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COVID-19, Technology, and the Math Classroom: Changes, Obstacles, and Victories Integrating Digitally

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COVID-19, TECHNOLOGY, AND THE MATH CLASSROOM:

CHANGES, OBSTACLES, AND VICTORIES INTEGRATING DIGITALLY

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ABSTRACT

COVID-19, TECHNOLOGY, AND THE MATH CLASSROOM:
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Old Dominion University, 2021
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Secondary math teachers faced new experiences and struggles this past virtual school year due to the global COVID-19 pandemic. Nine secondary math teachers from a school division in southeastern Virginia participated in this qualitative single case study. Data collection included individual semi-structured interviews and technology integration artifacts. Through a three round coding process, ten themes emerged to answer the following three research questions: 1) In terms of curriculum, teaching methods, and assessments, how did teachers describe their pedagogical change in virtual learning? 2) How do teachers perceive student performance has changed within the virtual learning space? 3) From teachers' perspectives, how has the digital divide and educational inequities affected students' virtual learning based on student race? The data were analyzed through two theoretical lenses: Critical Race Theory (Ladson-Billings & Tate, 1995) and Technological Pedagogical and Content Knowledge (Mishra & Koehler, 2006). Some of the themes included level of rigor, classroom structure, technology integration, and academic dishonesty. None of the participants felt that educational inequity based on student race manifested this past school year. Implications for practice include preparing teachers for potential curriculum gaps and encouraging classroom modifications that support student learning. Implications for future research include operationally defining technology integration, researching technology integration in other content areas, and gathering data on the student experience during virtual instruction.

Keywords: TPACK, CRT, COVID-19, virtual math instruction, technology integration

In loving memory of my grandparents

Charles E. Fifield Sr. and Nancy A. Fifield.

Although you aren't physically here to see my journey,

I know you are looking down from heaven.

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I know my village has so many more people than listed here. I had support from friends, family, and colleagues. For anyone who supported me during these past few years I am so grateful for you. This has been a life changing experience and I appreciate anyone who has been a part of it.

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CHAPTER 1

Introduction

It was Friday the 13th, March 13th, 2020 at 2:55pm to be exact. I received an email from one of my administrators that we had an emergency faculty meeting after school. My instinct was that schools would be temporarily closing due to the current COVID-19 pandemic. I had already reworked my pacing calendar and determined the most important Algebra 1 content that still needed to be taught in the remainder of the school year. I had found online resources and started to get my Algebra 1 teacher team ready for this possible virtual switch. During the faculty meeting, the school administrators did indeed inform us that schools were closing for two weeks per Virginia Governor Northam's emergency order. The teachers were informed that the Teaching and Learning Supervisors would be creating our class materials for the two-week closure and new content was not supposed to be taught. My pacing was immediately thrown out the window. While I had originally felt like I had a plan in the works, I quickly realized that most things were taken out of my hands. I had to go with the flow and deal with this pandemic as it affected me, my team, and my students.

Over the next two weeks, I spent time creating a Google Classroom (2020) and getting my students to understand how our lessons and assignments would be set up in this online platform that I had never used. On March 23, Governor Northam closed public schools for the remainder of the school year (Exec. Order No. 53). While the physical buildings would be closed, the learning would still be facilitated through a virtual setting. The Algebra 1 team and I worked to create online video lessons, practice assignments, and Google Form assessments. We tried our absolute hardest to still teach the intended Algebra 1 curriculum; however, none of us was really ready for virtual teaching. We didn't have the knowledge on how to use some of the

online platforms. We didn't have the technology at our homes to assist with creating and recording class material. In the year 2020, with technology at the forefront of almost everything, teachers and students were still not technologically ready for virtual learning.

Students faced additional challenges, such as lack of Internet in the home or not having a computer. Parents may have been working and students were caring for themselves and possibly their siblings. Multiple students in the home created difficulty with technology use, because every student needed a device to complete their work. Overall, the months of March to June were uncharted waters for teachers, parents, and students, and often led to immense frustration with trying to teach and learn virtually. During the summer months, school boards across Virginia had to make the tough decision about what the fall semester would look like for public schools. In Hampton Roads, all public schools decided to start the school year virtually. The different school divisions had slightly varying plans for how students would physically return to school, but the constant remained that school would be starting in a virtual space. With the knowledge gained from March to September, were teachers and students now technologically ready to teach and learn virtually?

My experiences during the initial virtual instruction due to the COVID-19 pandemic, as well as my experiences thus far in the 2020-2021 school year, greatly influenced the focus of this dissertation study. As a math educator who has had to change my viewpoint on curriculum importance, effective teaching strategies, and new methods of assessment, I find it extremely important to study how math education has been affected in the secondary school setting due to virtual education. In this study, I investigated how math teachers' pedagogies have changed, as well as their view on student performance, due to the current global pandemic. I also researched how educational inequities have changed. In this chapter, I will describe the history of COVID-

19 globally, in the United States, and specifically in the state of Virginia. I will then elaborate on the digital divide and technology inequities in public education. Lastly, I will explain the chapter structure of my dissertation.

History of COVID-19 Globally

To make sense of this drastic shift of face-to-face learning to a virtual environment, I find it important to understand the history of the COVID-19 pandemic that caused these educational changes. COVID-19 is the abbreviation for the novel Coronavirus Disease 2019 caused by the SARS CoV-2 virus (Lango, 2020). The initial mark in time for COVID-19 was in December 2019 when Li Wenliang, a doctor in Wuhan, China, reported multiple patients with SARS-like symptoms. These SARS-like symptoms included fever, cough, sore throat, and headache (dos Santos, 2020). The World Health Organization (WHO) in China was notified about the concern of similar symptoms of the previous SARS epidemic at the end of December. The Archived WHO Timeline – COVID-19 statement (2020) indicated that on January 5, 2020, the WHO published the first news on the disease outbreak. The initial cases in Wuhan, China were associated with the Huanan South China Seafood Market, where snakes, birds, and bats are sold (dos Santos, 2020).

By January 13, 2020, the first COVID-19 case was reported in Thailand and on January 30, 2020 the WHO declared the outbreak a Public Health Emergency of International Concern (WHO, 2020). In just a few short months, on March 11, 2020, the WHO officially declared COVID-19 a pandemic (Lango, 2020; WHO, 2020). Specifically, COVID-19 was considered to be a pandemic due to its speed and scale of disease transmission (dos Santos, 2020). As of March 29, 2020, the WHO confirmed 574,444 cases globally with 26,654 deaths (Jahangir et al., 2020). Since March, COVID-19 has continued to spread quickly and infect many people in the world.

By June 17, 2020, 8,142,129 cases had been reported worldwide since December 31, 2019, as well as 443,488 reported COVID-19 deaths (dos Santos, 2020). Dos Santos indicated that by June 2020 the United States and Brazil had the highest number of cases with 2,137,731 and 923,189 respectively. The United States' cases more than doubled the next highest country's cases.

History of COVID-19 in the United States

The United States attempted to implement measures to prevent the spread of COVID-19 into our country; however, these measures were unsuccessful. For example, on January 31, 2020, the United States began to prevent people from entering the country who had recently visited China (Lango, 2020). This measure was too late since the first COVID-19 positive case in the United States was in Washington State on January 21, 2020 (The American Journal of Managed Care [AJMC], 2021). This person had returned from Wuhan, China on January 15th and brought the disease with them. On February 3, three days after the WHO declared a public health emergency, the United States also declared a public health emergency. The United States barred entry of travelers from any European countries on March 11, 2020 (Lango, 2020); however, COVID-19 had already made its way into the United States. With the increasing positive cases in our country, a national emergency was declared on March 13, 2020 (AJMC, 2021). By March 19, California became the first state to issue a stay-at-home order, essentially having all residents stay home unless they were essential workers. While many states implemented strategies like social distancing, face masks, limited capacities, and stay-at-home orders, COVID-19 continued to spread. On August 17, 2020, COVID-19 became the third leading cause of death in the United States, following heart disease and cancer. Since the fall months have started, the United States has reached some of the highest positive case levels. According to AJMC, October 15 was

marked by 60,000 new cases and on November 4 the country reached 100,000 new cases in a single day.

History of COVID-19 in the State of Virginia

While the national timeline of COVID-19 is important, it is also necessary to look at how the virus impacted the state of Virginia specifically. The first official COVID-19 case reported in Virginia was March 7, 2020 (Rob Wittman, n.d.). This was only days before Governor Northam declared a state of emergency on March 12, 2020. The following day, March 13, 2020, Governor Northam stopped in person public school PK-12 education for at least two weeks (Ballotpedia, n.d.). Along with schools, certain businesses were forced to close and gathering sizes were limited. On March 23, all private and public schools were ordered to remain closed for the rest of the school year. One week later, the Governor issued a stay-at-home order until at least June 10. It was not until the end of April that the Governor started to release plans for reopening the state following new safety guidelines. The Phase 1 reopening began on May 15th for most of the state of Virginia. Certain businesses and religious places of worship were now able to open with limited capacity; however, anyone over the age of 10 was required to wear a face covering in public.

The first week of June started the second phase of reopening, as well as the announcement that schools could return for face-to-face instruction in the fall 2020 semester (Ballotpedia, n.d.). Virginia entered Phase 3 in the month of July, which increased gathering sizes to 250, as well as increased indoor capacity at gyms and restaurants. The Hampton Roads area of Virginia had more restrictions enacted during this same time due to an increase of COVID-19 cases. Hampton Roads' restaurant capacities were lowered to 50%, alcohol sales stopped at 10 p.m., and gatherings were now restricted to 50 people. Most recently, federal aid

was dispersed to the PK-12 public schools in October 2020, and more restrictions were placed on the state in mid-November due to an increase in COVID-19 cases. These new restrictions included lowering private gatherings to only 25 people and requiring anyone five or older to wear a face covering in public.

The COVID-19 Influence on Public Education

At the start of the COVID-19 pandemic in Virginia, the Governor decided when to close public school, as well as when to return to face-to-face instruction. However, once the Governor instructed that schools could open in September with face-to-face learning, each school division was tasked with how students would safely return to the school building. The Hampton Roads area consists of seven cities, each with their own school division and school board. While all school divisions started school virtually, each city created their own plan for hybrid or face-to-face instruction. Hybrid instruction involves the teacher teaching students in the physical classroom, as well as students online. Some school divisions decided to remain fully online for the first half of the school year, while others created plans for hybrid learning, when appropriate, to have students in the school building. Not all school divisions in Hampton Roads had sufficient technology to start a virtual school year. Some divisions had to purchase many more student technology devices, as well as hot spots for student Internet use. School divisions worked diligently to obtain the needed technology for both students and teachers in this online learning space. However, even when given a laptop and hotspot, not all technology inequity was removed. In the following section, I will describe the digital divide in public education, as well as how COVID-19 has influenced these digital inequities.

The Digital Divide in Public Education

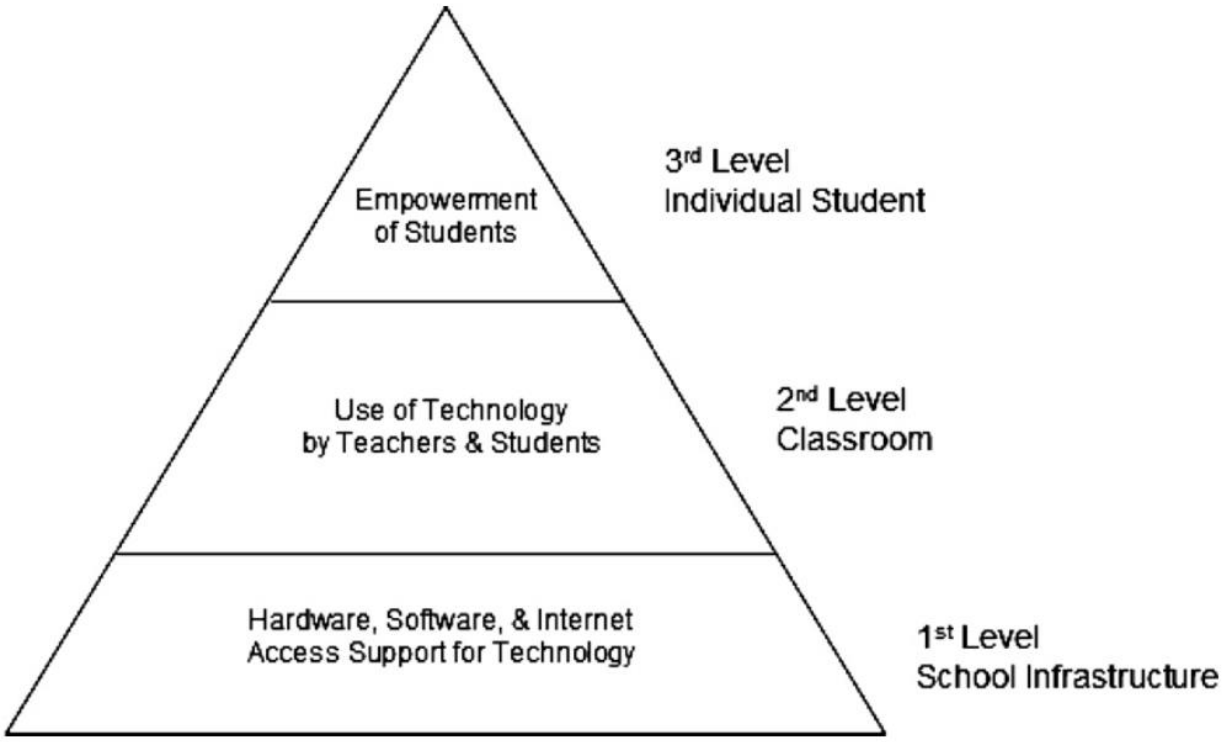
Public educators have now been tasked with teaching students the 21st century skills needed for success in the global economy and society (Hohlfeld et al., 2008). A critical part of these skills is having fluency with information communication technology. In order to promote this fluency, schools need to provide technological opportunities to teachers and students. Failure to provide these opportunities has created the digital divide. The digital divide is defined as the "inequities among individuals who have access to technology and opportunities to learn information communication technology skills" (p. 1649). These inequities often exist due to socioeconomic status. Students from economically disadvantaged backgrounds tend to have less computer access at home than their advantaged peers (The Organisation for Economic Co-operation and Development [OECD], 2006). Families with higher socioeconomic status are able to obtain and use technology sooner and more frequently than low socioeconomic status families (Tichenor et al., 1970). Attewell (2001) wrote that the digital divide has created a technology gap for poor and minoritized families. Access to computers and Internet has created a divide by the "information haves" and "information have-nots" (p. 252). Public schools should be bridging this technology gap. However, when public schools are located in low socioeconomic areas, it is often difficult for the school to have equitable computer and Internet access (Hohlfeld et al., 2008).

The digital divide is separated into three levels as represented in Figure 1 (Hohlfeld et al., 2008). These three levels are organized at the school level, classroom level, and individual student level. The first level represents equitable access to hardware, software, and Internet within a student's given school. This access is typically explained by student-to-computer ratios and Internet access within the school building. While this level would typically be the largest way to lessen the digital divide, due to the current pandemic, most school buildings are not

providing technology access within the building to the student population. While some students in Hampton Roads may be attending school face to face, a majority of secondary students are learning virtually from their own home. Because most students were not in the physical school building, the school divisions had a responsibility to provide computer devices, as well as Internet, to students who would be learning from home. However, the ability for individual schools to actually provide these materials varied based on socioeconomic status. The socioeconomic status of the community that the school serves is directly related to how much money that school spends on technology (Hohlfeld et al., 2008). In 2001, Anderson and Becker, as cited by Hohlfeld and colleagues (2008), found that schools in economically advantaged areas spent 173% more on technology per student than low-income areas. This demonstrates that while schools may be trying to close the digital divide, they are not always equipped with the needed resources. Greater digital inequities continue to grow in the homes based on the students' socioeconomic status (Hohlfeld et al., 2008). In 2003, only 37% of low socioeconomic status families had a computer in the home, while 88% of high socioeconomic status families had computers (DeBell & Chapman, 2006). In 2007, the OECD found that the technology gap that included access to computers and Internet had expanded between high and low socioeconomic groups. These numbers clearly demonstrate that issues of computer and Internet access within the home continue to be a problem for students from lower socioeconomic backgrounds.

Figure 1

The Levels of the Digital Divide (Hohlfeld et al., 2008)



The second level of the digital divide is defined by the frequency of technology use and the purpose of technology use. Hohlfeld and colleagues (2008) pointed out that without computer access and appropriate software, neither teachers nor students could meaningfully use technology. During this COVID-19 pandemic, however, public schools have worked to provide computer access to students and teachers. The mandatory switch to virtual learning also forced technology to be used in meaningful ways. At the start of the 2020-2021 school year, the teachers and students had no option but to use technology and virtual education to learn. This level of the divide, in my opinion, was closed quickly due to the daily use of technology to teach and learn the intended curriculum. The final level of the digital divide is defined by technologies used to empower individual students. This level includes the school's responsibility to prepare teachers and students for the technology skills of the 21st century.

COVID-19 and the Digital Divide

The COVID-19 pandemic restricted occupancy in many locations and forced the U.S. to rely more on the Internet for access to work, school, and social activities (Lai & Widmar, 2021). Lai and Widmar pointed out that during the pandemic rural areas had very limited access to any type of functional Internet. Also, when families did have Internet, it often could not support the use of multiple devices and users. This lack of Internet support for multiple devices has greatly impacted families during the COVID-19 pandemic. In Hampton Roads, most schools have a set schedule when students are supposed to log in for class. Lai and Widmar noted that staggered Internet times could be a solution for problems using multiple devices; however, it is impossible to stagger Internet times when student attendance is required at a specific time. If students are unable to log into class or complete their work when required, they will fall behind educationally. This educational struggle is directly related to technology issues created by digital inequities. Equitable access to Internet, especially Internet that will support multiple devices, should now be seen as a public good versus a private good. As a public good, the availability and effectiveness of the Internet should meet the requirements of supporting multiple devices in a household, especially when most PK-12 students are learning virtually.

Significance of the Study

Educators during the 2020-2021 school year were faced with numerous novel challenges. These new experiences and struggles are directly related to the global pandemic, as well as the extremely public racial injustices in the Unites States. It is important to understand that this global pandemic has forced all teachers into virtual learning. Technological knowledge is now a requirement for teaching due to COVID-19. Wanting to accept technology or even just to try a new online resource is no longer optional. Teachers have had to learn new technologies, teach

new technologies to students and colleagues, and modify their classrooms and curriculums to work within a virtual learning space. This study produced valuable insight into how educators modified their teaching pedagogies in the 2020-2021 school year. The findings from this study can be applied to future school years that use online learning or hybrid classroom models. As the first full school year during the COVID-19 global pandemic is coming to a close, the timing of this study is ideal. The participants will have had enough time to adjust to an online or hybrid teaching model during the school year. This will allow for more meaningful feedback on how to continue being an effective math teacher when teaching and learning are conducted fully online.

Alongside virtual learning, our students are also facing a very public racial divide in our country. The students in Hampton Roads stopped physically coming to school in the middle of March 2020, and some still had not returned to the physical school building during the 2020-2021 school year. This means that students have been at home and exposed to the tragedies in our country. Students did not have school, teachers, or friends as an outlet for dealing with their emotions. Students and teachers have both experienced staying at home and witnessing horrific racial events. These events include the deaths of Breonna Taylor and George Floyd. In March 2020, during a police raid, Breonna Taylor was shot eight times in her apartment while she was sleeping (BBC News, 2021). In May, George Floyd was pinned to the ground for 8 minutes and 46 seconds by police after being accused of stealing cigarettes and using a counterfeit $20 bill. After the death of George Floyd, multiple Black men and women had suspicious deaths involving being lynched. These deaths include Titi Gully in Oregon, Malcolm Harsch in California, Dominique Alexander in New York, and Robert Fuller in California (Byrd, 2020). The Black Lives Matter movement grew strong in the summer of 2020 due to these racial injustices. Students and teachers witnessed these events, watched new reports, obtained

information from social media, and had to process their emotions independently. The combination of global pandemic and racial injustice has made this school year like no other. This study is needed not only to look at the technological aspect of virtual learning, but also to analyze how inequity is still present in public education.

Dissertation Structure

This dissertation is separated into five chapters. The first chapter, the introduction, has set the stage for the study through illustrating the unique social and political circumstances that create the need for this research. In Chapter 2, I will present two theoretical frameworks: Critical Race Theory (CRT) and Technological, Pedagogical, and Content Knowledge (TPACK). CRT will be used to analyze the digital divide and changes to technology inequities during the COVID-19 pandemic. It was necessary to include a theory based on racial injustice since the COVID-19 pandemic also aligned with a heightened period of racial injustice in the United States. Students not only had to face a drastic change in schooling, but also had to witness police brutality, Black Lives Matter protests, and other social issues during a national pandemic. The TPACK framework applies to the current public teaching situation because teachers not only need technological knowledge, but they also need the knowledge for how to effectively use technology for virtual teaching and curriculum implementation.

