we get back to normal school days, will there be any change in the way you have used technology in the classroom? Did the global pandemic help you expand your skillset in using technology in the classroom? (Attitude)
Closing	19. Are there any ideas or recommendations you might have for the district instructional technology department, or for the other schools that might want to implement one-to-one initiatives? (Behavioral Intention) 20. What advice would you give to a teacher who is new to a one-to-one classroom? (Behavioral Intention) Reflection: Is there anything else you would like to add, something that I did not ask but you would like to share?

	Thank the participant for their time and cooperation. Ask for the best way to contact them in case I have any follow up questions or need any clarification in what was shared today.

Guidelines for follow-up questions:

Questions such as “Could you please provide an example?” or “What do you mean by that?” maybe needed to get a detailed explanation from the participant. After practicing the interview with a colleague, Green (2005) identified the following techniques of prompting during the interview without detracting from the rigorous data (p.37):

Seeking clarification:
‘Tell me more about that …’
‘Describe that to me from start to end.’
‘Tell me how you felt about that …’
Playing the naïve:
‘What do you mean? I am not clear …’
‘Your substantive area is not my own and so there are some things here that I am not clear about. (e.g., You used the term ‘XXX’, can you define it for me.)’
Exploring contradictions:
‘It is interesting to me that earlier you noted that X was significant, but later you talked about Y. These seem to contradict each other. Can you tell me about that?’

Appendix B

INFORMED CONSENT

Title of Research Study: One-to-One Technology Integration: A Phenomenographical Study of the Experiences of Secondary Mathematics Teachers in a One-to-One School District

Researcher's Contact Information:

Researcher: Safna Kalariparambil Contact: skalarip@students.kennesaw.edu
Adviser: Dr. Laurie Dias Contact: ldias@kennesaw.edu

Introduction

You are being invited to take part in a research study conducted by Safna Kalariparambil of Kennesaw State University. Before you decide to participate in this study, please read this document in its entirety, and ask questions about anything that you do not understand.

Description of Project

The purpose of the study is to acquire a better understanding of the experiences of secondary mathematics teachers with one-to-one technology in their classrooms.

Explanation of Procedures

This study is designed to gather information about teachers' experiences with integrating one-to-one technology in the math classrooms. Participation in the research study involves being interviewed by the researcher. The interview is divided into two parts. Part one will cover your experiences with using one-to-one technology prior to the pandemic. Part two will cover your experiences using one-to-one technology during the remote teaching. The interview will take place in Microsoft Teams and will be recorded for transcription purposes. The questions are open-ended, and the investigator may ask follow-up questions during the interview to acquire a better understanding of your experiences. During the data analysis, the researcher will contact you again if there is a need for clarification on any information you shared during the interview.

Time Required

The interview will take approximately 60 minutes. If the researcher has clarification questions after the interview, a follow-up interview or an email follow-up may be needed.

Risks or Discomforts

Your confidentiality as a participant in this study will remain secure. You will not be identified by name in any reports. Other faculty members and administrators from your school will not be present in the interview nor have access to the interview data, notes, recordings, or transcripts. You will not experience risks or discomfort beyond what is experienced in a normal day of life. If you decide to participate in the study and change your mind, you have the right to withdraw at any time. You may elect to decline to answer questions or stop participating at any time. Interview requires your time that might involve some scheduling discomfort for you.

Benefits
While there will be no direct benefit for participation in this study, participants will gain satisfaction through engaging in education research, communicating their professional experiences and concerns, and contributing to the limited, but much needed, field of K-12 one-to-one technology integration research.

Compensation (if applicable)
To compensate your time, an amazon gift card of $15 will be given to you at the end of data collection for participating in this study. Based on your preference, the gift card can be mailed to your home address or delivered to your school building.

Confidentiality
The results of this participation will be anonymous. No identifying information is collected. For the purposes of analysis and dissemination, pseudonyms will be used when referencing the participants and research context. References to people, places, or things that may be mentioned by you during the interviews will be replaced by pseudonyms to avoid identification of participation during the transcription process and final analysis. The interview transcript will be sent to you for your review. Signed consent form, interview transcripts and interview recordings will be stored in KSU's OneDrive on a password protected computer only accessible by the primary investigator. All data will be destroyed three years after the study's completion in April 2024.