In Chapter 3 I will present my methods. Using a pragmatic research paradigm, I conducted a single case study. The case was defined as secondary math teachers including middle school Math 7, middle school Math 8, high school Algebra 1, and high school upper-level math. The sample for the study consisted of nine teachers. I conducted individual semi-structured interviews and analyzed technology integration artifacts. The data were analyzed using a three

round coding process that included a priori coding, summative content analysis through word frequency, and pattern coding.

The findings will be presented in Chapter 4. In this chapter I present the themes and explain how they address each research question. The themes of lowering class and assessment rigor, shortening the length of assignments, and changing classroom structures will be discussed as related to teachers' pedagogical changes. The themes related to student performance include performance validity, academic dishonesty, and external factors that affect student learning. The themes related to the final research question about educational inequity are discussed as they relate to inequity of device access, inequity to Internet access, and additional forms of inequity witnessed by the teachers. The conclusions, discussion, and implications are presented in Chapter 5. The discussion section includes technology and inequity. The implication section addresses implications for practice and future research. Some of the implications include analyzing the current student knowledge level to address any gaps in learning, as well as continue to evaluate the most effective teaching practices.

CHAPTER 2

Theoretical Framework and Literature Review

This study is time stamped by the unfortunate events of 2020, including the global COVID-19 pandemic, as well as heightened instances of racial inequality in the United States. The pandemic forced schools in the state of Virginia to close in March 2020. Virtual learning became both teachers' and students' new educational norm. Hampton Roads school divisions all started the 2020-2021 school year virtually and set different parameters for when students could return back to the school building. However, no matter the decision of the local school boards, virtual learning would be a constant in the 2020-2021 school year.

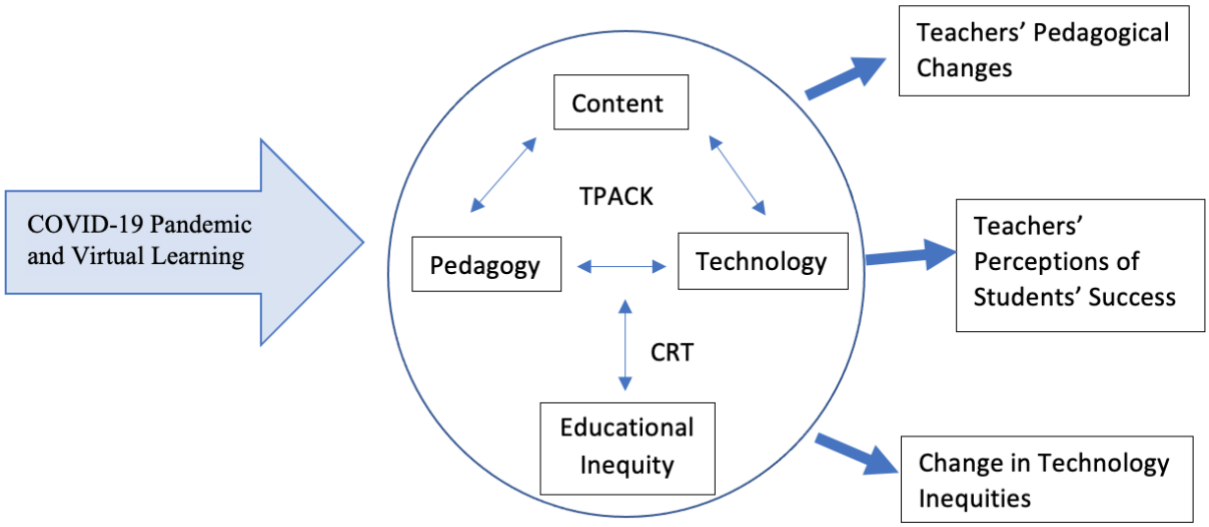
The Black Lives Matter movement also took a strong hold during the summer months of 2020 to support minoritized people in a time of racial injustice. Both students and teachers had to deal with an abrupt change to their education routine, be confined in their homes, as well as witness the trauma and violence towards people of color in this country. These unprecedented challenges created a space like no other. As an educator focused on diversity and equity, I cannot ignore the heightened state of racial inequality in our country. As an educator forced to teach virtually with less than two days' notice, I acknowledge the struggles of virtual learning, from both the teacher and student perspective, as well as the increase in the digital divide.

In this study, I answered the following three research questions: In terms of curriculum, teaching methods, and assessments, how did teachers describe their pedagogical change in virtual learning? How do teachers perceive student performance has changed within the virtual learning space? and, From teachers' perspectives, how has the digital divide and educational inequities affected students' virtual learning based on student race? I applied two theoretical frameworks to this study: Critical Race Theory (CRT) and Technological Pedagogical and

Content Knowledge (TPACK) as presented in Figure 2. I begin by outlining both of these theories before reviewing the empirical studies using TPACK. In my literature review, I will discuss the gaps and limitations of the current TPACK research that ultimately supports the need for my study.

Figure 2

Theoretical Framework



Theoretical Framework

CRT is a critical analytical lens for today's educational system due to the increasing number of minoritized students and the history of educational inequity for students of color. While the main theoretical framework of this study is TPACK, the inequities within education that have been heightened due to COVID-19 cannot be ignored. To analyze these inequities, a social justice focused theory is needed, which is why I chose CRT. As problems continue to arise with the digital divide and educational inequities, it is important that educators, researchers, and practitioners be informed about the historical background of educational inequity, as well as

current practices to increase equity for all students. I will outline CRT first, before elaborating on the TPACK framework.

Critical Race Theory

The student demographic in the United States has changed from predominantly White students to a much more ethnically and racially diverse student body. African American, Asian American, and Latinx students will comprise about 57% of the students in the United States by 2050 (U.S. Department of Commerce, 1996). The National Center for Education Statistics (2014) indicated that the once largest student group, White students, will drop to as low as 35% by 2060. With the majority of students representing minoritized groups, it is important to look at the influence this demographic change will have on education, specifically with our predominately homogenous teaching population of White, middle class women (Howard, 2003). With the possibility of cultural differences influencing educational outcomes, researchers and practitioners must address how White teachers can successfully teach students of different races. It is also critical to point out that the racial homogeneity of teachers is not an accident, but rather the result of racial annihilation (Lynn, 2004), most often credited to the *Brown v. Board of Education* verdict. The desegregation of schools placed students of color in White schools with White teachers, thus removing teachers of color from public education. Yazzie-Mintz (2007) also pointed out that challenges can even exist when students and teachers share the same culture. Differences between people of the same race people can still emerge since both teachers and students come into education with their own knowledge and life experiences. Specifically, students of color have experienced marginalization, while White teachers and students have experienced power and privilege. The demographic differences challenge “educational practitioners and scholars to think innovatively about how educators meet the academic, cultural,

and social needs of the diverse student body" (Howard & Navarro, 2016, p. 254). These differences force educators to not only look at the historical differences between how Black and White students were educated, but also work towards educating all diverse students equitably.

CRT sheds light on the deep roots of oppression which have created achievement differences between Black/African American[1] and White students. Examples of these differences include lower graduation rates, disproportionate levels of discipline, and fewer pathways to postsecondary education (Howard & Navarro, 2016). These differences are most commonly referred to as the "achievement gap[2]" and are deeply engrained due to the following societal and structural inequalities in the U.S.: poor teacher quality, lack of cultural relevance in curriculum, and racial re-segregation. To thoroughly examine the achievement differences between White and Black students, the history of our country must be analyzed. Ladson-Billings (2006) suggested that the achievement gap was actually an educational debt due to historical inequities. Through a critical race analysis of education, it is also noted that students of color have lower academic tracks, are overrepresented in special education, and are more frequently pushed out of school (Lynn, 2004). These examples of struggle for our students of color demonstrate how deep historical racism has created a seemingly insurmountable problem. Research continues to be needed that focuses on educational inequities, and "the depth of this work demonstrates the necessity of CRT in education, illuminating that we cannot truly access, respond, and promote educational research and praxis devoid of the deep and entrenched nature of White supremacy in U.S. Society" (Ledesma & Calderón, 2015, p. 208).

History of Critical Race Theory

[1] Black and African American will be used interchangeably in this study.

[2] The term *achievement gap* is used to maintain the status quo for how achievement differences are still typically discussed in public education.

CRT started around the 1970s in the field of legal studies. Scholars like Derrick Bell, Richard Delgado, and Kimberlé Crenshaw critiqued traditional approaches to civil rights action as producing smaller and fewer gains for people of color (Ladson-Billings, 1998). The scholarship that came from the critical legal studies movement supported the need for laws that would work specifically for people of color in social and cultural contexts. Key scholars exposed the law for supporting the class and racial structures of oppression in the United States. These scholars also contributed to some of the main tenets of CRT. Bell, for example, is considered the most influential scholar who critiqued civil right activism, exemplified CRT, and ultimately coined the definition of interest convergence (Tate, 1997). Delgado is credited with explaining the role of story, counter-stories, and speaking one's own reality. Delgado advocated for the use of story to bring personal history and subjectivity into the field of law. Crenshaw strongly disagreed with color blind legislation and the attempt to ignore the historically different treatment of people of color; however, one of her largest accomplishments was the explanation of intersectionality. Specifically, Crenshaw analyzed how Black women were oppressed by two categories: being female and being Black. Crenshaw also felt that antidiscrimination laws were created to prevent future oppression, but failed to acknowledge past injustices. In education, examples of antidiscrimination laws that attempted to fix inequity are school choice and vouchers, standards-based curriculum, and desegregation. While these three main scholars worked in the legal field, the implications of their work directly relates to how CRT applies to the field of education today.

The mother and father of CRT in public education are Dr. Gloria Ladson-Billings and Dr. William Tate. Their 1995 article is considered the germinal work in this field. The two scholars originally presented the new theory in 1994 at the American Educational Research Association

conference. The paper they presented was titled “Toward a Critical Race Theory in Education” and was met with much hostility due to the focus on race, and exclusion of the race, class, and gender triad (Ladson-Billings, 2013). Ladson-Billings and Tate were bringing to light that inequities were intractable, the civil rights movement failed in some ways, and racism would continue to endure.

Ladson-Billings and Tate acknowledged Woodson and Du Bois as the key scholars for the foundation of critical race work (Ladson-Billings & Tate, 1995). Woodson was the founder of the Association for the Study of Negro Life and History and editor of the *Journal of Negro History*. Woodson wanted to change the thinking of African Americans from one of inferiority to one of uniqueness. A striking concept from Woodson’s publication *The Mis-Education of the Negro*, as cited in Ladson-Billings and Tate, was that the same educational process can stimulate the oppressor, while simultaneously crushing the spark of genius in people of color. Du Bois examined how socialization of race caused African American people to feel like they had two identities: one of a Negro and one of an American. The beliefs of these two men show that the social construction of race in the U.S. divided the people into privileged and oppressed, as well as made the Black community feel that they were different than other Americans.

Ladson-Billings and Tate (1995) opened up a conversation that would allow other scholars to continue to question and analyze the educational system, policies, and procedures. The history of Black oppression is still relevant in today’s society and greatly influences the education of minoritized students. The critical legal studies movement provides the history that our “educational systems are built on laws, policies, and folkways requiring macrolevel analyses that overlap with microlevel issues such as curriculum and instruction” (Tate, 1997, p. 227). The purpose of the following section is to provide a historical account of how legislation in the U.S.

continually oppressed people of color and supported Whiteness as property which I will emphasize in this section. After the legal macrolevel connections of oppression are illustrated, CRT in education will be explored in depth.

Critical Legal Studies Movement

The start of this historical summary must begin with the creation of the Constitution. Beginning in 1786, the authors of the Constitution laid the foundation for a racial divide in the United States. Main examples of White privilege and Black suppression include counting Black people as three-fifths of a person, the slave trade, and the creation of slave laws. Additional examples exist for how law and governance have failed to support people of color. The predominant belief system in education has "been premised upon political, scientific, and religious theories relying on racial characteristics and stereotypes about people of color that help support a legitimating ideology and specific political action" (Tate, 1997, p. 199). Scientific and religious theories supported the idea that Black people were biologically and genetically inferior, which led to the inferiority paradigm. Politics, such as the use of IQ tests to determine educational aptitude, were then put in place to continue the racial divide. IQ tests would "prove" the intellectual superiority of White people over those of color. Even before the IQ tests, Black people were considered less intelligent, which allowed the government to prohibit their education. The law even supported fines and imprisonment if someone helped a Black person become educated.

Once Black people were allowed to be educated, they had to do so separately. In 1896, *Plessy v. Ferguson* upheld the doctrine that "separate but equal" was constitutional. The Supreme Court supported the social idea that White people were too superior to share space, resources, and knowledge with people of color. African Americans were excluded from New

Deal programs, Social Security, and, in education, unable to use the GI Bill in higher education (Martin, 2013). This concept of White supremacy and Black oppression has a long history of being supported by laws. Since the start of the slave trade, legislation has been used to create Whiteness as property, and the most desired property at that.

Whiteness as Property and the Legislative Support. The previous section was a brief overview of a select number of political actions that oppressed people of color. In this section, I define property and explain how Whiteness was constructed and maintained from the beginning of our country. Being White in the U.S. naturally comes with a status of power and privilege, as well as the concept of Whiteness as one's property. The typical definition of property includes the right to use and enjoy, the right to exclude, and transferability (Crenshaw et al., 1995). Whiteness is a property that can only be used and enjoyed by those within that racial category. These privileged rights elevated Whiteness from just an attribute to a resource that would maintain control over those who were subordinated. A White person uses and enjoys their property any time they explicitly, or even implicitly, use their White privilege. Whiteness as property was supported further by legislation on defamation of character. If a White person was called Black, they were considered to be defamed and slandered. The ability to be slandered was a privilege of White people that Black people lacked. A Black person being called White could not sue for defamation under this same legislation. Once again, a law was created to support White people and uphold their hierarchy.

The right to exclude is when White people do not allow non-White people to be included in their same social hierarchy and place of power and privilege. The entire concept of Whiteness is a theoretical construct built to exclude and racially subjugate (Crenshaw et al., 1995). This idea of exclusion was supported by the "one-drop" legislation. This law determined social

groupings and hierarchy, and stated that one drop of Black blood contaminated the pure White race. This legislation increased the power of White people to determine who would be classified as pure and White, and who would be considered contaminated, impure, and not White.

The final characteristic of property is that it needs to be transferable. However, Whiteness is a characteristic that cannot be given to someone else, and as shown, Whiteness would not be chosen to give away because it is too valuable. Ladson-Billings (1998) pointed out that "Whites know they possess a property that people of color do not" and by possessing this property, White people have "aspects of citizenship not available to others" (p. 15). Even though Whiteness fails to meet this transferability criteria of property, the law created a work around. In cases of divorce, the law acknowledges marital property as inalienable property (Crenshaw et al., 1995). This means that things like educational degrees and professional certificates, that cannot be transferred from spouse to spouse, are still considered property when ending the relationship. This law demonstrated that property does not always have to be transferable, thus supporting Whiteness as property even without transferability.

It is important to understand Whiteness as property since "Whites have come to expect and rely on these benefits, and over time these expectations have been affirmed, legitimated, and protected by the law" (Crenshaw et al., 1995, p. 277). The origin of our country is based on racial domination, both of Native Americans and African Americans. The seizure of land from the Native Americans and enslavement of African Americans were both systems of oppression that became ratified laws dealing with property. Slavery was a law that represented owning Black people as property, and land acquisition laws represented the White man's right to land. Both examples represent how the White perception of property and value was strengthened by legal support. Crenshaw and associates believed that "when the law recognizes, either implicitly

or explicitly, the settled expectations of Whites built on the privileges and benefits produced by White supremacy, it acknowledges and reinforces a property interest in Whiteness that reproduces Black subordination" (p. 281).

While it cannot be said that racial divides were not present during early colonialism, it is clear that slavery was the time period in which the racial divide was fully constructed, creating White identity and White hierarchy (Crenshaw et al., 1995). The 1660s began a long road of legal support for oppression against African Americans. For example, owning enslaved people as property was legal, trading slaves was legal, and using slaves to pay off debt was legal. All of these laws labeled African Americans property rather than human. When trying to consider Black people as humans and property together, the Representation Clause of the Constitution was created. This clause legally stated that a Black person would count as three-fifths of all other people. Although the law granted some human rights to the slaves, it continued the dialogue of a Black person being worth much less than other people. Another example of positive law perception that hindered the Black community would be the 1662 Virginia assembly's ruling on the children of Black women. Typically, a child's status was determined by the father; however, this law specifically noted that a Black child's status would be determined by their mother. This could be presented as a way to keep children and mothers together, when in actuality the purpose was to use Black women as slave producers.

Even after slavery, the law was still used to support Whiteness. In the labor market, White workers were perceived as hierarchical to the Black workers and received higher wages (Crenshaw et al., 1995). In education, White schools received higher funding. The Naturalization Act of 1790 allowed citizenship to those with good character, who held U.S. residency for at least two years, and who were White. Once again, privilege, power, and resources were

maintained for the White community and supported by legislation. The critical legal studies movement analyzed law to demonstrate how Whiteness was used to continue supporting a political structure that placed White people above Black people. CRT in education can be used as a lens to analyze how our political system and Whiteness have translated into inequitable education for students of color.

Critical Race Theory in Education

CRT is intended to deconstruct oppression, reconstruct human agency, and construct equal and socially just power relations (Ladson-Billings, 1998). To understand CRT and its implications in education, the specific propositions and tenets of the theory must first be defined. It is also important to note that not every CRT scholar applies the same five tenets to their work. However, scholars are all unified by these two ideas: understanding how White supremacy was created and maintained in America, and how to change the narrative between racial power and the law. The propositions defined relate to the legal background that spurred CRT, while the tenets specifically define the main characteristics of CRT. The current study directly relates to how Whiteness and property were used to exclude Black people from education. When people of color were allowed to receive an education, the education was not equitable to a White person's education. The inequities between Black and White education are still present today and have exacerbated during the current pandemic.

The Three Propositions of Critical Race Theory

Social inequity is explained through the following three propositions about race and property: (1) race is a significant factor that contributes to inequity in the United States, (2) society is based on property rights, and (3) race and property intersect to help understand social

inequities at large and in schools (Ladson-Billings & Tate, 1995). The propositions will be explained in the following subsections.

Race as a Significant Factor of Inequity. Although race can have an effect within all countries, the use of socially constructed race to create oppression and inequity is a specific, ongoing, and seemingly never-ending issue within the U.S. The social creation of two different racial categories, Black and White, has served to create opposition between White and non-White people. This racial separation has even been included on the U.S. census since 1790 (Lee, 1993). Even though biologists have presented evidence that the concept of race is useless (Ladson-Billings & Tate, 1995), the United States continues to divide people into different races. As seen previously, this divide, strengthened by laws, has been socially constructed to keep a dominant race in power, while suppressing and oppressing the other races. Morrison (1993) stated that racism is just as alive today as it was during the Enlightenment, and moves beyond the economy into our daily discourse.

Race as a social construct has led to institutional and structural racism (Ladson-Billings & Tate, 1995). Researchers must acknowledge this social construct and not view race as ideology, since ideology denies the reality of a racialized world and the daily impact felt by the minoritized groups (Ladson-Billings, 1998). In respect to education, the institutional system that supports the poverty of non-White people also supports poor school conditions and educational outcomes. Whiteness maintains authority over people of color and forces them to receive less than equal rights, funding, and educational opportunities. The power difference between White and Black people has also created a school system that is more segregated than ever. While *Brown v. Board of Education* had a positive intent, desegregation caused White people to leave school districts that began to include more minoritized students, as well as removed Black

teachers and administrators. This White flight and educational race annihilation once again created segregated schools, but now without any Black leadership to support the student population of the time. Bell's 1987 essay "The Civil Rights Chronicles" directly critiqued the Supreme Court ruling and offered ways in which this legislation could have been improved (Tate, 1997). Examples of improvement included desegregating school funding rather than the students, making all school facilities equitable, and requiring African American representation on school boards and other school district leadership. These legislative steps may have actually answered the call for equal education for students of color.

Property Rights and Their Intersection with Race. The fundamental idea of how race is socially constructed to oppress people of color is foundational to understanding the concept of property and its intersection with race. Property in an educational context can relate to multiple topics. First, and most directly related to physical property, is that property taxes are used in educational budgets. While an in-depth analysis of school finance is outside of the scope of this dissertation, the basic facts are that higher property values equal higher taxes and, thus, more money going into that school system. Lower economic areas are left with few funds to support the education of students in the most need. Ladson-Billings and Tate (1995) presented ideas of non-physical properties, such as curriculum as intellectual property, and the quality and quantity of curriculum and teachers as schools' property, "critical race theory sees the official school curriculum as a culturally specific artifact designed to maintain a White supremacist master script" (Ladson-Billings, 1998, p. 18). This master script removes the histories, stories, and viewpoints of African Americans and Latinx people. Yosso (2002) explained that traditional curriculums focus on middle class White communities and cater to their educational needs, while the experiences and home values of marginalized students are discounted. A culturally

appropriate curriculum would incorporate learning and resources that directly link to the cultural knowledge of student experiences at home and in their community (Yazzie-Mintz, 2007). A critical race curriculum would challenge the dominant narrative and, instead, include important contexts for minoritized students. Additionally, before blaming students of color for lower levels of achievement, a critical race scholar would analyze the curriculum that reinforces low academics (Yosso, 2002). When the school curriculum is based on the education of White students it becomes intellectual property that continues to serve White students and fails to serve Black students.

The intersection of property and race stems from our nation's history with slavery. White people of privilege used legal means to oppress, enslave, and consider Black people as property. In education, the social and cultural dynamics encourage Whiteness as the norm and the level for which all students should aim to reach. Students are praised when they conform to the notions of Whiteness such as "proper" dress, speech, and knowledge base (Ladson-Billings & Tate, 1995). Whiteness is so powerful that being called something other than "White" represents slander, as noted in the legal section. These positive and negative connotations of White and Black carry over into schooling, with Black schools being perceived of as "at-risk" or unsafe, and White schools having more money and resources.

The property right of exclusion also intersects with race in schooling. At one point in history, Black people were not even allowed to attend school, which is the ultimate exclusion. Once Black students were accepted, they were accepted in segregated schools, which once again excluded them from the privileges of Whiteness. After desegregation, Black people were still excluded from the best education due to White flight, school vouchers, private schools, magnet schools, and resegregation based on school tracking (Ladson-Billings & Tate, 1995).

The Five Tenets of Critical Race Theory

While the three propositions relate to the legal aspects of how race and property intersect, the five tenets of CRT provide the main beliefs and driving forces of the theory. The five tenets of CRT are: (1) racism is ordinary and normal[3], (2) interest convergence, (3) race is socially constructed, (4) intersectionality, and (5) counter-narrative (Ladson-Billings, 2013). Although some of these tenets overlap with the three propositions, in this section I will explain each tenet, even if only briefly. As thoroughly explained in the legal studies movement section, our country was formed with a racial divide that placed Whiteness above all races. The law supported this racial hierarchy and oppression of Black people, leading racism to be a common thread in the history of the United States. Racism lived through slavery, world wars, desegregation, and the current Black Lives Matter movement (Ladson-Billings, 2013). Racism has been able to survive so long in our country, that its elimination seems almost impossible. Therefore, CRT does not focus on how to eradicate racism, since it is normal (Delgado & Stefancic, 2001) and permanent, but rather how race and racism have limited the educational opportunities for students of color (Tate, 1997).

The concept of interest convergence, coined by Derrick A. Bell, is that White people seek racial justice when there is personal benefit (Ladson-Billings, 2013). A notable example is affirmative action being placed as an executive order to ensure applicants for jobs and schools were treated fairly regardless of race or national origin. This order was changed years later to include religion and amended a third time to also include sex. This final change to affirmative action moved the order from racial justice to one of interest convergence with the main beneficiary being White women. To the public eye, affirmative action was perceived to assist

[3] Delgado and Stefancic (2001) explain racism to be ordinary, not aberrational or normal. They also discuss racism as the usual way of society.

people of color when, in reality, the White population reaped the most benefits. The White politicians at the time were willing to make a law in favor of non-White people, as long as it still mainly benefited their personal race. Another example, albeit an example that some scholars disagree with, is desegregation by *Brown v. Board of Education.* During this time period, Black people had just returned from fighting in World War II and did not want to return to segregated facilities (Delgado, 2002). Delgado claimed that the White Supreme Court justices did not overturn *Plessy v. Ferguson* due to their morality, but rather for economic and policy advantages internationally. Desegregation was not really about equal education for Black students, but was a political move to appear as a unified country to enhance international relationships.

The third tenet, race as a social construct, stems from scientific evidence that race is not a scientific reality, but rather categories created by humans to group people based on genetic differences, and apply characteristics and power to these groups (Ladson-Billings, 2013). Intersectionality, the fourth tenet, is another characteristic of the theory. Delgado and Stefancic (2001) defined intersectionality as the examination of how race, gender, class, origin, and sexual orientation interact in various settings. The pieces of identity are always interacting, and it is very difficult to separate one factor from another. For historically minoritized people, especially minoritized females, multiple systems of oppression can interact to create varying levels of exclusion, prejudice, and discrimination (Howard & Navarro, 2016). CRT takes on the challenge of engaging in the difficulty of multiple oppressive systems, rather than trying to simplify life to one simple explanation (Ladson-Billings, 2013). Within intersectionality, CRT also denies essentialism. Essentialism is that all people within the same group have the same way of thinking. Essentialist thought can be detrimental because it leads to stereotypes and lack of individuality. While essentialism has been a critique of CRT, the theory explains that all people

of one race are not to be viewed homogenously. All people represent differences, even if they are from the same racial group.

The last tenet of CRT, counter-narrative, represents using storytelling not to place one's racial struggle on exhibit or rant, but to use voice for racial justice (Ladson-Billings, 2013). The purpose of these stories is to contextualize the feelings and interpretations of minoritized groups, as well as bring cultural viewpoints to the table to help reconstruct our hegemonic world (Ladson-Billings, 1998). CRT aims to challenge notions of neutrality, meritocracy, color-blindness and objectivity through speaking one's own truth (Ladson-Billings & Tate, 1995). One's truth and voice are needed to combat the social construction of race, self-preserve, and overcome differences between the teller and listener (Delgado & Stefancic, 2001). Since oppressors are not always aware of their oppression, the use of stories and voice from people of color can be used to overcome oppressive constructions in the world (Tate, 1997). In the eye of the law, truth and understanding are a universal system of rights and wrongs which discounts historical, social, or specific and personal instances (Ladson-Billings & Tate, 1995). CRT contradicts this universal system since truth only exists for a specific person at one specific moment. CRT uses voice and counter-narrative to bring power to the legal realm involving racial injustices (Ladson-Billings, 1998), as well as empower traditionally minoritized groups. Marginalized people can be threatened by the internalization of their negative stereotypes. Through the use of voice and story, these marginalized groups can "heal the wounds of pain caused by racial oppression" (p. 57). If one can realize that societal dynamics and racism are the root of their pain, they will also realize they are not the problem, and can create a more positive self-image. Stories also help create a sense of common culture between people and ensure mental preservation (Tate, 1997).

Critical Race Theory Summary and Relevance

CRT is intended to deconstruct oppression, reconstruct human agency, and construct equal and socially just power relations (Ladson-Billings, 1998). The tenets of CRT focus on the normalization of racism, interest convergence, the social construction of race, intersectionality, and counter-narratives. The United States' historical background supports constructing differences based on race to uphold White supremacy. The current COVID-19 pandemic has shed even more light on the inequities and educational divides that exist in our country based on race and socioeconomic status. The digital divide is evidence of the history of Whiteness as property, as well as how legislation supported the opposition of Black and White people. Legislation was also used to create educational differences between Black and White students' education, which still affects today's public schools. CRT is the appropriate lens to analyze the inequities currently taking place in the virtual math classroom. The participants were able to express perceived issues that students are facing. While this is not direct student voice, it would still represent the narrative of the students' experiences and struggles. CRT also provides the platform to analyze the intersection of multiple student categorizations such as race, virtual learning capabilities, and math abilities. For example, a strong math student may struggle in the virtual learning space for different reasons than a struggling math student. A typical struggling student may be thriving in this online environment. In sum, CRT supports that the current inequities evident in American education stem from the history of the United States.

Technological Pedagogical and Content Knowledge

TPACK, also known as Technological Pedagogical and Content Knowledge, is a framework that builds on Shulman's (1986) concept of pedagogical content knowledge. The TPACK "framework allows us to make sense of the complex web of relationships that exist

when teachers attempt to apply technology to the teaching of subject matter" (Mishra & Koehler, 2006, p. 1044). This framework helps identify important aspects of teacher knowledge that should be present when thoughtfully integrating technology into the classroom (Mishra & Koehler, 2006). This section will include an overview of pedagogical content knowledge, TPACK and definitions of its constructs, as well as provide a literature review that synthesizes the current TPACK research, including limitations and gaps.

Pedagogical Content Knowledge

The creators of TPACK, Koehler and Mishra (Mishra & Koehler, 2006; Koehler & Mishra, 2009), acknowledge Shulman's work on pedagogical content knowledge as the start of the TPACK movement. Shulman (1986) studied how teacher examinations and assessments have moved from a focus on content knowledge to pedagogical knowledge. When examining the California State Board elementary teacher examinations questions, Shulman found that out of 1,000 questions, only 50 related to the theory and practice of teaching. This means that 95% of the teaching examination related to content and subject matter knowledge, rather than actually how to teach the content. Shulman wrote that while "knowledge of the theories and methods of teaching is important, it plays a decidedly secondary role in the qualifications of a teacher" (p. 5). Teachers were expected to just be masters of their content knowledge, rather than teaching skills and philosophies. By failing to focus on the actual ability to teach the content, Shulman (1987) argued that teaching was trivialized. The complexities and demands of the teaching profession were ignored. Research on teacher effectiveness often ignored skills that could not be assessed by a standardized test, such as subject matter taught, classroom context, student characteristics, or other classroom accomplishments. This led policymakers to define good teaching based on only observable skills, such as writing the daily learning objective on the

board. However, in reality, a teacher's ability to translate content into student knowledge takes more than just an objective on the board. Effective teaching began to be evaluated without any reference to ideas and information actually transmitted to the students.

Shulman (1986) pushed to distinguish between three types of teacher knowledge: subject matter, pedagogy, and curriculum. Joseph Schwab (1978), as cited in Shulman (1986), considered subject knowledge to include basic concepts, principles, and a specific way that truth is established. For example, we have a set of basic rules for grammar and mathematical operations that are accepted truths. For a teacher to be successful, they must know their subject matter knowledge and be able to present this set of basic concepts to students. Pedagogical knowledge refers to how a teacher represents the subject matter and delivers instruction to make this subject matter understandable for students. For students to comprehend the material, teachers must also be aware of portions of the subject matter that tend to be difficult, as well as common misconceptions that students hold. By being aware of these common misconceptions, as well as why they may occur, teachers can plan ahead on how to combat these difficulties. The focus of a teacher is to transform understanding into pedagogical representations and actions that students will understand (Shulman, 1987). Lastly, curricular knowledge is defined by the range of instructional materials within a subject, as well as the ability to relate the content to other courses (Shulman, 1986). Instructional materials could include a textbook, manipulatives, and supplementary resource material.

Shulman (1987) expanded on a teacher's pedagogical knowledge, specifically with how it "represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (p. 8). Pedagogical knowledge involves a cycle of

comprehension, transformation, instruction, evaluation, and reflection. A teacher must first comprehend the ideas being taught. An effective teacher would also understand the material in a multitude of ways. Next, an effective teacher transforms this knowledge into easily comprehendible material. The transformation process includes preparing, adapting, and tailoring the material to the specific students in the classroom. The teacher will plan activities and instruction to support opportunities for growth and learning for the student. The third phase in the cycle is to teach the material. This phase includes the "most crucial aspects of pedagogy: organizing and managing the classroom; presenting clear explanations and vivid descriptions; assigning and checking work; and interacting effectively with students through questions and probes, answers and reactions, and praise and criticism" (Shulman, 1987, p. 17). After instruction takes place, the teacher must evaluate the understanding or misunderstanding of the material. In order to identify what a student understands, a teacher must have deep knowledge of the content, as well as the process of learning, which represents pedagogical content knowledge. Lastly, to continue improving pedagogical content knowledge, a teacher must reflect. The teacher will look back at their teaching and reconstruct the lesson if needed. Through this reflection phase, a teacher may realize a new or different way of comprehension, which starts the pedagogical knowledge cycle all over again. A summary of each phase of the pedagogical knowledge cycle is included below in Figure 3.

Figure 3

A Model of Pedagogical Reasoning and Action (Shulman, 1987)

A Model of Pedagogical Reasoning and Action

Comprehension

Of purposes, subject matter structures, ideas within and outside the discipline

Transformation

Preparation: critical interpretation and analysis of texts, structuring and segmenting, development of a curricular repertoire, and clarification of purposes

Representation: use of a representational repertoire which includes analogies, metaphors, examples, demonstrations, explanations, and so forth

Selection: choice from among an instructional repertoire which includes modes of teaching, organizing, managing, and arranging

Adaptation and Tailoring to Student Characteristics: consideration of conceptions, preconceptions, misconceptions, and difficulties, language, culture, and motivations, social class, gender, age, ability, aptitude, interests, self concepts, and attention

Instruction

Management, presentations, interactions, group work, discipline, humor, questioning, and other aspects of active teaching, discovery or inquiry instruction, and the observable forms of classroom teaching

Evaluation

Checking for student understanding during interactive teaching

Testing student understanding at the end of lessons or units

Evaluating one's own performance, and adjusting for experiences

Reflection

Reviewing, reconstructing, reenacting and critically analyzing one's own and the class's performance, and grounding explanations in evidence

New Comprehensions

Of purposes, subject matter, students, teaching, and self

Consolidation of new understandings, and learnings from experience

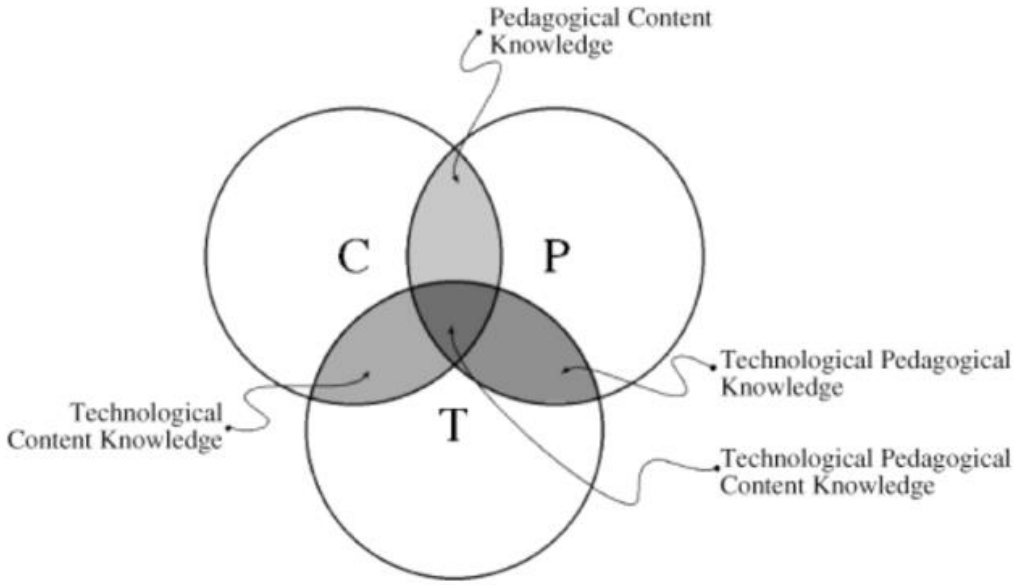
Technological Pedagogical and Content Knowledge

The field of education has faced an enormous shift due to the increase of technologies. Instead of just referring to a pencil as the needed technology, teachers are now using the Internet, learning management systems, graphing calculators, and a plethora of web-based instructional supports. Mishra and Koehler, the researchers who conceptualized TPACK, began their work with this new framework due to the dramatically changing technology practices in teaching. These authors acknowledged that teaching requires many forms of knowledge; however, the typical knowledge systems discussed are content and pedagogy (Mishra & Koehler, 2006). The concept of technological knowledge was left out of the teaching realm. Koehler and Mishra (2009) argued that TPACK research has two main domains: 1) to understand the relationship between teacher thought processes and knowledge, and 2) to understand the relationship between

the teachers' actions and observable effects. Through research on how technology knowledge is taught, learned, and implemented, better techniques for teaching future teachers can be developed. Research can also present the various ways that technology supports or hinders various subjects. Mishra and Koehler presented their framework through the use of multiple Venn diagrams, as presented in Figure 4, to show the relationships between content, pedagogy, and technology. In the following sections, I will explain the individual constructs, as well as the overlapping constructs.

Figure 4

TPACK Venn Diagram (Mishra & Koehler, 2006)



Pedagogical Content Knowledge. Pedagogical content knowledge represents the overlap between a teacher's content knowledge and their knowledge of how to plan and present instruction. Content knowledge is the knowledge one holds in regard to the specific subject, like Biology, English, or Algebra. Teachers are expected to know the basic facts, concepts, topics, and theories of their subject matter. Pedagogical knowledge is the knowledge of best practices and methods of teaching. Examples of pedagogical knowledge include classroom management,

lesson planning, instructional delivery, and student assessment (Mishra & Koehler, 2006). Research-based practices for teaching, as well as developmental appropriateness for students would also be included in pedagogical knowledge. Teachers must understand the "cognitive, social, and developmental theories of learning and how they apply to students in the classroom" (Koehler & Mishra, 2009, p. 64).

Rather than analyzing content and pedagogical knowledge separately, pedagogical content knowledge overlaps these two constructs. Mishra and Koehler (2006) credited the pedagogical content knowledge portion of TPACK to Shulman (1986). Rather than having teachers focus solely on content or pedagogy, pedagogical content knowledge "represents the blending of content and pedagogy into an understanding of how particular aspects of subject matter are organized, adapted, and represented for instruction" (p. 1021). In practice, this blending would be demonstrated by a teacher's decision-making process on how to present subject matter to the students and ensure they grasp the material. Shulman described the overlap of content and pedagogy as how one takes the most regularly taught topics and decides on the most useful teaching strategies and representations. Pedagogical content knowledge "is concerned with the representation and formulation of concepts, pedagogical techniques, knowledge of what makes concepts difficult or easy to learn, knowledge of students' prior knowledge, and theories of epistemology" (Mishra & Koehler, 2006, p. 1027). Teachers with deep pedagogical content knowledge know how to address learner difficulties and overcome misconceptions. The transformation to deep pedagogical content knowledge occurs when teachers are able to interpret their content, present the material in multiple ways, and adapt instruction based on students' needs (Koehler & Mishra, 2009).

Technological Knowledge. The T in TPACK stands for technological, and it is important to define *technology*. Technologies have always been present in education; however, these technologies are drastically changing at a very rapid pace. In the past, technology in school would have been considered the chalkboard or overhead projector. Currently, our technologies have advanced to more digital technologies such as computers, emails, Internet, and digital videos (Mishra & Koehler, 2006). Additionally, these new technologies are readily available and expected to be used in daily teaching. With every student now having access to a technological device and the Internet due to virtual learning, educators must use learning software and online educational tools. While some content may now be more accessible to learners, there is the opportunity for technology to constrain a subject (Mishra & Koehler, 2006). An example of constraint would be that teachers can only use certain software and websites that have been approved by the school division. While the Internet may have amazing resources, teachers and students may lack the ability to access and use all of these resources.

While teachers may initially resist the use of technology in the classroom (Mishra & Koehler, 2006), our increasingly technological age requires technology use for student learning. Some teachers are afraid of these new technologies or lack the time and support to learn the new technologies. Even with resistance and fear, the use of technology is not going to fade away. Especially in this time of COVID-19 and virtual learning, all teachers must use technology as a part of their daily teaching. The TPACK framework provides practical applications for how technology should be integrated into the classroom, rather than just a separate add on. The use of technology must be carefully planned since it can constrain representations, define how the instruction moves, or change other pedagogical decisions.

Technological Content Knowledge. Technological content knowledge examines how technology can constrain or enhance the curriculum by presenting new and varied representations of a subject, as well as limiting the representation. Mishra and Koehler (2006) presented Geometer's Sketchpad (2020) as an example of technology that allowed for more flexibility and ease of shape constructions for students. The students were able to use the Geometer's Sketchpad to construct shapes and see the shapes immediately in 3D. In this example, technology supports and expands the Geometry curriculum. However, Geometer's Sketchpad also has numerous buttons and functions, which may take students an extended time to learn. This use of instructional time to simply teach how to use the technology tool may be seen as a constraint. For a teacher to have technological content knowledge, they must know how technology can be used to teach content. This knowledge includes both the positive improvements to content, as well as the way in which the content may be limited.