Inclusion Criteria for Participation
You are selected based on your experiences with teaching mathematics using technology in a one-to-one school district. Participants must have at least one year of experience teaching in a one-to-one classroom.

Signed Consent
I agree and give my consent to participate in this research project. I understand that participation is voluntary and that I may withdraw my consent at any time without penalty.

____
Signature of Participant or Authorized Representative, Date

____
Signature of Investigator, Date

Note: Completing and submitting the Research Participation Interest & Informed Consent Acceptance Form (link provided in the email) will count as your digital signature. You do not need to physically sign this document.

Research at Kennesaw State University that involves human participants is carried out under the oversight of an Institutional Review Board. Questions or problems regarding these activities should be addressed to the Institutional Review Board, Kennesaw State University, 585 Cobb Avenue, KH3417, Kennesaw, GA 30144-5591, (470) 578-7721.

Appendix C

Research Participation Interest & Informed Consent Acceptance Form

1. I have read the Informed Consent Form (click the link above to read) *

◯ Yes

◯ No

2. I agree and give my consent to participate in this research project. *

◯ Yes

◯ No

3. Enter your first and last name.
(This will count as your digital signature for the informed consent.) *

Enter your answer

4. Date signed: *

Please input date (M/d/yyyy)

5. Contact Information (Please provide the best way to contact you regarding scheduling a Teams appointment - work or personal email address or phone number) *

Enter your answer

6. Grades you teach (Check all that apply) *

- [ ] 9
- [ ] 10
- [ ] 11
- [ ] 12
- [ ] Other

7. Please list the courses you teach *

Enter your answer

8. Number of years teaching at this school district *

Select your answer

9. How would you prefer your Amazon gift card delivered? *

- ◯ Digital delivery to my email address
- ◯ Send via USPS to my home address
- ◯ Hand deliver to my school building front office

10. Optional:
I have the following question(s) about my participation.

Enter your answer

Appendix D

Code Listing

Project: One-to-One

Report created by Safna K on 7/11/2021

Code Report – Grouped by: Code Groups

All (45) codes

Attitude toward one-to-one

Created by Safna K on 6/21/2021

7 Codes:

- **Attitude toward learning**

  Created by Safna K on 6/23/2021

- **Beliefs about needed skills and knowledge**

  Created by Safna K on 6/21/2021

- **Change in approach over time**

  Created by Safna K on 6/21/2021

- **Deciding factor**

  Created by Safna K on 6/21/2021

- **Post-pandemic thoughts**

  Created by Safna K on 6/21/2021

- **Suggestions for implementation**

  Created by Safna K on 6/21/2021

- **Understanding of one-to-one**

  Created by Safna K on 6/21/2021

Experiences during the face-to-face instruction

Created by Safna K on 6/21/2021

21 Codes:

- **Challenging experience**

  Created by Safna K on 6/21/2021

- **Classroom management**

  Created by Safna K on 6/21/2021

- **Designing lessons**

  Created by Safna K on 6/21/2021

- **Differentiating with technology**

  Created by Safna K on 6/21/2021

- **Experience with ILD days**

  Created by Safna K on 6/21/2021

- **Experience with learning to use technology**

  Created by Safna K on 6/21/2021

- **Experiences dealing with challenges**

  Created by Safna K on 6/21/2021

- **Feelings about one-to-one**

  Created by Safna K on 6/21/2021

- **Grading**

  Created by Safna K on 6/21/2021

- **Learning from peers**

  Created by Safna K on 6/21/2021

- **Learning from PLC**

Created by Safna K on 6/21/2021

- **Planning for ILD days**

  Created by Safna K on 6/21/2021

- **Preparedness for one-to-one**

  Created by Safna K on 6/21/2021

- **Providing feedback to students**

  Created by Safna K on 6/21/2021

- **Real life connections**

  Created by Safna K on 6/21/2021

- **Self-learning**

  Created by Safna K on 6/21/2021

- **Success factors**

  Created by Safna K on 6/21/2021

- **Successful experience**

  Created by Safna K on 6/21/2021

- **Technology & instruction**

  Created by Safna K on 6/21/2021

- **Technology & teacher responsibilities**

  Created by Safna K on 6/21/2021

- **Visual experience**

  Created by Safna K on 6/21/2021

Experiences during the remote instruction

Created by Safna K on 6/21/2021

10 Codes:

- **Experiences with remote teaching**

  Created by Safna K on 6/21/2021

- **Feelings about remote teaching**

  Created by Safna K on 6/21/2021

- **Feelings about the transition**

  Created by Safna K on 6/21/2021

- **Impact of ILD days on transition**

  Created by Safna K on 6/21/2021

- **Online teaching & learning background**

  Created by Safna K on 6/21/2021, modified by Safna K on 6/23/2021

- **Preparedness for remote teaching**

  Created by Safna K on 6/21/2021

- **Remote teaching challenges**

  Created by Safna K on 6/21/2021

- **Student motivation in remote teaching**

  Created by Safna K on 6/21/2021

- **Transition to remote teaching**

  Created by Safna K on 6/21/2021

- **Understanding of remote teaching**

  Created by Safna K on 6/21/2021

External variables

Created by Safna K on 6/21/2021

7 Codes:

- **Admin support**

  Created by Safna K on 6/21/2021

- **Background**

  Created by Safna K on 6/21/2021

- **Feelings about PL**

  Created by Safna K on 6/23/2021

- **Peer support**

  Created by Safna K on 6/21/2021

- **Professional development**

  Created by Safna K on 6/21/2021

- **Resource availability**

  Created by Safna K on 6/21/2021

- **Technology support**

  Created by Safna K on 6/21/2021

Appendix E

Outcome Space Table (Adapted based on the work of Han and Ellis, 2019)

Categories	Descriptions	Representative Statements
Experiences during the face-to-face instruction	Experience with learning to use technology	We have mandated professional development. Sometimes it's useful, sometimes it's not. I am pretty much the type of person that likes to figure things out on my own. So, I don't usually try to put myself in a professional development unless they require us to do it. – Beth-HHS I had great support from my peers in the math department who constantly helped me to improve my own learning process as far as how to implement technology in the classroom. And the trial and error that came with it was not as dreadful as it could have been because I had a lot of peer support. – Weston-HHS
	Experience with IL days	… give something simple for the kids to complete about content that I have already gone over in class, not really asking them to go out of their way to learn something on their own. – Tiffany-SHS … didn't use the IL days to introduce new content because honestly, I didn't trust that that they would do it or understand it well enough. – Carter-EHS
	Successful experiences	Giving students like actual simulations so that they could

		see what's going on real time. – Beth-HHS … found that those experiences were very valuable, very engaging, interactive and the students got instant feedback as they were working through problems. – Jacob-EHS … the success with that has been the connections that I have been able to make with the students to make the learning fun and challenging. – Weston-HHS
	Challenging experiences	You planned this activity, and the network goes down… Those are the things that are frustrating. Sometimes you spent 10 minutes trying to get it to work, and you realize, you just wasted 10 minutes. Those are disappointing times. – Jacob-EHS There is so much stuff out there and figuring out what to incorporate is hard. – Emma-ROC You always have that person who was watching basketball or football on their computer while we are trying to find the zeros of a quadratic. – Charles-SHS
	Technology and teacher responsibilities	Now there are several quality platforms that can ease our grading responsibilities. It's allowed me more time to do other stuff such as differentiating or research more stuff instead of just grading all day and night. It's