Technological Pedagogical Knowledge. Technological pedagogical knowledge is the "knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as a result of using particular technologies" (Mishra & Koehler, 2006, p. 1028). Related to the example of Geometer's Sketchpad (2020), technological pedagogical knowledge would include knowing the program existed, understanding how to the use the program, instructing students on using the program, and understanding issues that may arise. Technological pedagogical knowledge is not simply using an online assessment to make test grading quicker, but using technology to support and strengthen instruction. Mishra and Koehler (2006) provided more general examples of technological pedagogical knowledge such as using technology systems to

take attendance and upload grades, as well as using WebQuests and discussion boards in the classroom.

Simplified Definitions of Technological Pedagogical and Content Knowledge

While reading the germinal works on TPACK, it was sometimes difficult to separate the various types of knowledge. Cox and Graham (2009) supported the idea that the TPACK framework had blurred lines between pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge. These two researchers aimed to create one precise definition for each TPACK construct and provide examples. To achieve this goal, Cox and Graham completed a technical use analysis, and examined model, contrary, related, borderline, and invented cases. Their study followed the following nine steps: (1) review current definitions of technological content knowledge, technological pedagogical knowledge, and TPACK; (2) interview TPACK researchers; (3) revise definitions; (4) search for model cases; (5) compare model cases with definitions; (6) revise definitions again; (7) test definitions with real and invented cases; (8) finalize definitions; and (9) utilize definitions and graphic representations.

After completing the nine steps, the following simplified definitions and examples were presented. The definition of pedagogical knowledge was simplified to focus on a teacher's general pedagogical activities (Cox & Graham, 2009). These activities would be considered independent from any subject. Examples of general activities included strategies to increase student motivation and classroom management tools. The definition of content knowledge remained consistent in that it explains an individual's knowledge of a specific topic and subject. Pedagogical content knowledge was simplified to the knowledge of activities (pedagogy) and the knowledge of representations (content) to facilitate learning.

Cox and Graham (2009) incorporated a new key word into the definition of technological knowledge that I find to be extremely useful: emergent. Technological knowledge is not just understanding how to use technology, but rather how to use emergent technologies. By including the word *emergent*, the researchers were able to clarify the difference between some of the TPACK constructs. For example, in mathematics, most teachers know how to use a graphing calculator. However, this graphing calculator is not an emerging technology. The knowledge of how to use a graphing calculator within one's math subject would be considered content knowledge, while the use of Desmos (2021), a new online graphing tool, would be considered technological content knowledge because the technology is emergent. Another prominent example of a shift within the TPACK framework is the use of interactive Whiteboards, such as SMART boards (2021) or Promethean boards (2021). When these interactive Whiteboards were first introduced into public schools, teachers had to learn how to use the technology, as well as how to connect the content with the technology. This initial use of the interactive Whiteboard would have been considered technological pedagogical knowledge; however, now that these Whiteboards are common in the classrooms, it would just be considered pedagogical knowledge. Overall, technology is considered part of technological content knowledge and technological pedagogical knowledge when it is emergent to the field of education. Once the technology is normalized in education, it fails to meet Cox and Graham's definition of emerging technologies.

In the current COVID-19 pandemic, the use of Zoom (2021), Google Meet (2021), and other learning management systems is considered new and would support a teacher's TPACK. Years from now, when these online systems are no longer novel in education, they would only support a teacher's technology knowledge. This consistently changing view of what is considered technological content knowledge, technological pedagogical knowledge, and TPACK

will remain constant as long as new technologies continue to be invented and implemented in education (Cox & Graham, 2009). This supports the need for the TPACK framework and how it will continually be used as school technologies continue to grow. The rapid growth of new technologies used in public schools due to the COVID-19 pandemic calls for a framework focused on emergent technologies as they relate to pedagogy and content.

Technological Pedagogical and Content Knowledge Limitations

TPACK presents a complex relationship between technology, content, and pedagogy. Proficiency in just one of these areas will not translate into strong teaching using the TPACK framework. For example, a teacher who understands technology doesn't always produce a strong, developmentally appropriate lesson using technology (Mishra & Koehler, 2006). Most teachers have mandatory training courses and workshops on technology, which ultimately fail to provide the deep understanding teachers need to use technology appropriately in their field. Through simple professional development sessions, teachers become challenged with the following four problems: (a) rapid change; (b) inappropriate designs of software; (c) nature of learning; and (d) the emphasis on what is being taught, rather than the how. In terms of rapid change, technology has the potential to change so quickly that teachers cannot keep up with the most current version of the given technology. By the time teachers learn, explore, and actually use the technologies in their classrooms, there is potential for a newer version or newer program altogether. Teachers may never really be up to date with the tech world. The designs of the software can also cause issues. For example, certain programs may have much better functionality with particular subjects. Mishra and Koehler pointed out that most software used in education originated as a design for the business world. This means that content and pedagogy were not considered during the technology's design. Through using technological systems that

weren't intended for education, teachers have to repurpose these technologies to fit their content. Teachers may also have to spend valuable class time teaching the technology to the students, rather than teaching their content. The third potential problem, as explained by Mishra and Koehler, is that the nature of learning is not context neutral. Technology cannot be seen as a generic solution to issues within the field of teaching and education. Educators cannot assume that teachers teach the same way and will use technology the same way. Subject matter, teaching style, and teaching philosophy are all important factors to how one uses technology. Finally, the emphasis during technology training is usually what the technology is, rather than an explanation of how the technology should be implemented into the content. This lack of training leaves teachers independently trying to figure out how to appropriately use the technology in the classroom, which takes time and effort. Mishra and Koehler noted that knowing how to use technology and successfully teaching with that technology are two very separate notions. Teaching successfully with technology includes creating, maintaining, and adjusting if needed, the relationship between content, pedagogy, and technology (Koehler & Mishra, 2009).

Technological and Pedagogical Content Knowledge Literature Review

In order to review the most recent research on TPACK, I completed a Monarch OneSearch on the Old Dominion University (ODU) Library webpage with a basic search for "tpack." When I revised the search to peer reviewed, full articles online, and published within the last ten years, I had 1,518 results. A majority of the articles found with this search were about pre-service teachers, which would not apply to the current study involving in-service teachers. When I narrowed the search to "tpack and math" and kept the same search parameters, only 353 results were presented. Once again, numerous studies were focused on pre-service teachers. Using the search terms "tpack and covid" 9 articles were found. Only one article from this search

applied to this study. Most of the TPACK and COVID-19 articles related to higher education, elementary education, or parent perceptions. Lastly, I searched using the terms "tpack and covid and math." This search produced only five articles, but they were the same articles found in the third search I completed. Overall, I read ten empirical articles that discussed the use of the TPACK framework in a current education setting. In this section, I will summarize and synthesize the TPACK research including research questions and methodologies to identify gaps and limitations of previously published research.

Overview of Empirical Studies

Graham and colleagues (2009) presented specific examples of each TPACK construct, specifically in the science domain, through a survey administered to fifteen in-service science teachers. The data measured the teachers' confidence in the four TPACK constructs, how they currently used technology in science teaching, and what digital technologies they wish they had access to (Graham et al., 2009). The results indicated that the teachers had the highest levels of technological knowledge, followed by technological pedagogical, TPACK, and finally technological content. The teachers felt more confident in their ability to teach science with technology rather than do science with technology, as well as preferred to use technology as something teacher centered rather than student centered. The authors concluded that professional development was needed for the teacher to help them learn more science specific ways to use technology.

Archambault and Barnett (2010) researched what online teachers' ratings of their perceived TPACK knowledge suggested of the framework in general. Teachers from virtual schools were emailed a web-based survey about the online teachers' TPACK. The results from the 596 participants indicated that seven specific TPACK constructs may not exist in actual

practice, but rather only the three factors of pedagogical content knowledge, technological content knowledge, and technological knowledge.

Jang and Tsai (2013) answered two research questions: is TPACK effectively employed by secondary science teachers? and, does TPACK differ with secondary science teachers based on gender and teaching experience? A questionnaire was mailed to secondary schools randomly chosen from all over Taiwan and the results were analyzed from the 1,292 participants using factor analysis. Overall, secondary science teachers were more comfortable with content and pedagogical knowledge than technological knowledge, male science teachers rated themselves higher on technological knowledge than female teachers, experienced teachers had higher ratings on content and pedagogical content knowledge than novice teachers, and novice teachers rated themselves higher in technological knowledge than more experienced teachers. The authors detailed the need for additional trainings and resources.

Koh and colleagues (2014a) studied the influence of contextual factors on teachers' co-construction of TPACK during lesson planning. Twenty-four teachers from both the upper and lower levels of an elementary school in Singapore were chosen for the sample. The data collected were from recordings of the teachers' discussions during team lesson planning sessions. The results indicated that cultural/institutional factors, such as school policies, lesson objectives and logistics, comprised 55% of the total units coded from the discussion audio tapes. These results led the researchers to claim that teachers need training on how to effectively use time for deeper pedagogical discussions to improve TPACK co-construction.

Koh and colleagues (2014b) researched practicing teachers' constructivist-oriented TPACK perceptions, as well as how teacher demographics and TPACK constructs predicted constructivist-oriented TPACK. Three hundred fifty-four practicing teachers attended a

professional development program and completed the TPACK for Meaningful Learning Survey (Chai et al., 2011). The data analysis consisted of descriptive statistics, Pearson's correlations, independent sample t-tests, and stepwise regression. The findings illustrated that teachers rated themselves above average for all TPACK constructs, and that age and teaching experience were not strongly related to TPACK constructs. However, males rated themselves higher on any construct involving technology, and teaching level and experience had significant influence on constructivist TPACK. Three implications for teacher professional development were then explained in the conclusion.

Koh and Chai (2016) completed a study in Singapore focused on TPACK and lesson design frames. Specifically, the authors examined design talk of 27 teachers. Through thematic analysis, Koh and Chai characterized the types of design frames teachers used when redesigning their existing lessons. The three research questions focused specifically on what aspects of TPACK were used, what kinds of design frames were used, and what design frames were used when considering different aspects of TPACK. The findings indicated that pedagogical content knowledge, design knowledge, and TPACK dominated the design discussion. Design knowledge was a new category that developed and included issues related to which design to use, how to choose design goals, how to organize the designs, and how to present the designs to the students. The two main design frames used were that of idea development and design management, defined as what the students would be doing and what would be considered student success for the lesson. Koh and Chai presented implications for technology integration professional development.

Urbina and Polly (2017) examined how four elementary school teachers integrated technology and used TPACK in mathematics. Classroom observations and interviews were the

data collection methods for this study. Technology integration included the use of an interactive Whiteboard, projector, and document camera, as well as math websites for independent practice. During the observations, the use of websites was often a time filler for the students who finished early, rather than an instructional support. The examples of TPACK in the math classroom were actually evidence of technological content knowledge since they were teacher-centered activities. These examples included using the interactive Whiteboard or document camera to explore, model, and solve math problems. Urbina and Polly called for future research on teachers' decision-making process for using technology in the classroom, as well as using technology and Internet-based programs for higher level thinking.

Koh (2019) examined 47 participants in a graduate course in Singapore to answer research questions about teachers' perceived change in confidence with designing TPACK lessons before and after using TPACK design scaffolds, change in rating their lessons before and after using TPACK design scaffolds, and teachers' feedback about TPACK design scaffolds. The first four weeks consisted of an introduction to meaningful learning rubrics followed by setting pedagogical goals based off of these rubrics. Weeks 5-11 were used for collaboration with TPACK lesson designs and TPACK activity types. The finale of the course included individual lesson designs and self-reflection. The data collection varied by research question. Teachers' confidence was measured using a survey, rubrics were used to rate the lessons, and the reflections were coded through content analysis. The findings were as follows: teachers had a significant positive increase in technological knowledge, technological pedagogical knowledge, and TPACK; large effect sizes were found between the initial and final rating of the redesigned lessons; and 48.5% of the coded units demonstrated teacher comments on the strength of design

scaffolds. Koh concluded that TPACK design scaffolds can support pedagogical change through information and communication technologies professional development.

The final two articles were both published in 2020 and included the influence of the COVID-19 pandemic. Rap and colleagues (2020) conducted an applied research approach with 193 chemistry teachers during the pandemic. The TPACK framework was chosen for this study for the focus on how teachers need to develop technological knowledge components for effectively teaching chemistry online. High school chemistry teachers in Israel were sent an online survey with multiple choice questions about technology used, teaching experience, and attitudes towards online teaching. Most teachers reported negative attitudes toward online learning and low levels of pedagogical skills that translated to teaching with technology. In regard to the technology tools used, teachers claimed to use one or two technology tools prior to COVID-19; however, the pandemic caused them to shift to using more than three technology tools. Rap and colleagues provided the teachers in the study with best practices and strategies they had learned from previous literature of online technologies in the chemistry teaching field.

Similarly, Portillo and colleagues (2020) researched how competent teachers perceived themselves during emergency remote teaching, if Digital Competence of Educators was biased based on demographic information, and if Digital Competence of Educators training impacted the well-being of teachers during emergency remote teaching. A questionnaire was used as the data collection method and the authors generated 4,586 responses. The findings were as follows: teachers perceived themselves as partially competent during emergency remote teaching; men, younger teachers, and private schools showed higher level of competence; and negative emotions were strongly related to the workload during COVID-19. However, the Digital Competence of

Educators training was associated with more positive emotions. The pandemic reinforced the importance of teacher professional development for online learning.

Synthesis and Gaps of the Literature Review

Most of the empirical studies included in this literature review were quantitative studies in which the authors used some form of a survey as their data collection point. Surveys or questionnaires were used in seven out of the ten studies that directly related to teachers' perceptions of themselves and their teaching within the TPACK framework. Transcripts from teachers' conversations during lesson designs and TPACK planning were analyzed in two of the studies. Teacher observations and interviews were only conducted in one of the studies. Professional development, additional trainings, and resources needed for teachers to effectively use TPACK in the classroom were the conclusions from seven out of the ten studies.

In the studies reviewed above, the first notable gap is the lack of teacher voice through data collection methods like interviews or focus groups. This limitation stems from the emphasis on quantitative research. Most of the data presented are the teachers' self-perception of their skills through a survey, rather than a conversation about implementing TPACK. None of the researchers dove into the actual utilization and practical applications of various technologies in the classroom. Koh and colleagues (2014a) included teacher voice through recorded lesson planning conversations; however, they did not emphasize how to actually use TPACK in the classroom and the after effects of using such a framework. Another gap would be the number of studies completed since COVID-19 started. The first eight articles, all conducted before the pandemic, presented teachers with a high confidence level for technology integration in the classroom. However, the two studies conducted during the pandemic presented negative feelings about technology use and the ability to effectively teach with technology. This made me wonder

if teachers may feel more comfortable with a tool that they use at their convenience, versus being thrown into an all-virtual teaching world. In the current study, I focused on these gaps: including teacher voice and actual classroom implementation of TPACK. Teachers' perspectives will still be analyzed; however, the focus will be on their perception of technology as it relates to student performance, rather than simply their personal comfort level. The digital divide and school inequities during the pandemic are also gaps in the current literature.

Technological and Pedagogical Content Knowledge Summary

TPACK is not a simple framework for just using technology in the classroom. TPACK requires thought and planning to integrate content with technology, as well as use the best pedagogical practices. TPACK can include the use of technologies to ease in concept representations, assist with problems and misconceptions in the curriculum, and build on students' existing knowledge (Mishra & Koehler, 2006). While technology has been forced into every virtual classroom due to the COVID-19 pandemic, Mishra and Koehler argued that technology is not the sole solution for improving teachers, teaching, or content. While technology may be beneficial for some subjects, it may also constrain a subject drastically. In math, for example, it is difficult to type out math steps or use appropriate math symbols in some learning management systems, as well as basic programs like Microsoft Word and PowerPoint. Microsoft Word supports writing papers in English class more than solving integral equations in Calculus. Specific tools that are forced upon teachers may also affect content and instructional delivery. In the Southeastern part of Virginia, most teachers are teaching through Google Meet (2021) or Zoom (2021). Some schools mandated that a teacher use one or the other, which can drastically affect how one makes pedagogical decisions within their content.

In this study, I analyzed how math teachers were integrating technology into their virtual learning space. With the TPACK framework, I was able to understand how content knowledge, pedagogical knowledge, and technological knowledge are all interconnected during virtual learning. I gained a deeper understanding of how technology supported and hindered math instruction during the COVID-19 pandemic. The use of technology supported auto-grading, immediate feedback, and multiple attempts for the students. The teachers felt these new abilities helped greater support the math learning of the students during virtual instruction. However, technology use hindered the teachers' ability to view student work. Additionally, the use of technology was not always used in an honest way, but rather was used to assist students in finding correct answers without completing the work themselves. In the ensuing chapter, I will explain the methods for this study.

CHAPTER 3

Methods

In this study, I examined how secondary math teachers in the Marvel[4] School Division in southeastern Virginia changed their math curriculum, teaching strategies, and assessment practices in the virtual learning space during the COVID-19 pandemic. Since March 2020, teachers in Virginia have been forced to teach virtually. As a math teacher, I have encountered many issues regarding how to demonstrate math concepts through a computer, check students' work virtually, and assess the students on their actual knowledge, rather than ability to find the correct answers on the Internet. I also personally believe that student performance has changed in both positive and negative ways. Some students are thriving in the virtual world, while others are floundering. I wondered if my experiences were happening in other math classrooms. Lastly, COVID-19 has increased the digital divide in education. While having in-depth conversations with teachers, it is important to ask how racial inequity has been present in their COVID-19 virtual teaching experience. The year 2020 led to heightened awareness of racial injustices, and I could not miss the opportunity to obtain current data on what recently faced our students and teachers. The current study sits at the intersection of technology and racial equity in public education. In this chapter I will present the research questions as well as the supporting theoretical frameworks for this study. My positionality, paradigm, and research design will also be discussed. The research design section will include the site context, sample, data collection and data analysis techniques. Lastly, I will address trustworthiness and credibility of the study.

Research Questions

In this qualitative case study, I answered the following three research questions:

[4] All names of people and places are pseudonyms.

RQ1: In terms of curriculum, teaching methods, and assessments, how did teachers describe their pedagogical change in virtual learning?

RQ2: How do teachers perceive student performance has changed within the virtual learning space?

RQ3: From teachers' perspectives, how has the digital divide and educational inequities affected students' virtual learning based on student race?

Theoretical Framework

The data from this study were analyzed through the lens of Critical Race Theory (CRT) (Ladson-Billings & Tate, 1995) and Technological, Pedagogical, and Content Knowledge (TPACK) (Mishra & Koehler, 2006). CRT sheds light on how the deep roots of oppression have created achievement differences between Black and White students. Examples of these differences include lower graduation rates, disproportionate levels of discipline, and fewer pathways to postsecondary education (Howard & Navarro, 2016). These differences are most commonly referred to as the "achievement gap[5]" and are deeply engrained by the following societal and structural inequalities in the U.S.: poor teacher quality, lack of cultural relevance in curriculum, and racial re-segregation (Howard & Navarro, 2016). Ladson-Billings (2006) suggested that the achievement gap was actually an educational debt due to historical inequities. Specifically, I focused on how the digital divide may be causing additional educational inequities. CRT provides the historical legislative and educational support for Whiteness as property and its effects in creating sub-par education for students of color.

TPACK is a framework that supports technology integration with the content and teaching in a classroom. TPACK requires thought and planning to integrate content with

[5] The term *achievement gap* is used to maintain the status quo for how achievement differences are still typically discussed in public education.

technology, as well as use the best pedagogical practices. TPACK can include the use of technologies to ease in concept representations, assist with problems and misconceptions in the curriculum, and build on students' existing knowledge (Mishra & Koehler, 2006). Prior to COVID-19, many teachers may have used technology simply as a support or add-on for instruction; however, with the drastic change to all-virtual teaching and learning in 2020, teachers have had to learn how to integrate technology seamlessly into their classroom spaces. I used CRT and TPACK as the analytical lens for this study. The following section will detail the methods used for this study.

Research Methods

The purpose of this section is to present my positionality as a researcher and my research paradigm. I will explain the research design for this study in detail including the context, sample, data collection, and data analysis techniques. Trustworthiness and credibility of the study will also be addressed.

Researcher Positionality

As I began this study, I understood my positionality as a researcher. My feelings on improving the overall educational experience for minoritized students, specifically for Black students, are strong and deeply rooted. As a public-school math educator during the COVID-19 pandemic, I have my own lived experiences with virtual math education. I am a White, female, secondary math teacher who married a Black man and birthed a racially mixed son. I am aware of the level of privilege I was afforded in the educational system that my husband was not. The COVID-19 pandemic has drastically changed my teaching, my students' performance, and my view on how education really supports students. In both positive and negative ways, my teaching strategies and assessment practices have changed from how I would have implemented them in

face-to-face instruction. The questions that I ask on math assessments are also vastly different. During this pandemic, it has been extremely difficult to have such high numbers of students struggling and failing, with no real support from the school system. Once the school division I work for provided the students with a chromebook and Internet Wi-Fi hotspot, all potential barriers for virtual learning were supposed to be removed. However, in my opinion, students are facing more battles during this pandemic than any other year I have taught. I hope this research can shed light on both what is working well and areas for growth for public education during a pandemic and virtual learning within the context of the math classroom.

Research Paradigm

A research paradigm represents the belief systems of the researcher (Hays & Singh, 2012) and encompasses a world view and epistemological stance that is shared within a community of researchers (Hall, 2013). Paradigms encompass elements of axiology, ontology, and epistemology. Kaushik and Walsh (2019) defined axiology as beliefs about values and morals in research, ontology as assumptions about reality, and epistemology as knowledge assumptions and relationships we have with knowledge. Hays and Singh (2012) presented the following paradigms: positivist, post-positivist, social constructivism, critical theory, feminism, and queer theory. Lather (2006) presented the research paradigms of positivism, interpretivism, critical theory, and deconstructivism. Hall (2013) claimed that the world view on paradigms included the four following paradigms: post-positivism, constructivism, transformative, and pragmatism. While wording may vary, the research paradigms present a spectrum that ranges from one single truth, or positivism, to socially constructed truth, or even lack of a real truth. Post-positivists claim the worlds exist from how we understand it, and constructivists claim that our world is created by our conceptions (Morgan, 2014). As a researcher with personal emotions

and investment in my research, it is impossible for my research paradigm to be positivist. I do not think a single, objective truth can be found to my research questions. Research involving math teachers of varying levels and technology integration at varying degrees will lead to data that represent multiple teachers' experiences. These experiences, however, aren't necessarily the lived truths for every math teacher in the world.

As I researched paradigms, I struggled to place myself into one box or another. I was confined to pick a way of researching that would ultimately define my study. To allow for more freedom in my research design and data analysis, my research was conducted using the paradigm of pragmatism. In the late 19th century, pragmatism originated due to scholars rejecting the traditional views about the nature of reality and knowledge. Pragmatists decided to focus on how they approached inquiry, rather than decide on a set ontology and epistemology (Morgan, 2014). Pragmatism does not aim to find a causal effect or claim some kind of truth but, rather, pragmatists look to investigate research questions, theories, and phenomena (Feilzer, 2010).

Morgan (2014) focused on Dewey's contribution to pragmatism through his concepts of human experience and inquiry. According to Morgan, the emphasis of research should be on humans' current experiences, rather than abstract concepts. Interviews with my participants directly tapped into their current teaching experience. Research and inquiry should follow Dewey's five systematic steps: (a) recognize a problem, (b) consider defining the problem from different perspectives, (c) develop a line of action, (d) evaluate possible consequences of these actions, and (e) take action to address the problem. I identified the COVID-19 pandemic as the current problem in education and decided to examine this problem through the perspective of math teachers' technology integration, as well as the experiences with student performance and the digital divide.

A pragmatist believes that no two people share the same life experiences, and would therefore have different worldviews; however, shared experiences may lead different people to ultimately have some shared beliefs (Kaushik & Walsh, 2019). My participants were all facing their own highs and lows during this pandemic, but they were all living and experiencing the same pandemic and the similar effects the pandemic has had on education. Through this shared COVID-19 event, the participants demonstrated shared changes and beliefs about their pedagogies and student performance. The shared changes and beliefs will be expanded upon in the data analysis section below.

Lastly, pragmatism is a known paradigm to use with social justice research (Kaushik & Walsh, 2019). The third research question focuses on educational inequities that ultimately relate to White Supremacy in the United States. This paradigm allows researchers to grapple with contemporary issues around social inequality and power (Kaushik & Walsh, 2019), thus making it appropriate for my study.

Research Design

The current study was a qualitative single case study (Yin, 2009). According to Leedy and Ormrod (2019), a case study is when "a particular individual, program, or event is studied in depth for a defined period of time" (p. 230). Case studies are useful to learn about little known concepts, as well as the result of any changes. The COVID-19 pandemic definitely qualified as an educational change and I researched how teaching pedagogies changed as a result of the virtual learning shift. Yin (2009) noted that case studies also allow researchers to retain the characteristics of real-life events. Once again, the current pandemic is affecting all teachers' real lives.

Case studies are the appropriate research design when the research questions ask how or why, no behavioral event needs control, and the focus of the research is on contemporary events (Yin, 2009). All three of the research questions allowed me to examine how a specific concept changed due to COVID-19. This required me to look at the change in education over a specific time frame, rather than just one specific incident or some concepts' frequency. My research questions also directly tied in with a current event that is being studied in real time. This study took place during the first full school year during the COVID-19 pandemic. I interviewed participants who were directly involved in the event, which is another characteristic of a case study. Case study researchers learn from their cases through the thick, rich narrative data (Flyvbjerg, 2006) and that was true of the current study as well. Ultimately learning, rather than trying to prove something, was an important aim of this case study.

The research design was a single case study rather than a multiple case study for several reasons. Yin (2009) wrote that single case studies are used to test well-developed theories, and either confirm, challenge, or extend the theory. The research questions were aimed at finding differences in pedagogies during virtual teaching to expand upon gaps in the TPACK literature. The results of this study will also confirm or challenge the historical underpinnings of educational inequities as explained in CRT. My single case was secondary math teachers in the Marvel School Division who changed their teaching pedagogy to successfully integrate technology in virtual math learning. This single case included the following four different math subjects: middle school Math 7, middle school Math 8, high school Algebra 1, and high school upper-level math. The different math subjects were not considered multiple cases on their own. During the interviews the participants did not discuss content related concerns, so it was unnecessary to analyze and differentiate by math subjects. A single case study was also a more

feasible research design for this study as Yin warned that multiple case studies may involve time and resources that go beyond a single student or individual researcher.

Context of the Research Site

This study was conducted within a public school division[6] in the Southeastern region of Virginia. The Marvel School Division has more than 40 school buildings and serves more than 30,000 students. The two largest demographic categories for students are Black and White students. In the next three sections, I will elaborate on the sample, methods of data collection, and data analysis techniques. I will present a summary of my research questions and methods in Table 4 following the data analysis section.

Research Sample

For the current study, I used purposive sampling in which the participants were selected based on certain criteria and for a specific purpose (Leedy & Ormrod, 2019). Purposive sampling must be used to ensure that the participants included within the study can inform the research questions. Secondary math ranges from sixth grade math to higher levels such as Calculus. The sample for this study consisted of nine teachers from the Marvel School Division who taught one of the following math levels: middle school Math 7, middle school Math 8, high school Algebra 1, and high school higher-level courses above Algebra 2 (e.g., Trigonometry, Calculus, etc.). From the two middle school math levels, I interviewed three teachers who taught Math 7 and three teachers who taught Math 8. I interviewed two high school Algebra 1 teachers and one upper-level high school math teacher. Overall, the study included interviews with nine teachers. While I hoped for a diverse sample, I did not place any parameters on teachers' gender identity, race, age, or years of experience. The demographic information for the participants is presented

[6] In this study school division is synonymous to a school district. It is defined as a group of public schools in the same geographical city location.

in Table 1. Overall, the sample was weighted more in the middle school math subjects than the high school math subjects. Additionally, the participants were primarily White female teachers.

Table 1

Participant Demographic Information

Category	Sub-Category	Frequency	Percent
Gender	Female	8	89%
	Male	1	11%
Ethnicity	Caucasian/White	8	89%
	African American	1	11%
Age Range	20-30	2	22%
	30-40	6	67%
	40-50	1	11%
Years of Teaching Experience	1-5	1	11%
	6-10	3	33%
	11-15	2	22%
	16-20	2	22%
	20-25	1	11%

Data Collection Methods, Measures, and Procedures

I began this study by sending an email to the math supervisor of the Marvel School Division. This email contained an introduction to the study and the characteristics of my ideal participants. Specifically, I asked the math supervisor to recommend teachers who truly integrate technology into their math instruction and had some kind of pedagogical shift due to virtual learning. The math supervisor had the knowledge of teachers' abilities and performance in the classroom without school-level bias, such as which teachers are always involved on committees or which teachers are often tardy. After receiving the list of names from the math supervisor, I sent an email from my Old Dominion University student account to each individual teacher's

school email address. I explained that the teachers had been recommended as participants in my study. I included an introduction to my study, consent forms, as well as my contact information to set up interviews. All interviews took place via Zoom (2021) and were recorded, both audio and visual, if the participants agreed.

I conducted a pilot interview with a secondary math teacher from a different school division than the one the current study was situated in. I reviewed the answers to the interview questions and wrote a detailed memo on how well the questions worked or how they failed to access the information I intended to find. This math teacher understood their role in the pilot interview and the need for confidentiality. Since the interview questions were researcher created, I wanted to ensure the questions were understood by the participants and generated appropriate data for the research questions. As noted by Yin (2009), the pilot interview allowed me to refine my data collection points in regard to the content of my data, as well as my interview procedures. This pilot interview strengthened the interview questions used in my actual case study, but was not used in my data analysis.

Once adjustments were made to the interview questions, I conducted a semi-structured interview with each participant. The interview protocol is outlined in Appendix A. Each interview lasted no more than 80 minutes. The shortest interview was 19 minutes, and the longest interview was 76 minutes. On average, the remaining seven interviews were 36 minutes in length. During the interview I followed the intended line of inquiry and asked the interview questions in an unbiased manner (Yin, 2009). To accomplish these goals, I asked interview questions about change in teaching pedagogies without using any adjectives that indicated that I was looking for positive or negative changes. Through my pilot interview, I ensured that my

questions about the digital divide and educational inequities were not leading or pushing my participants in a specific direction.

As another source of data, I analyzed technology integration artifacts. In my initial email to the potential participants, I asked for artifacts that represent technology integration within the classroom. These artifacts could have included, but were not limited to, lesson plans, digital resources, or student work. If student work was used, all identifiable information was redacted before being shared with me. Since a principle of case study research is the use of multiple sources of data (Yin, 2009), it was necessary to have artifacts that supported the teachers' responses during the interview process. Through the use of multiple sources of evidence, I hoped to develop converging lines of inquiry, which is similar to how researchers triangulate in quantitative studies. After the initial interview and review of artifacts, follow-up interviews were not needed. The initial data collected were adequate to determine the thematic findings.

Data Analytic Techniques

The qualitative data analysis method used in this study consisted of a three-round coding process. Coding is a fundamental part of qualitative research that allows researchers to break down data and make something new (Elliott, 2018). While Miles and colleagues (2013) presented a two-cycle model, an additional round of coding was needed to ensure relevant and quality codes, as well as identify information that was missing from the data. The first round of coding was a priori coding, also referred to as deductive coding. In a priori coding, the researcher develops an initial list of codes before beginning the field work (Miles et al., 2020). The set of initial codes for this study is listed as a code book in Appendix B. I created this code book based off my literature review as well as my theoretical frameworks. I not only used CRT and TPACK

to develop my code book, but they also served as my theoretical lens to drive my focus and attention during the data analysis phase.

Based upon the TPACK and CRT theoretical frameworks, as well as my research questions, I developed 13 initial codes. From the TPACK framework, I included codes on technology use, technology integration, pedagogy, pedagogical changes, and content knowledge. I included codes based off the five tenets of CRT: racism is normal (Delgado & Stefancic, 2001), interest convergence, race is socially constructed, intersectionality, and counter narrative. Based on my research questions, I also knew that I needed codes on assessment, student performance, and inequity based on race. After conducting my pilot interview, I updated my codebook to include student performance validity, digital concerns, academic dishonesty, and environmental/contextual factors. During the pilot interview it became clear to me that I needed codes that included concepts like cheating, home concerns, actual student learning versus perceived learning, and a code for other issues and concerns that participants discussed that didn't fit within another code. Lastly, I added an inequity based on socioeconomic status code. While the focus of this study is student race, the literature from the TPACK framework focused on technology inequity due to socioeconomic status, rather than race. Thus, it is important to code with the same lens as other TPACK literature.

Once all nine transcripts and the 31 artifacts were coded, it was clear that digital concerns, pedagogy, pedagogical change, student performance, and technology use were the most common codes. Table 2 presents each code and the number of times it was used during this first round of coding of the interview transcripts.

Table 2

Code List and Number of Times Used

Code	Number of Times Used
Academic dishonesty	38
Assessment	78
Content knowledge	34
Counter narrative	2
Digital concerns	220
Environmental/Contextual factors	97
Inequity based on race	69
Inequity based on socioeconomic status	36
Interest convergence	0
Intersectionality	0
Pedagogical change	158
Pedagogy	105
Race is socially constructed	1
Racism is normal (Delgado & Stefancic, 2001)	0
Student performance	155
Student performance validity	27
Technology integration	46
Technology use	175

Based on the number of times a code was identified, it was evident that the data represented more of the TPACK framework than CRT. Additionally, technology use was more frequent than technology integration.

An important step in the coding process is to revise codes as the data change and evolve. To assist with this refining process, I used a second round of coding that entailed looking at word frequencies through a summative content analysis. Summative content analysis allows the researcher to analyze and interpret word frequency to identify patterns and conceptualize original codes (Hsieh & Shannon, 2005). While word frequency does not always convey importance, this information, alongside my a priori codes, would produce the most relevant initial codes for my data. Miles and colleagues (2013) supported using word frequency midway during the data analysis portion to confirm or disconfirm assertions. Additionally, researchers with pragmatic views may consider counting as a systematic approach to qualitative coding (Elliott, 2018). The

word frequencies were determined through the use of NVivo (2021) software. The results of the word frequencies showed the most frequently used words, as well as words or concepts that were missing. With my third research question being directly tied to inequity in race, it was important to analyze what teachers were saying, as well as what they weren't saying.

After completing the initial round of a priori coding, I completed a summative content analysis using word frequency in NVivo 12 (2021). I selected all nine interview transcript files, including stemmed words, set the minimum word length to three, and displayed the top 1,000 words. This first analysis created a long list of small words like *just, year, see, going,* and *okay,* that did not have meaning regarding my research questions. I then kept the parameters the same, but reduced the number of words displayed to 100. Out of these 100 words, very few directly related to the research questions. Examples of words that were relevant to the study were *math* (187 count), *technology* (134 count), *assessments* (84 count), *changed* (64 count), *inequity* (54 count), *integration* (54 count), and *race* (50 count). I continued to increase the minimum word length until the top, or most frequent, words displayed represented more meaningful vocabulary to the study, as well as removed the repetition of any of the participants' names. At each increase in minimum word length, I looked for words that supported, or directly opposed, my code book. This was to ensure that my analytical lens was constantly being tied back to either the TPACK or CRT framework. When I ran the query with a minimum length of five, the work *African* presented with a count of 35. With the minimum length increased to six, *concerns* (count 23) and *struggling* (count 23) were presented in the top 100. Once the minimum length was increased to seven, *pandemic* (count 20), *economic* (count 20), and *challenge* (count 18) were introduced into the word frequency list. As the length of the words increased, the count of each word greatly decreased. For example, technology was stated 134 times, while challenge was only stated 18

times. Additionally, the frequency of words related to technology use had a greater count than those related to race or inequity. While relevant terms presented in each minimum length query, the final word frequency query included stemmed words, a minimum word length of nine, and displayed the top 100 frequently used words. I skipped from a minimum word length of eight directly to nine to remove the participant's name *Hermione* from the top ten more frequent words and focus on more relevant terms. The top ten most frequent words included *technology, something, assignment, assessments, different, instructional, understand, questions, classroom,* and *Schoology*[7]. The frequency of these words is displayed in Table 3.

Table 3

Top 10 Most Frequent Words

Word	Count
Technology	134
Something	102
Assignment	80
Assessments	76
Different	72
Instructional	71
Understand	64
Questions	63
Classroom	62
Schoology	57

These ten words aligned with my initial codes about technology use, pedagogy, assessment, and student performance. Within the top 100 words I did not find a concept that was not already included in my initial code book. The word frequency list, however, only noted a few words related to race, such as *demographic* and *ethnicity*. *Inequity* and *socioeconomic* were in the word

[7] Schoology (2021) is a web-based Learning Management System where teachers and students can create, share, and store academic materials. It includes content materials, graded assignments, and communication features.

frequency list, but they each only had a count of 11 and 8 respectively, compared to *technology* with a count of 134. This supports the lack of coded data using the five tenets of CRT during the first round of a priori coding. The word frequency supports findings focused more on technology and classroom aspects than race and inequity. A word cloud representation of the final word frequency is presented in Figure 5. The words closer to the middle of the figure, as well as in larger font, were the most frequently used words. The words on the outside edges of the word cloud in smaller font represent the least frequently used words within the top 100.

Figure 5

Word Cloud Top 100 Most Frequent Words

The third, and final, round of coding was pattern coding (Miles et al., 2013). While I summarized segments of data in the first round of coding, in the third round of coding I grouped these summaries into categories, themes, or concepts (Miles et al., 2020). Pattern codes identify emergent themes, configurations, or explanations. Table 4 shows how my research questions, proposed methods of data collection, and data analytic techniques aligned.

Table 4

Summary of Methods and Research Questions

Research Questions	Data Collection Methods	Data Analysis
RQ1: In terms of curriculum, teaching methods, and assessments, how did teachers describe their pedagogical change in virtual learning? RQ2: How do teachers perceive student performance has changed within the virtual learning space? RQ3: From teachers' perspectives, how has the digital divide and educational inequities affected students' virtual learning based on student race?	1. Semi-structured interviews with participants 2. Collection of technology integration artifacts	Three rounds of coding 1. A priori coding 2. Word frequency through summative content analysis 3. Pattern coding

Trustworthiness and Credibility of the Current Study

Typically, qualitative researchers use the term *trustworthiness* rather than *validity* and *reliability* (Hays & Singh, 2012). Trustworthiness in this study was created through credibility, transferability, confirmability, and coherence. Yin (2009) explained four tests to establish credible and quality social science research through the use of case study. The four tests included construct validity, internal validity, external validity, and reliability. The credibility of the current study was established through construct and external validity. Construct validity is defined by

using the correct measures for the study and can be strengthened by multiple sources of evidence and participants' review of the case study findings. Since the study is a single case study, the use of multiple sources of evidence, such as interviews and artifacts, helped strengthen the construct validity of the single case study. The participants were also able to review the findings through member checking. My member checks consisted of sharing my themes from the pattern coding process with the participants. I wanted to ensure that I was grasping the big picture and overall main idea of their responses to my interview questions. To complete the member checks, I emailed a narrative summary of their perspectives based on my analysis and asked each participant to review how their narrative tied into the themes I had found. This email also included any verbatim quotes used from their specific interview. If the participants felt their voice was represented incorrectly, or they wanted to clarify how they intended to come across in the interview, I then scheduled a follow up Zoom (2021) call to discuss any discrepancies. If the participants felt their voice was represented correctly, they simply responded back to my email with their approval. This step confirmed that the participants felt their interview and artifacts aligned with my themes. Out of the nine participants, four responded back to the member check that they approved their quotes and representation. The remaining five participants did not respond to the member check at all. I did not need any follow up Zoom calls for member checking purposes.

A research tactic to strengthen external validity in single case studies is to use theory (Yin, 2009). Since TPACK and CRT are both well-recognized theories in the field of education, my theoretical framework for this research was sound. CRT served as the lens for me to analyze the digital divide and educational inequities through the concepts of historical educational injustices. TPACK provided multiple types of knowledge to interpret how teachers changed due

to the virtual space. Rather than analyzing one aspect of a teacher, TPACK presented an overlapping view of pedagogy, curriculum, and technology use. These two theories were broad enough to cover any responses to my research questions, but focused enough to be used in this study. My literature review of these theoretical frameworks increased the external validity of this case study. Through the analysis of the empirical studies, I identified common conclusions and practical applications from the research, as well as gaps. The information that I learned helped to shape this study. The findings from this study can be applied to other math virtual learning experiences, as well as other content areas. Most of the TPACK literature was focused on technology integration with content and pedagogy as a whole, rather than being content specific. By completing a study specifically in math, the findings can be applied within the realm of other forms of online math instruction and for virtual math educators. Confirmability, another way to create trustworthiness, is defined by the degree to which the findings are true reflections of the participants. To confirm my findings, I conducted member checks as indicated above.

Coherence in my data analysis was supported by team coding. Team coding allows for clarity in the initial codes, as well as increases the reliability of the codes (Miles et al., 2013). A member of my dissertation committee assisted in team coding 12% of my interview transcript data for code coherence and credibility. Miles and associates (2013) recommended an intercoder agreement between 85-90%. The interview data I transcribed and reviewed with this committee member consisted of 155 coded sentences. Out of those 155 coded sentences, we negotiated 35 of them, leading to an intercoder agreement of 77%. While this percentage is lower than the recommended percentage, it is important to note that only 14 coded sentences were originally coded with different codes between the two of us. Seven sentences were changed from a single code to a double code, five sentences had codes removed, and nine sentences that were originally

not coded were coded after discussion. If I compare my initial codes with the negotiated list and only look for the codes that were initially different between the two of us, the intercoder percentage becomes 91%.