		fast on the kids' side too. They get that instant feedback without having to wait for you to take it home and bring it back. – Tiffany-SHS It immediately tells them if they're right or wrong. It explains how to do it if they got it wrong, and that's something I cannot provide for them at home. It's much better than them turning in something that I'm going to grade a week later. – Jane-EHS
	Technology and instruction	… easily use technology to identify kids in different groups and provide practice based on their levels. – Emma-ROC For example, today I taught about cross sections of 3 dimensional figures, and you can provide students with the simulation showing a plane going through a cone and having them see in real time like what is the cross-section shape. I think that is very important because it provides the spatial reasoning for them and make it more concrete for them. – Beth-HHS Math is hard to see in your mind unless you just have a math mind. For those folks that doesn't have a math mind, technology helps them see it. – Mason-ROC
Experiences during the remote instruction	Preparedness for remote teaching	I thought that I was going to be more prepared because I had been teaching a few units

		flip model. Our district was more prepared because we were already one-to-one. – Jane-EHS I had to figure it out, so me and another teacher friend of mine, we got together that Saturday. I went over to her house, and we actually played with it, her being a teacher and I being in her class and vice versa to try to figure out the little nuances of Teams…I know the situation was pretty much same for everybody in the district. – Celia-SHS
	Transition to remote teaching	It is not simply a transition from classroom practices being done virtually. I think it needs to be a modified schedule. It needs to be a modified curriculum and modified planning and instruction. – Weston-HHS When we went into the remote teaching mode, it wasn't a matter of familiarity. I was already familiar with it. – Charles-SHS
	Experiences with the student engagement during remote teaching	I am still getting hand raises, and still getting the feedback from them. They are still answering questions and they are all following along with me for the most part. – Beth-HHS I feel very comfortable using all the technology that we are required to use. Maybe the area I can improve on is

		probably the student engagement because in some of my classes, students are not engaged. – Ann-RHS The most frustrating thing is the students not logging in to the meeting on time. And it has been the same students. – Tiffany-SHS
Attitude toward one-to-one	Attitude toward using	…if you are ambitious enough and you really want to try new things, you are going to learn it no matter what the barriers would be. I don't think it necessarily means like you need to have a strong background in instructional technology, you just have to have the willingness to learn. – Beth-HHS I am the kind of teacher who likes to do more activities with my students rather than standing in front of the classroom and just talk. Now I can make all my activities online, and they can access it from anywhere. Technology has made me even more creative in what I can do for my students. – Tiffany-SHS
	Change in approach over time	At first, laptops were a complete distraction. So, I was like, if they are going to be on it anyway, let me give them something to do on it. What can I do that will help me make my job easier? How can I use this to do some of the activities I do in class so that I don't have to grade for three hours? So, I think a lot

		of just spurred out of necessity, and then other parts of it spurred out of learning about new things. – Jane-EHS I got much better at it, finding different ways to incorporate technology. And just being comfortable with it. I feel like I am definitely much more efficient now in using technology in the classroom. – Jessica-HHS Continuous improvement has been the change. I'm a lifelong learner and all of these technology and resources only improve me as an educator. I am constantly learning from my peers and collaborating with them in order to find out what resources they are using, or what tricks they have learned that they can pass on to me to just make me better. – Weston-HHS
	Suggestions for implementation	There are people who really need to be trained on how to use something, and there are people who need to be trained on how to effectively use something. I don't necessarily need to be taught how to use something because I can figure it out, but I need to be taught how to implement it in an effective way. A lot of the times, professional learning focuses on how to use something, and not quite personalized enough in the way that makes me feel like it's helping me increase my pedagogy. – Emma-ROC

External variables	Professional development	I was told to go to a training where we talked about using technology in the classroom and the problems involved in it. But we do have a coach, and I spent a lot of hours with her every week, working on how to do things with technology and how to navigate the learning management system. – Mason-ROC Every year I went to the technology conference provided by the district. They were helpful because I grew up not using computer, and I needed to learn how to use computers for teaching. – Jane-EHS
	Technology support	We have a lot. The district actually buys a lot of subscriptions and things. I don't use all of them. – Jane-EHS My administrator consistently checks in with us, attends our PLC meetings. She is very forward-thinking, and she brought Study Island to us because she went through a training and thought it would be useful for our classrooms. – Weston-HHS