Lastly, I conducted all portions of this study with ethical validation, which also built trustworthiness (Hays & Singh, 2012). Hays and Singh wrote that researchers should conduct research that will provide insight into practical and meaningful real-life problems as a part of ethical validation. Teaching math in a virtual space is a very practical problem during the COVID-19 pandemic. Ethical validation also includes generating new ideas for the field, as well as transforming practitioners' actions. The findings demonstrated current ideas and practices that math teachers are using to teach virtually. These ideas and practices can be spread to other math teachers through professional development and resource sharing. Lastly, ethical validation was demonstrated through the use of consent documentation and sharing of my findings with the Marvel School Division hosting my study. Once this study was completed, the findings, conclusions, and implication sections were given to the department that approved the study within the division. The math supervisor was also given a copy of these sections. By providing my findings, conclusions, and implications, I did not just use the site for its participants, but rather I tried to give back and improve future virtual math instruction. The math supervisor and the research department can base specific future actions on these findings to improve virtual math education and equitable learning for all students.

Limitations

The main limitation of this study is the small number of participants from the high school setting. While I wanted to look at secondary math classrooms, both middle and high school, most of the participants represented the middle school setting. Most of the participants also were

White, female teachers. Additionally, only one participant was interviewed who taught an upper-level math course. Future research should be conducted specifically in the high school math setting with a focus on male teachers and teachers of color.

Another limitation of this case study was the lack of evidence in teacher artifacts to support the descriptive interview data. Three participants did not submit any artifacts to demonstrate technology integration. Two additional participants did not submit any technology integration artifacts, but they did share an activity through Zoom (2021) screenshare during the interview. The remaining four participants sent me digital artifacts. While analyzing the artifacts, almost every artifact fell into the code of technology use rather than integration. Participants were using technology to provide a different format for an assignment, like a Google Slide rather than a worksheet, as well as using technology to provide instant feedback on whether the students were right or wrong. Out of the 31 artifacts submitted and coded, only three were coded as relating to technology integration. In the future, more guidelines should be given to the participants about what technology integration means and may look like before asking them to submit artifacts.

A final limitation was the lack of student voice. As an important part of CRT, counter-narrative involves speaking about one's reality (Ladson-Billings, 2013). While the teachers were speaking their perspectives of reality about student performance, the students' realities were missing. An avenue for future research would be to interview students about their perceptions of the changes in education due to the COVID-19 pandemic, as well as the changes to their academic performance.

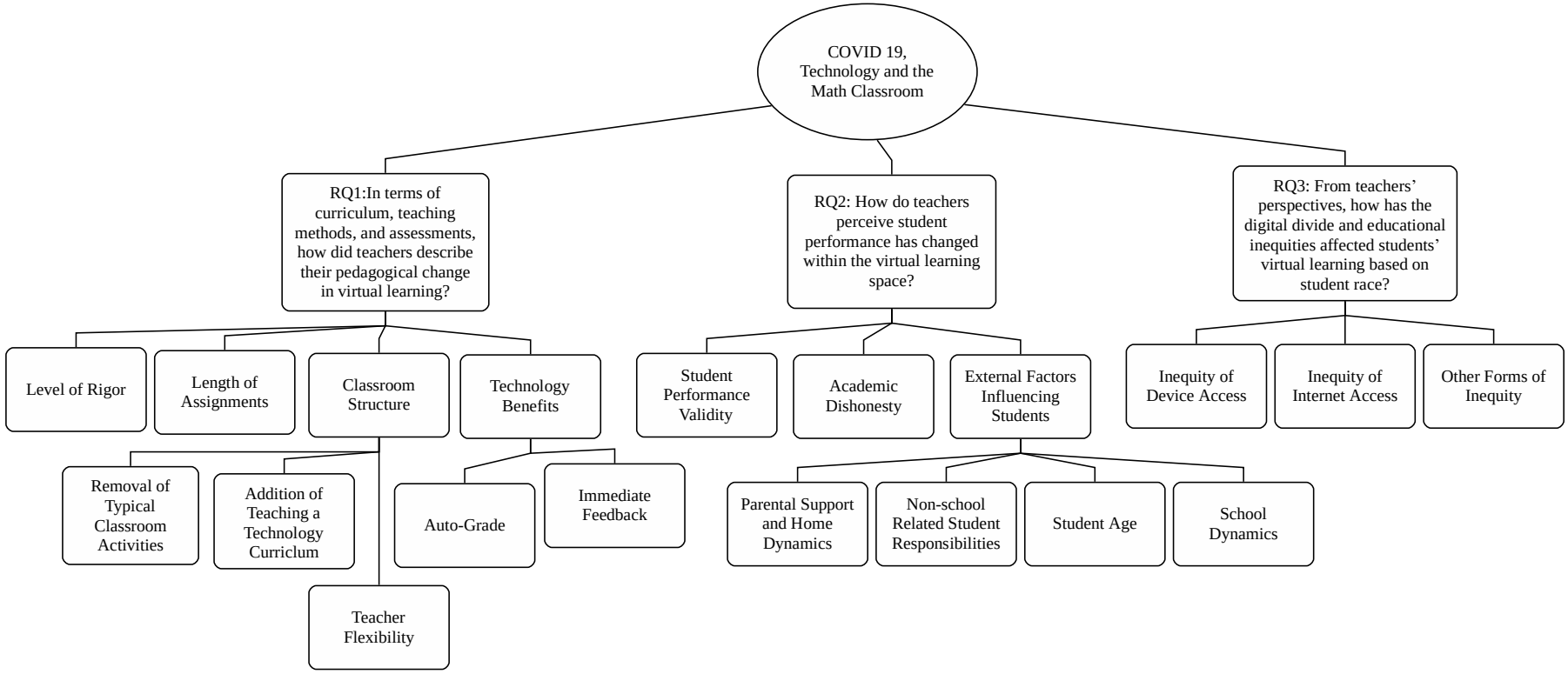
CHAPTER 4

Data Analysis and Findings

In this single case study, I conducted nine interviews with secondary math teachers and analyzed 31 relevant technology artifacts. The single case being examined was secondary math teachers teaching virtually due to the COVID-19 pandemic from the Marvel School Division in southeastern Virginia. Through a three-round coding process of the interviews, I examined how teachers changed their math curriculum, teaching strategies, and assessment practices in the virtual learning space during the COVID-19 pandemic. Additionally, I analyzed how teachers' perceptions of student performance had changed, as well as the possibility of educational inequity based on student race. Through the theoretical lens of Technological Pedagogical and Content Knowledge (TPACK) and Critical Race Theory (CRT), I created a codebook to analyze my interview transcripts and technology artifacts. In this chapter, I will discuss my themes as they relate to my three research questions: (1) In terms of curriculum, teaching methods, and assessments, how did teachers describe their pedagogical change in virtual learning? (2) How do teachers perceive student performance has changed within the virtual learning space? (3) From teachers' perspectives, how has the digital divide and educational inequities affected students' virtual learning based on student race? A concept map of the research questions, themes, and subcategories is displayed in Figure 6.

Figure 6

Concept Map of Themes



Themes

Research question one asked about teachers' descriptions of their pedagogical change in virtual learning in terms of curriculum, teaching methods, and assessments. The following four themes will be discussed: (a) level of rigor, (b) length of assignments, (c) classroom structure, and (d) technology integration. The second research question asked teachers about their perception of student performance during this past virtual learning school year. When analyzing the transcript data focused on student performance, the overall connotation was negative. While some participants discussed students thriving in a virtual environment, for the most part student performance was discussed in a negative light. The three themes of this research question include (a) student performance validity, (b) academic dishonesty, and (c) external factors influencing students. The final research question asked teachers to discuss how educational inequity affected students this past school year specifically based on student race. During the participant interviews, we discussed inequity in terms of technology, education, and then focused the inequity conversation specifically on student race. With the limited number of coded sentences as well as word frequency directly related to racial inequity, it was clear that participants spoke more broadly about inequity and did not perceive a direct connection with student race. The data did not present a clear theme of racial inequity. When I asked the participants about any technological or educational inequity this school year based specifically on student race, five of the participants clearly stated that they did not feel inequity based on student race was present this virtual school year. The three themes within this research question are (a) inequity of device access, (b) inequity of Internet access, and (c) other forms of inequity.

This purpose of this section is to expand upon each theme and provide direct quotes to represent the voices of the nine participants. Support from the technology artifacts will also be

discussed. The themes presented describe the changes that secondary math teachers had to make during this past COVID-19 pandemic school year. The themes represent the overall commonalities within this case study of secondary math teachers during virtual instruction in the Marvel School Division.

Level of Rigor

The theme *level of rigor* addresses teachers' changes for both curriculum and assessment as a part of my first research question. All participants indicated that the level of rigor of their math instruction was lower this school year than previous in-person school years. This lower level of rigor started with surface level instruction and ended with a surface level form of assessment. Captain America[8] bluntly said, "we had a lot of very surface level instruction… we didn't have a lot of deeper learning that we could have had." Hermione agreed, "I also felt like the content, I had to go at more of a surface level this year." Blue also kept the level of instruction at a surface level to ensure that all students were able to reach the content. Blue stated:

> I'm trying to hit the surface, as much as possible, without losing them trying to delve deeper into it. And for that reason we felt like, okay we're just kind of hitting, skimming the surface with some of this stuff.

With the teachers only being able to hit a surface level of instruction, they also felt their assessments had to have reduced rigor. Mavis stated, "I have definitely dialed it back looking for understanding," when discussing the level of rigor of assessments. Hermione agreed, "once again, I'm instructing at a surface level, I had to bring my assessments down to a more of a surface level." Blue also noted obvious changes to the classroom assessments when converting

[8] All names of people and places are pseudonyms.

the paper copies to online versions. Blue said, “Because I’ll be honest, well, no I tell you what, our assessments have been a little less rigorous. Um so I know we have lost some of that deeper level of thinking type question, um, through the assessments.” A specific example that Blue provided related to solving two step equations. Blue described that typically they would include questions that “would throw in something that was all fractions. Like two thirds X plus three fifths equals four eighths or something along those lines.” However, questions involving all fractions were thrown out of the assessments this school year. While Blue noted that answers could still come out to be fractions, fractions within the initial question were removed over concerns of being too high level this school year. Captain America submitted an artifact that also demonstrated a lowered level of assessment practice. Instead of having a paper and pencil assessment, an online tool called Quizizz (2021) was used to assess triangle similarity. The lessened rigor was evident in that all questions on this assessment were multiple choice. The virtual learning environment forced simple question formats, which lowered the deep level that could be assessed. The participants continued to express that, typically due to time concerns, their level of instruction was not as rigorous, which led to assessments with lessened rigor as well.

The lower level of rigor was attributed to shortened instructional weeks and instructional time blocks. Teachers felt that they did not have the time to really reach a high, rigorous level of math instruction this school year during virtual instruction. Kelly stated, “some teachers need[ed] to cut some things out to get, you know, to get everything in because we have a shorter amount of time of teaching.” Hermione wanted “to make sure that I was having enough time to deliver a bare minimal amount of instruction within the time that we were provided.” The time crunch really affected what teachers chose to teach and how long they taught the material. Hermione

stated, “with the reduced instructional time, um, especially in the pre-algebra classroom, I really had to, unfortunately, I had to strip away things that were typically embedded within my typical delivery of a lesson.” Blue also stripped away material due to time concerns and had to cut down the length of her typical instruction. Blue said, “we felt like there are things that we would spend probably a week and a half to two weeks on, that we cut down to three days.” By shortening the amount of time a concept is taught, it is impossible to still reach the same level of deep knowledge that could be attained in a typical school year. Hermione claimed, “I was not able to dig as deep because, once again, trying to teach virtually was just eating up so much time.”

While Thor agreed that the level of assessments had lowered this school year, the change was attributed to the new learning platform rather than just less instructional time. Thor explained:

> Rigor, um, I felt like we struggled more in that area to find, you know, really higher level stuff because again we weren't comfortable with Schoology[9] in the beginning. So I feel like our rigor probably got better as the year went on, but in the very beginning, we were pretty much just like, you know, what can we kind of do, and just make sure we get this together?

Although Thor felt the cause of lower rigor was different than most of the other participants, it is important to note that rigor was still changed this virtual school year. Whether due to time or learning a new technology platform, most participants agreed that the rigor of both instruction and assessment had been reduced. When answering the first research question, the secondary math teachers of the Marvel School Division expressed a needed change for both curriculum and assessment in the form of lowering the overall math content rigor.

[9] Schoology (2021) is a web-based Learning Management System where teachers and students can create, share, and store academic materials. It includes content materials, graded assignments, and communication features.

Length of Assignments

Length of assignments is another theme that addresses a needed change in both curriculum and assessment within my first research question. With the shortened instructional time, and changes to rigorous teaching and assessment, the format of most assignments within the secondary math classroom also had to change. The participants noted that assignments, whether homework, quizzes, or tests, all had a reduction in the number of problems. Hermione noted, "I was not able to have nearly as lengthy of an assessment that I typically would." While Hermione may have liked a longer assessment for the students, she realized that changes needed to be made this school year. These changes were evident in almost every technology artifact she submitted. Hermione typically had students complete assignments that were about three problems in length. Belle stated:

> I think the other thing that has been really big is realizing that 50 question tests or 25 question tests are just really something that we don't have to do, every day… I think less is more, has kind of been one of the key takeaways from the year, is like, if you can see in five problems that a kid knows how to do it, why are you making them do 50?

Captain America also adjusted the length and stated, "trimming down the homework assignments like I said, instead of making it 10 problems, made it two or three, made a little bit easier to still capture." Captain America's statement was supported be a technology artifact that showed a functions and relation class activity that was only two problems. 7-11 also submitted artifacts that showed a variety of homework assignments with less than 10 problems. It was evident that fewer questions were starting to be more beneficial for both the students and the teachers. Not only did the students have fewer problems to solve, but the teachers had fewer problems to grade. Additionally, more thought went into how to really assess student knowledge

in as few questions as possible. The participants were starting to pay more attention to how, when, and why they were assessing their students. Belle stated that this school year she changed in “just knowing when to, when it's appropriate to assess and when it's not appropriate to assess.” Additionally, in this virtual school year, Kelly felt that she “didn't need to overly assess, overly question.” These participants indicated that teachers’ mindset on assessments may have started to change due to this virtual school year. Since the time demand forced changes to instruction and assessments, teachers had to put more conscious effort into their assessment practices. All math teaching levels within the defined case of this study shortened their assignments. Hopefully this is a pedagogical change that will continue to grow in the future and support student learning. Specifically, teachers can make more focused decisions on what they assess and how long those assessments really need to be.

Classroom Structure

Other than lowering the level of rigor for instruction and assessment and shortening assignments, other commonalties were presented about changes in the secondary math classroom structure. In this study, classroom structure is defined as the typical pieces of a teacher’s classroom in previous school years. An example of classroom structure would be when a teacher requires all students to have a composition notebook and take notes by hand during each class period. Another example would be having an exit ticket every Wednesday and a quiz every other Tuesday. Classroom structure, in this study, is synonymous with classroom routines. Participants cited changes to the classroom structure including the removal of typical classroom activities, the addition of teaching technology, and teacher flexibility. These three themes address the teaching method changes that were necessary due to virtual learning and directly answered research question one.

Removal of Typical Classroom Activities

Two participants spoke directly about having to remove warm-ups, or bell ringers, due to the lack of class time. 7-11 stated “Um, due to lack of time, and, you know, kind of all of this instruction that we talked about prior to, I’ve not been able to do warm-ups like I really want to.” Hermione also mentioned, “I didn't do as many bell ringers as I would in a typical class, or a typical year, whereas every single day is started with a bell ringer or warm-up within my normal setting.” These two participants specifically spoke about the negative effect that removing warm-ups from the classroom structure had for them. Without the constant review and content spiraling, the students were not retaining the math content as well as in previous school years. 7-11 specifically said:

> not incorporating my warm-ups, that was something that really, like I said, that really I feel like has, not hurt my students, but I can tell that they're not, you know, when I, when I ,we've, we've been reviewing for our SOL test here… I’ve noticed that they, you know, it's not as familiar, things that we did, that were maybe a little bit more intricate.

The removal of the bell ringers also made Hermione feel that, “I had to strip away, um, review time that I typically would build into every single class.” These two teachers spoke about how this virtual school year had negative influences on their typical curriculum and pedagogical practices. They both always used warm-ups to review previous material and keep the content fresh in their minds. However, during this virtual school year, they were forced to remove this instructional support for students. While this study included multiple levels of secondary math teachers, the only teachers who discussed concerns over removing warm-ups were middle school level teachers. The three high school level participants did not address warm-ups in their interviews.

Blue also indicated having to remove an important part of her typical classroom structure due to time concerns. While not a warm-up specifically, Blue removed discovery aspects from her class. She stated, “we kind of had to come away from that self-discovery just a little bit because we just didn't have the time built in that we normally do.” Blue felt as if her classroom had more periods of direct instruction and simply telling the students how to do the math, rather than exploration and self-learning.

While warm-ups and self-discovery activities were often removed from the class period due to time concerns, other parts of a typical classroom structure were removed due to COVID-19 regulations. Some participants spoke about the removal of manipulatives, group work, and projects due to school rules and COVID-19 policies and procedures. Blue noted:

> we couldn’t use any type of manipulatives, because it was, if you hand them out, you got to clean all of that, and so it was a lot of that, kind of got taken away from us. Um I mean we used to use dry erase boards all the time. It was a quick way to check and have the work shown to us and we couldn't do that this year.

It was clear that in Blue’s classroom, the COVID-19 policies and procedures affected the typical structure of her math instruction. She was unable to use materials to assist with concrete understanding or use her typical pedagogical practices to get immediate feedback from the students. 7-11 also indicated that COVID-19 had affected her typical classroom structure of using activities. She explained “normally in class I would have, I have escape rooms, things like that, and, you know, working here or walk abouts.” Once again, due to COVID-19 social distancing limitations, 7-11 was unable to complete some of her normal class activities. Wonder Woman echoed this sentiment about being unable to complete her typical classroom projects. She stated, “that's another thing I think that really limited us this year. I couldn't really do any of

those fun math projects like really in person." Wonder Woman did not have the time to convert her in-person projects to virtual projects, which she felt limited her instruction. While the in-person students could have benefited, she felt that it would have been pretty tough for the virtual students to also complete the same project. It seemed that Wonder Woman usually completed projects regularly and was forced to remove that from her classroom this year. Once again, within this case study, the only participants to discuss a specific item being removed from their classroom, whether self-discovery or projects, were all at the middle school level. With six of the nine participants representing the middle school level, this is to be expected. However, I cannot conclude that all secondary math teachers had to remove a portion of their typical classroom structure this school year in terms of warm-ups, self-discovery, and projects.

One of the concepts that the participants emphasized that was removed from the math classroom this year was student work. The removal of work was a concept addressed by all of the secondary math teachers included in this case study. In a typical school year, a teacher can physically see the steps that students are writing down to solve their math problems. However, in this virtual learning environment, teachers had great difficulty with being able to see student work. Hermione explained her difficulty with collecting work in a virtual environment versus an in-person school year and said:

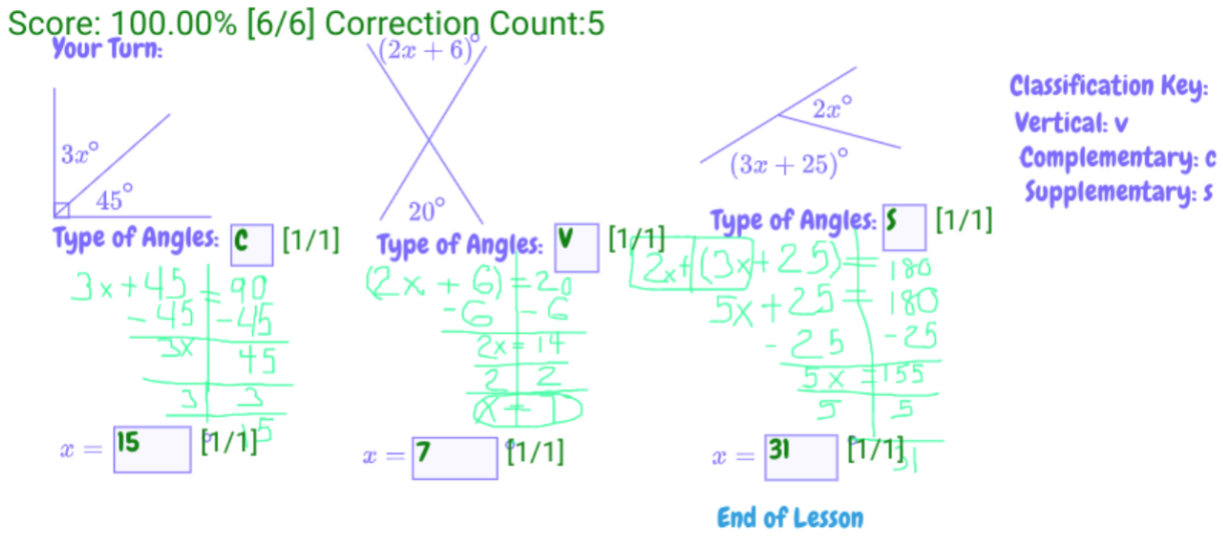
> if I'm doing an assessment in this school year, it's not a paper assessment, the work isn't right there. So if I have it set in Schoology I've also got to have a separate location to be able to collect their work. Um, which became difficult to kind of juggle that, um, and to be able to look at students' written work.

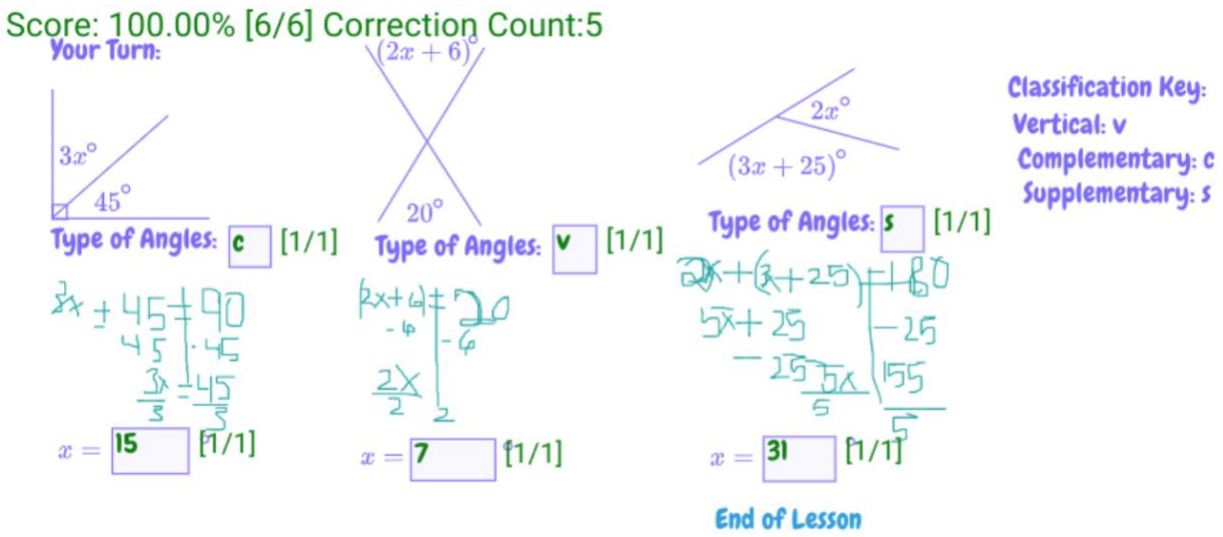
Hermione submitted multiple artifacts of student handwritten work. The students took a picture of their work and then uploaded it virtually. However, as addressed earlier, she struggled to

match all the work submitted with the online assignments. Therefore, Hermione put a lot of effort into finding ways for students to effectively show their mathematical work. She eventually began using the website whiteboard.chat (2021), where students could write on the screen and she could view the responses in real time. However, due to difficulties with typing math work, students usually had to write using their mouse. Using a mouse to solve math problems can be difficult for students, and difficult for teachers to read. Figure 7 shows two examples of student work from Hermione's class using the whiteboard.chat website. It is clear to see that variations exist with the clarity of the work based on the students' abilities to write using their mouse cursor.

Figure 7

Two Student Work Samples Using a Mouse to Write





Blue also faced difficulty in being able to view student work and stated, “honestly some things where we were like just, just give me the answer, because I don't even begin to know how you're going to show me the work.” Blue did discuss how certain high schools were having students take and upload pictures of their work, but she felt that may be too overwhelming for her middle school students:

> I probably could have done that, but then I didn't want to put another, uh, load on the kids, well now you got to do this and take a photo and submit the photo and do, because that's a whole other level of technology usage that they were going to have to do.

As a teacher, Blue had to compromise her desire to see student work with the technology expectations it would have put on her students. Ultimately, showing work did not become the focus in Blue’s classroom.

In some way or another, the COVID-19 virtual school year removed a normal part of the secondary math classroom structure for these teahers. While some examples appeared to be more directly related to middle school level math teachers, all secondary math teachers had to adapt their classroom structure in some way. These adaptations included losing warm-ups, skipping over self-discovery, removing class projects, and failing to view student math work.

Addition of Teaching Technology

Secondly, a notable change to the classroom structure was the amount of time teaching the technology being used rather than math content. Two participants started the school year off with two weeks of only technology instruction, while another participant spoke to the amount of class time taken up with technology explanations and instructions. Captain America "started with two weeks of activities designed to understand navigating Schoology, as well as on how to send emails, stay organized, um, fun activities that really brought the class, classes together." Figure 8 illustrates a sample assignment that Captain America gave to his students to learn how to use a computer keyboard to type math symbols. The students had to practice the keyboard shortcuts in order to learn how to type math symbols online. Captain America felt it was extremely important to learn how to communicate math virtually and wanted to ensure that his students knew how to express their math symbols within this digital learning environment.

Figure 8

Student Assignment to Learn Math Type

Kami Math Symbol Typing

Intended Learning Outcome: I can type mathematical symbols using the Equation tool in Kami to communicate mathematics accurately and effectively.

Rationale: Throughout the learning process, especially in upper-level mathematics courses, symbols are used in mathematics to represent essential vocabulary and topics. For example, instead of writing "the square root of", we use the symbol √. Instead of writing the word triangle, we use the symbol Δ. Additionally, it is imperative to communicate in mathematics with proper symbolic notation to allow the reader to understand the mathematics topics being discussed.

Directions: Retype the following expressions using Kami's Equation tool by following the shortcut and/or programming codes. Place your answers in the boxes to the right of each mathematical expression. Note: When you are using the programing language you will notice the "\" symbol followed by a list of letters or words. When you see the "(space)" notation, press the space bar once. The intended symbol should appear.

Description	Mathematical Expression	What to Type	Place your Answer Here
Multiplication (Dot)	$5 \cdot 2$	5\bullet(space)2	
Greater Than or Equal To	$x \geq 5$	x >=5	
Less Than or Equal To	$y \leq -1$	y<=-1	
Square Root	$\sqrt{9}$	\sqrt9(space)	
N-th root (Including Cube Root)	$\sqrt[3]{8}$	\nthroot(space)3(space)8(space)	
Not Equal To	$5 \neq 7$	5\ne(space)7	
Plus or Minus	± 5	\plusminus(space)5	
Pi	π	\pi(space)	
Angle	$m\angle A$	m\angle(space)A	
Parallel	$m \parallel n$	m\parallel(space)n	
Perpendicular	$a \perp b$	a \perp(space)b	
Degrees	98°	98\degree(space)	

Although Captain America had concerns about losing two weeks of instructional time, he felt it was important for the social emotional learning of the students to really be comfortable with the Schoology (2021) learning platform and the online learning space before starting math instruction. Blue also indicated that she lost two weeks of math instructional time to ensure her students understood the new technology needs. She explained:

> we lost them, two weeks up front, because we were trying to make sure that all the students could get logged in, have a computer, um, able to access Schoology, and so it was kind of a learning those first two weeks.

Both Blue and Captain America pushed their math curriculum back in order to accommodate the new technology learning that students needed. In this new virtual school year, the students

needed a lot of instruction on how to work the learning management system, as well as complete basic technology tasks that would have been new to these students.

While 7-11 did not commit a full two weeks to technology instruction, she did comment on the increased amount of class time used to explain how the technology worked. For example, she stated:

> So teaching them to, you know, manipulate the Google slide has certainly been an ongoing process and showing them how to use the tools, because that's one thing that from day one, I have to realize that I can't expect them to know where all these features are just because.

7-11, when speaking about a specific activity, mentioned, “I had to spend probably 10 or so minutes just explaining, not how to only, how to do the activity, but in Google slides what to do with it and how to share with each other.” While thinking about all the time she really spent this year explaining technology directions, she stated:

> So that has definitely made an impact on how much time, I don't want to say time wasted, but, you know, time where normally I would just say, you know, in class really quick and I can show everybody at one time and they usually pick up on it much quicker.

The virtual secondary math classroom created a space where it was much more difficult to give directions to the entire class at one time. Late students, connectivity issues, or in-person students could all affect how quickly directions could be explained. Additionally, if any virtual students were struggling with an online assignment, 7-11 would have to work one-on-one with them, which delayed assistance to the other students in the class. In the case of all three of these participants, a lot of math instructional time was used to teach the technology being used in the math classroom.

Teacher Flexibility

Third, participants spoke about how they had to become more flexible this school year to encourage student success. This flexibility included changing their teaching format and showing grace with assignments through multiple attempts and demonstration of growth. Belle completely changed the teaching format of her classroom to accommodate the needs of her students. Belle explained, “this year, I’ve really had to find ways with my students, because of their situations to make it so that they can have stuff on their time. Um, and more of a self-paced thing.” Belle began pre-recording all her lessons and posting those videos with copies of the blank notes. She set completion rules in the learning management platform so that students had to watch the videos before they could take any of the quizzes or tests. Belle also wanted to ensure that she didn’t waste students’ time and afforded them the instruction they really needed. She explained:

> I think that's one of the big things is having like choices and giving them like edited versions of things so that they can go back and replay it if they need to or if they don't need to watch something, not making them listen to it.

Belle also submitted a technology integration artifact to support her pedagogical change to self-paced learning and student choice. This example (see Appendix C) gave students choice about which method they preferred to use to multiply polynomials. The student choice aspect allowed for this math instruction to be strengthened rather than forcing students to complete work in a way that they did not feel comfortable. During the notes portion, the students had three options on the screen, but were only required to watch and work with one of the methods. The multiple options provided instructional support for the students and would help them learn the concept more efficiently.

While 7-11 did not change her classroom to self-paced with choices, she did adjust the format for what was typically independent practice for her students. She stated, “that has been a big learning experience too is what, what assignments are better through guided instruction and what assignments are better through independent work.” 7-11 spoke about one homework assignment in particular that she will make as a guided assignment in the upcoming school year because it was too difficult for the students to complete at home independently. The difficulty in this assignment was not focused on math content, but rather on how to work the technology of the color by number Google Slide. The color by number example (see Appendix D) demonstrates that if the students were unable to get the first question correct then they were unable to move on to the remaining questions. If a student missed the first problem, then they would miss the entire assignment. In the future, 7-11 wanted to be able to complete assignments like this during a class period so that she could help monitor, assist, and troubleshoot any of the technology issues. Hermione also used new technology this school year to change her typical approach to assessments. She was able to grow as an educator and expand her method of assessment as she explained:

> I will say that I do feel the technology allowed me to open up to a whole new variety of questions that were a little bit tough to create in previous years. So being able to use drag and drop, fill in the blank, drop down, matching, um, you know, different things of that nature. Oh! Even hotspots like where they're able to select multiple items on a coordinate plane or something of that nature.

While COVID-19 created a school year that involved multiple compromises to instruction, like lowering rigor, shortening assignments, and removing warm-ups, it also provided teachers a new lens to change how they structured their typical math instruction.

Every participant spoke in some way about showing grace to students this school year. Reflecting on all of the effects of COVID-19, Mavis stated, “it's definitely giving the kids grace right now.” The grace could have been shown by allowing students more than one attempt on an assignment, providing a practice assignment before the actual graded assignment, or using grade replacement once mastery had been shown. Captain America stated “giving students multiple attempts and stuff because we're learning.” He claimed that “this year has been an eye-opening experience to help me understand that students might need more than one attempt before they submit assignments.” Wonder Woman echoed the thoughts of Captain America when she said, “that's really changed my assessments, you know and giving multiple attempts, you know, to do well, because I, because this year to me now, it was more about a student’s confidence.” Wonder Woman also specifically spoke about grace with her students and explained that “now when it comes to my assessments there has been a lot of grace now, [more] than what I had in the beginning.” Both participants realized that students, while learning, may need more than one opportunity to show growth and, hopefully, mastery. Once students showed mastery in Belle’s class, she would change the previous failed grades so that each student’s grade was a true representation of their learning. She stated:

> Well why am I going to still hold that 20 that they got on a quiz against them? Like why not go back and be like, “Hey you showed all this growth, you know how to do that now, let's go back and change that grade.”

Belle’s rationale not only supported student achievement, but she felt that, by giving students this grace, the students would want to work harder in math class to really show their growth and understanding. During this virtual school year teachers showed flexibility by changing their instructional format to best serve the students and adding more attempts to demonstrate student

learning. This case study provides positive examples of how the COVID-19 virtual school year changed the secondary math classroom in the Marvel School Division.

Technology Integration

Moving from an in-person classroom environment to a virtual learning space inherently forced teachers to use more technology this school year. All participants discussed technology use such as the Schoology (2021) learning management platform, Kahoot (2021), Quizizz (2021), Edpuzzle (2021), Nearpod (2021), and Google (2021) products. However, the purpose of this study was not simply to look at what technology was being used, but rather how the teachers were integrating the technology to support student learning. Two main technology integrations repeatedly came up in the participants' interviews: the ability for technology to auto-grade math assignments and the immediate feedback features, were indicated by most participants as technology that provided a helpful tool to increase student learning and student achievement. These two specific ways to integrate technology address changes within the secondary math classroom curriculum, teaching methods, and assessment practices. Technology integration is another theme under research question one.

Auto-Grade

Because of their limited classroom instructional time, teachers needed a quick way to disaggregate their data and improve future instruction for their students. When time is of the essence, teachers looked for any method that could help save time. The auto-grade, or self-grade, feature of Schoology (2021) became a large benefit this past school year. 7-11 explained "with Schoology, like I said with it being self-graded, with Schoology, it allows me the opportunity to really assess each individual item or skill significantly better because it does calculate that data for us." 7-11 was able to use technology to assess her students and analyze the data from the

assessment more specifically. Captain American shared this sentiment when he stated, "Schoology allows, of course, for the instant grading, as well as allows me to provide audio feedback or typed feedback for students and allows me to quickly disaggregate the data from their assessments and have review sessions afterwards." Captain America clearly pointed out how he provided feedback in multiple ways and used the data to improve student achievement in the future with his review sessions. Hermione stated, "another component that was more advantageous, um, was the ability to auto-grade, to auto-score, which in the math world I did not really experience much of that before." While this technology support was new to Hermione, she was excited to try a new feature that wasn't typically used in the math realm. Prior to COVID-19, most math assessments were given in a pencil-and-paper format. The new learning management platform allowed assessments to assess specific skills, automatically grade the results, and disaggregate the data for the teachers' future use.

Immediate Feedback

With the challenges that this virtual school year presented, it was integral that teachers found a way not only to receive feedback on student performance, but also to provide immediate feedback to the students. Captain America stated, "the instant quick feedback has been necessary or it has been highlighted as being more necessary, um, because I don't get to see my students all the time." 7-11 also benefited from using the learning management platform to provide immediate comments and feedback to her students. She explained that "normally prior to COVID if I gave a paper pencil test, um, I would you know, maybe write a comment, but now I can just go in and type that comment, um, to provide that feedback too." Participants offered multiple remarks about how technology allowed them a quick, sometimes in real time, way to provide feedback to students. It was even mentioned that through the use of technologies, some

participants felt like they were sitting right next to their students and helping them with their math instruction. Technology allowed for one-on-one support and immediate feedback even when teachers and students had to be physically separated.

Two of the artifacts analyzed supported the idea of providing immediate feedback to students through technology in order to strengthen their math learning. These two examples supported student learning by allowing the teacher to have a private conversation with the student in real time while the student was completing the assignment. During our interview, Blue shared her screen to show me an example of a Nearpod (2021) activity where she was able to click on each student's page and type notes, reminders, and comments to them if they were having any issues. Blue enjoyed the privacy of typing in Nearpod. Blue said that eventually her class started to request that she review their assignments before they submitted them. Students were taking ownership in ensuring they were completing the math correctly. The second example (see Appendix E) is a screen shot of a student's screen where the student and teacher were going back and forth in a live dialogue. The student was able to privately raise their hand to inform the teacher they needed help. This live dialogue is almost like a chat feature, but it is on the specific work screen the student is completing. Even with virtual students who were not physically near the teacher, these two artifacts show how technology can be incorporated to remove that barrier and strengthen a student's math understanding, even from a distance. Technology tools were used to provide immediate feedback to the students, which then supported their learning and became technology integration within the secondary math classroom.

Other artifacts were submitted that supported immediate feedback, but not true technology integration. One example (Appendix F) shows the students having to type their equations for graphing a linear equation. If the students answered incorrectly, the box

immediately turned red. This supports teachers changing their assignments and assessments to provide immediate feedback. However, if the student doesn't learn anything from the red box, or the teacher doesn't use these mistakes to change future instruction, the technology was simply used as a tool for quick feedback rather than an integration piece to support student learning.

Student Performance Validity

The theme of student performance validity addresses the second research question about teachers' perceptions of student performance in the secondary math classroom during virtual instruction. Most participants expressed concerns with feeling like they could not truly gauge their students' levels of understanding and what was truly being learned in the classroom. Wonder Woman expressed that she went home each night and wondered if the students actually learned anything, or if they just remembered it for the 30-minute class period. Belle agreed that "sometimes it's harder to gauge what kids know." 7-11 attributed this difficulty to not being able to physically see her students:

> I'm not getting that, those facial expressions, you know, that I would normally see. You know if you have a student that obviously you tell, you can tell they might be a little tired from the night before, you might see glazed over look, and they're just not getting it, you can see that.

Without the "physical human interaction," as Thor put it, the teachers struggled to have an accurate measure of their students' knowledge. Multiple participants agreed that assignment and assessment data may not have really given a true picture of the students' abilities. Captain America claimed, "the assessments I'm a little iffy with and see if it actually measures their true academic ability." Thor also felt that she "didn't always have accurate data to go off of… I don't know if those grades were actually accurate and indicative of their current level of

understanding.” 7-11 provided a specific example in the math classrooms where students just completed work to do it, rather than show their level of understanding. She stated, “they'll go and just drag and drop and not really pay attention to where the item should be going, you know, really focusing on am I understanding, am I demonstrating that I have learned the content.” With students completing assignments with lack of attention and focus, it provided a tainted picture on what the student may or may not have mastered. The secondary math teachers in this case study had general concerns about student work and student grades being an honest reflection of the students’ performance and math knowledge.

Some concerns of student performance validity were mitigated when students started to come back into the building for in-person instruction. Wonder Woman described how she felt, “at least for the ones who are in school with me, I know that that is your true grade, that's your true effort there.” However, Hermione and Thor expressed concerns over the students who remained all virtual. Hermione explained, “the first monitored assessment the entire school year for me to know what the students’ own ability level was going to be, would be the SOL.” This end-of-the-year state exam would be the first opportunity for secondary math teachers to have assessment data that were guaranteed to solely be based on the students’ knowledge and not outside sources. However, with this state exam coming at the end of the school year, the teachers spent an entire year unsure of what their student data actually meant. Thor provided an example of a student who received As all year, but then failed the end of year SOL. This prompted Thor’s question: “What was actually happening behind the computer screen?” Without any supervision of students as they worked on classwork, homework, and assessments, the participants found it difficult to feel they had an accurate representation of each student’s math knowledge.

Academic Dishonesty

Academic dishonesty is another theme under research question two that relates to the perception of student performance. Within this virtual learning environment, every participant noted, in some fashion, a concern about academic dishonesty in the 2020-2021 school year. More specifically, the concern was about students completing work at home and using additional resources to cheat on assignments. The most frequently referenced method of academic dishonesty was the use of an app called Photomath (2021). Belle expressed concern for when students completed work at home using Photomath because they weren't monitored like they are when they are physically in school. She stated that "when they're sitting in your class, like you can see if they pull out their phone and take a picture on Photomath." Blue expressed:

> That has been probably the bane of every math teacher's existence this year is the kids using that app, which is a wonderful app if it was used the way it's intended to be used and that's not what's happening this year… it's designed to help kids so if they don't know how to do something they can see that, but that's not the way it's being used. It's being used to pass tests and quizzes and that kind of thing, unfortunately.

Hermione supported the fact that students use outside sources on assignments and claimed, "I've overheard plenty of conversations of students in the hallways talking about being able to Google things or utilizing Photomath." As a middle school teacher, Hermione also noted that students may be using Photomath because they genuinely do not understand that it is cheating. She explained that "we have honestly had to have this conversation, legit conversation with students, about they do not understand that Photomath is not an acceptable method of showing work." Whether students understand it is acceptable or not, Kelly expressed, "the biggest thing that, and frustration, that I've had was kids cheating and using apps such as Photomath." Kelly felt that

cheating and using Photomath was a disservice to the students who were trying to learn math honestly. She explained:

> And so I was like, it's not fair, and I guess that would be an equity issue, it's not fair to the students who are trying, not cheating, and wanting to learn, that they would take a quiz and say get a B or C because they didn't cheat, but the kid that's cheating is getting an A.

The other participants did not name Photomath directly, but they expressed other concerns around academic dishonesty. Belle simply stated, “I think there's also a bit of skepticism sometimes, um, because there are so many things and ways that they can use an outside aid for help.” Thor added to this sentiment, “I would say unsure [about student performance] because, again with them being middle school students, they do find ways to not, you know, always have to do their own work.” Captain America also agreed and said,

> Speaking very honestly, I believe that a lot of students are, it's been more evident in my opinion, that a lot of students are cheating and copying down things from websites, um, or having, they could also be having somebody else complete the assignments for them.

7-11 spoke directly about somebody else completing assignments and explained, “I’ve had issues of siblings taking quizzes and tests.” Wonder Woman explained that the parental involvement in her math classroom had gotten to the point of parents and guardians completing assignments for their children. She explained that “another thing is, um, with the parents, you know, I, you know, I'm all for parental involvement, but not to the point where you are doing it for your child and not with your child.” Even with taking steps such as turning cameras on during assessments, 7-11 found that “there's still no guarantee that there's not, you know, somebody else on another screen that’s still logged in and taking it for them right then and there.” Even without the mention of the Photomath app, it was still evident that teachers perceived that students were not

always completing their own work. Whether it be Google, a sibling, or a parent or guardian, students were being dishonest with their own work completion by using outside resources.

Overall, at all math levels, Math 7, Math 8 and Algebra 1, some form of academic dishonesty presented itself this virtual school year. Through the use of Photomath, Google, or family support, students were finding outside resources to unfairly assist them in assignments. The only participant who did not have such a focus on academic dishonesty was the upper-level math course teacher. When speaking about academic dishonesty, Mavis stated, "I suspect it may have occurred, but I am not, I'm not overly concerned about it." While she acknowledged that it may have happened in her classroom, she did not seem as frustrated by the academic dishonesty as some of the other participants. However, since she did discuss the possibility of cheating, every participant in this case study of secondary math teachers answered research question two with the perception that student performance was not always valid due to cheating and academic dishonesty.

External Factors Influencing Students

During this virtual school year, obvious factors influenced students and their ability to be successful such as having a computer or having the Internet; however, every participant also presented other factors that influenced student success that weren't necessarily in the control of the student or the teacher. The theme of external factors addresses the root of some concerns focused on student performance, and responds to research question two. These external factors include parental support and home dynamics, non-school related student responsibilities, student age, and the school dynamics.

Parental Support and Home Dynamics

Parental support was discussed in the interviews as parents checking on students' academic progress and parents being able to assist with technology. 7-11 remarked, "that's where we've seen a big deficit as well, um if they do not have that support at home or someone kind of following up." 7-11 felt that students needed adult support, even if only for a few minutes at the end of the day, to see how their day went in school and check that their assignments were complete. Wonder Woman agreed that checking in on a student's day at school would be beneficial, but:

> A lot of my students, I see that their parents have to work… and so when they get home from work, you know they tired, you know as well and they probably don't wanna talk about hey what you did in, you know, school today because they tired.

This lack of daily check ins with students may have hindered this academic progress. Kelly also felt that "one parent household or absent parent household, definitely was a factor" in a student being successful. Captain America provided some specific examples:

> these two students are single parent households too. So they are, they have both, and the parents, that individual parent works two jobs just to make ends meet. So they have a lot of things going for them, you know, a lot of barriers to go through.

All four of these participants agreed that students need involved parents who will check their daily work to make sure they are staying on track with school. In addition to checking on their daily work, Blue discussed the point that parents also need to be able to assist their students with the technology related to virtual education:

> I think parents that are more tech savvy or able to help their kids better. Um, things like they know how to check if a student's turned in an assignment, they know how to check if they've been in class, they are able to help if something doesn't open right on the

> computer, they can kind of help guide their kids through that. And then I think, um, students who maybe have, are with grandparents or older or less tech savvy house households, they don't have that extra support at home.

Blue described the need for parental support, but in a more specific way of being able to assist with technology and understand the technology of virtual learning. So even if students have parental support at home, but it isn't "tech savvy" as Blue put it, the students are missing support that they need to be successful.

Along with concerns over parental support, some participants made clear remarks about students' home dynamics that may have negatively affected their education. These dynamics included the number of people in the home, and obligations, such as trips, that are taken during school hours. Three participants discussed how having multiple children in the home may affect virtual education. During 7-11's interview, she really focused on parental support. She discussed how it may be challenging to support all children in the home just from a time perspective. 7-11 explained:

> I understand that some families, you know, you have three, four or five kids, but if that time can be allotted to those students and just at least kind of a quick check through, I think that could really be a saving grace for a lot of students.

7-11 felt that it may be more difficult for a parent to check through their child's schoolwork when there are multiple children in the home. When Wonder Woman spoke about multiple children in the home, she focused on the digital concern over Internet usage, "I can say that if you got more than maybe one child in your household and you're trying to share this little hotspot, you know, access, that has become a challenge." Thor agreed with the concern over multiple students on one Internet connection and noted if "they had a lot of kids and they were

all on at once, it like, it couldn't support all of the, you know, computers that needed that Wi-Fi." These participants expressed concerns of having multiple students in one household in terms of the support that both the parents and the Internet were able to provide.

Additional concerns were brought up regarding the home dynamic and the decision for families to go on trips during the school day or students to use school time for non-instructional purposes. Both Wonder Woman and Kelly specifically spoke about parents taking their children out of school for trips. Wonder Woman even asked, if this was a regular school year, "would you be pulling your child out to go on a trip like right now?" She also provided examples of students missing class because they had to go to the store with their parents. Kelly specifically spoke about a struggling student who was given the opportunity to return to school for in-person instruction, "and even when they had the option to bring him back in person, she [mom] didn't want to because, uh, they were doing other things during the school day, like traveling or going places." Kelly also explained that in her classroom "the biggest [concern], would be like truancy and not attending." Kelly described that even when students attended class they may be at the store or washing their car. Kelly had multiple instances of students using class time for non-math related things. Wonder Woman and Kelly both provided clear examples of students and parents using virtual instruction time for non-school related items. Student performance is hindered when students aren't in class due to vacations, trips to the store, or lack of attention during class. The participants in this case study also felt that student performance is hindered by lack of parental support in terms of daily check-ins and technology assistance.

Non-School Related Student Responsibilities

Mavis and Belle, both high school teachers, brought up concerns of students needing to work or take care of siblings this school year. Mavis was very clear that "we have kids that are

working now to support their families." Belle echoed this sentiment and provided an example of a 15-year-old student who had to work and support her family because her mother had been laid off due to COVID-19. Belle also explained that "a lot of them had situations where they were watching… younger siblings, or parents were out of the picture, or just responsibilities, such as jobs and stuff." With the increase of non-school related responsibilities on these young adults, there was a potential for their educational responsibilities to take a back seat and not be that student's focus. This sub-theme of working directly relates to high school secondary students. None of the middle school participants discussed concerns of middle school age students working or having to watch their siblings during school hours. The overarching theme of external factors addresses all teachers in this case study; however, this sub-theme is specific to the high school level of secondary math classrooms.

Student Age

Four participants spoke directly about the age of the students and its possible effect on their performance. All four participants expressed concerns over young adults being able to manage themselves in an online learning environment without distractions. 7-11 stated:

> In my opinion, they're not capable, they're, I mean they're seventh graders, they're 12 and 13 years old, their maturity level is not at the point where they need to be, to be basically telling themselves to be self-monitoring, to teach, you know, to tell themselves I got to stay on this computer all day long.

Wonder Woman agreed that middle school students were unable to manage some of the responsibilities of virtual learning without support, "the parents are leaving this huge task of their child, you know, logging into their classes and they're not doing that." Without constant supervision, it seems that the middle school students were struggling to keep up with their virtual

schooling. Belle attributed these struggles to the drastic change in how students had to learn. She explained that "as a 13-year-old or 14-year-old, you went from having structured school for seven hours a day, where we literally said take out your paper and pencil, and told you what to do," to now having to be responsible for their own learning, including logging into classes and completing assignments on time. Captain America felt that some of his online students just didn't have the organizational skills to be successful in an online environment. He felt these skills were also directly related to his middle school grade level. Captain America explained:

> [a] lot of students who chose option two didn't have, um, the word I'm looking for is, organized, um, they didn't have a true organizational drive to stay or, I guess stay organized, be on top of things… so the, the lack of, and it's the, I guess, an inherent just organization that students have at my particular grade level of eighth grade.

The age and maturity level of students may have played a role in how successfully they managed virtual learning. The examples provided mostly came from middle school level participants, with one high school participant agreeing. This high school teacher taught mostly freshmen this past school year. Within the case of secondary math teachers, the concern of student age and their maturity level was represented more within the middle school. Because they teach younger students, the middle school level participants had more concerns about the ability of their students to self-regulate and successfully manage virtual instruction.

School Dynamics

The theme of school dynamics includes the amount of instructional time and the return to school plan decided by the city's school board, as well as concerns over teachers' technological abilities. The instructional time for secondary math classrooms was decided completely out of the hands of students, parents, and teachers. The Marvel School Division's school board

determined how much time would be spent on each subject and how many days per week students would have instruction. During this 2020-2021 school year, no secondary math classroom had five days of instruction. The math classrooms had four days of instruction with less than 60 minutes of actual teaching time. Hermione pointed out that time was a huge factor that was outside of her control and her students' control, "it was more so the fact of there was, there was just not time, enough time" she said. This external factor of limited time greatly affected what was taught and assessed this school year, as explained previously in research question one. 7-11 felt that students were disserved based on the return to school plan, specifically with how many students could return for in-person instruction. 7-11 expressed that virtual instruction could have created educational inequity based on a student's ability to return to school or not:

> one way is for students that are not able to, or not, I don't want to say allowed, but because our building is at capacity. They allowed some students to come in four days a week, um those that were really struggling academically, which makes sense. And so now that that has kind of reached capacity, there are other students that want to attend and other parents as well of these students that want them to attend four days a week. So I do feel like that is an inequity in a sense, just because that child may not follow along as well, or they may need that face-to-face piece.

While 7-11 understood the guidelines for social distancing when students started to return to the physical school building, she still felt a sense of inequity that not all students who needed face-to-face instruction were able to receive it.

The last concept under the theme of school dynamics involves teachers' technology skills. During the interview with Blue, she brought up the idea that student performance may

suffer and they may face educational inequity based off the teacher they were assigned. Blue explained:

> from a teacher standpoint, not all of us are, are technic… technology, technologically able, and so I feel, I feel that some students benefit from the teachers that can do, and are able to create, and able to manipulate the stuff, and the students who have teachers who really aren't there, kind of suffer and lose out on some of that inequity on, or lose out on that instruction because the teacher just can't do it. Um, and I know that's going to create inequity throughout the school building because some of our teachers are really great and able to do this stuff, and there's others that just can't do it.

So while most participants discussed factors around student ability, parental support, or external factors that may hinder education, Blue was the only participant to indicate that teachers with low technology skills may also hinder the education of students. If teachers were unable to be successful with their own personal technology use while teaching, it would be extremely difficult for the students to learn, too. Additionally, if teachers did not want to actively learn new technologies or how to make math accessible in a virtual platform, the students were at risk for missing much of their math curriculum.

This case study focused on how secondary math teachers in the Marvel School Division integrated technology within their classroom to support student learning; however, not every secondary math teacher in the division may have mastered the basic technology knowledge needed for virtual instruction. Without the basic technology knowledge, teachers would be unable to obtain technological content knowledge or technological pedagogical knowledge. Blue's statement made it clear that public education needs to ensure that all teachers have the needed technological knowledge for adequate virtual instruction. While the participants in this

case study were chosen due to their technology integration skills, it is important to note that there were teachers who struggled with basic technology use this past virtual school year. The students who had to learn from these struggling teachers may face larger disadvantages than students in the classroom of teachers with strong technological knowledge.

Inequity of Device Access

Inequity of device access is a theme that addresses research question three regarding educational inequity. While research question three specifically asked about educational inequity based on race, most participants did not observe racial inequity this past school year. Most participants did not feel that inequity of any kind was present this past school year. The participants felt that, because the school division[10] provided devices to each student, that device access was equitable for all. 7-11 noted, "I do feel like our district made it very, they wherever they got the money from, they got it, and they were able to distribute devices, chromebooks to our students." Blue, Captain America, Mavis, and Belle also spoke about students having equitable access to a computer device due to the roll out of one-to-one devices from the Marvel School Division. 7-11 claimed, "because our school provided everything, um so there really was no, no race factor involved, which is a good thing." Wonder Woman also stated that she did not see any differences between the education of her White students versus her African American students. All the students had the ability to log into their virtual learning environment. While access to a device cannot guarantee logging into class or learning, the majority of the participants agreed that educational inequity was not created this school year because all students had access to a device. The data failed to present educational inequity based on student race. The

[10] In this study school division is synonymous to a school district. It is defined as a group of public schools in the same geographical city location.

participants perceived no educational inequity because all students were provided with their needed virtual learning supplies.

During the time of the interviews, all schools were one-to-one with devices, meaning that each student had access to their own personal computer. Kelly brought up a concern from the very start of the school year before all devices were handed out. She discussed financial concerns in combination with student race at the start of the school year:

> Before the school provided them if they didn't have one or have the money to get one that would have been an issue as well. And typically that would be in, uh, my African American students, is probably where I saw it the most.

So, while the schools eventually did provide device access, Kelly felt it was important to remember the very start of the school year when not everyone had equitable access. She felt the students from lower socioeconomic backgrounds, as well as African American students, may have faced greater challenges with accessing virtual school at the start of the school year. The interviews for this case study were conducted towards the end of the school year. In this school division, students had been one-to-one for over six months. The answer to research question three may have looked different if the interviews took place within the first two months of the school year. Educational inequity based on race may have been more visible before the schools provided the needed computers and Internet access.

Inequity of Internet Access

With each student eventually having access to a device, the concern for equity this school year focused on access to the Internet and Wi-Fi. When participants spoke about possible inequity this past school year, their concern was related to Internet connectivity and was mostly in regard to socioeconomic status with some mentions of race. Wonder Woman claimed, “as far

as an access, you know, um, I haven't really seen any of the, you know, the socioeconomic you know issues regarding students not having, you know, access to their schooling," Blue, Hermione, and Mavis all mentioned socioeconomic status being a factor in the students' educational success. Blue stated, "we have seen some inequities in students, because I know early on we ran out of the mobile hotspots, and so students who didn't have Internet access or parents who weren't able to pay their bill would lose their Internet service." If families were financially unable to pay for Internet access, the students were unable to access their virtual education. In Blue's example, the students facing this inequity of Internet were both low socioeconomic status and African American. Blue stated, "of course when you break [down] socioeconomic, then that does bring in race, because in our, in my particular school your lower socioeconomic tends to be African American." Hermione agreed that "connectivity, consistently came up, um, with low socioeconomic, as well as African American students." Mavis also supported student challenges based on socioeconomic status and race. Mavis explained that she was "from a primarily White, high socioeconomic school. Overwhelmingly. So there is definitely some, those that, um, may not be at that status are the ones that are definitely disadvantaged." This quote refers to students at Mavis's school who may have not had their own computer or Internet access at the start of the school year. Mavis spoke to possible disadvantages for low socioeconomic, non-White students in both access to devices and access to Internet. Lastly, Captain America discussed concerns of Internet access equity solely in terms of student race:

> Typically the students who were mostly affected that I, that I can recall from my particular students were African American students. Very few Caucasian or our non-

> Hispanic students were, um, expressed a concern, such as the one with the Internet connectivity issues.

Overall, it appeared that concerns over Internet access fell in the lines of students of low socioeconomic status and African American students. Within this case study it was more evident that the participants were concerned with the lower socioeconomic status students and their ability to pay for and maintain an adequate Internet connection. However, even when bringing up socioeconomic status first, it is important to note that the participants then related these concerns also to their African American students. While race may not have been the initial factor that the participants felt influenced inequity of Internet access, it eventually emerged from the data.

Other Forms of Inequity

Three participants, Belle, Blue, and Thor, all discussed inequity in a different form than just device or Internet access. Thor was concerned overall that the African American students did not have what they needed for virtual learning:

> A lot of times, um, with like my African American students, if they were in a home with a lot of kids and there wasn't a lot of supervision, they would come to school without their chromebook, they would say, oh you know it was dead, um, oh my little sister had to borrow it, you know, that, that kind of stuff was really alarming to me, knowing that not everyone in the house had what they needed.

Thor's comment aligned with previous concerns of external factors like parental support and home dynamics; however, she became more specific about what her African American students actually lacked. Instead of simply not having parental support, the students appeared to be lacking supervision and school materials. Blue also commented on inequity based on parental support:

> I think that has been the biggest inequity, um, which will probably follow along socioeconomic lines, you know, parents that could be home for their kids versus parents that are going to have to go to work, um has been probably an issue with being able to keep up with the school… we're seeing that and again it's the lower socioeconomic that may not have a parent that's able to stay there with them while they're in school or check up on them.

For Blue, parents with lower socioeconomic status were unable to provide as much support as parents with a higher socioeconomic status. The lowered amount of support was because the parents have to work and aren't physically in the home to spend as much time with their children. In Blue's school, the lower socioeconomic status students align with being African American students, too.

Belle discussed inequity for students in multiple ways. She discussed socioeconomic status, current events, and language barriers. Belle noted, "that's been harder and I think a lot of our kids who are at the lower socioeconomic status, have a lot more responsibilities than students who maybe aren't." Belle was referring to students having to work and support their families. Although work was already discussed as an external factor, it is important to revisit Belle's comment because it was stated as a specific concern for students based on their low socioeconomic status. Students from less fortunate families were forced to work and support the home, which created educational inequity since their time was not always dedicated to their education. Belle also spoke about current events and students having a forum to speak about their thoughts, ideas, and concerns. Belle gave an example and said, "you know when everything went down with George Floyd and everything like that it was, it was disturbing, um for lack of a better word." She was concerned that inequity had taken place because students failed to have a forum,

or an outlet, to discuss the horrendous events of last year. Belle also felt inequity took place in her school based on the student population versus the teacher population. While not related to the pandemic, Belle noted that "our school is 70% African American yet, I'm pretty sure half, like probably 70% of our staff is White. And it's not right, it's not fair for them to not experience people that look and act like them." Once again, Belle was bringing up concerns that could relate to educational inequity for students of color. Lastly, Belle discussed inequity of the language barrier that the English Language Learners (ELL) had to face. She stated, "the biggest inequity they have this year is they have no forum to talk English and be around people who are speaking English all day long." Belle explained that some of the ELL students have gone almost a year and a half without English immersion in the in-person school setting. She was concerned for the inequity that ELL students are facing due to limited interaction with English speakers. If an ELL student is learning virtually from home, they may be getting some English from the Zoom meeting, but the majority of their day is in their native language. Belle was very concerned for this student population moving forward into the upcoming school year.

When I initially asked the participants about educational inequity based on race, most of them claimed that inequity was not a concern this school year and definitely not inequity based on race. However, when analyzing the interview transcripts and examining the students who the participants talked about, most of the student examples came from African American students. When the stories, examples, and concerns all discuss African American students and not really any White students, it presents a different picture than what the participants initially answered when asked about research question three. For example, Kelly initially stated that it was hard to generalize about educational inequity since her lowest performing student was African American, but her highest achieving student was also African American. Later in the interview,

Kelly discussed her poor attendance concerns with African American students, as well as African American students having difficulty getting the needed parent signatures to sign out their chromebook from the school. 7-11 explicitly stated that she didn't see any race concerns this school year; however, she discussed an African American student having their sibling take a test, as well as an African American student needing weekly attendance updates sent home. Blue spoke specifically about an African American male student who was being raised by his great aunt. This aunt struggled to understand the technology and was unable to help the student with any of his technology concerns. Captain America spoke about two specific African American students. One African American female was late to class often and failed to complete her work. She also had moments where she was caught lying about school related items. Captain America also spoke about an African American male student who had in-person instruction, but lacked the memory recall needed to succeed in math. Hermione discussed how students from low socioeconomic backgrounds, which coincided with being African American, did not have their own devices when school started. Although the school division provided computer devices and Internet hot spots, some students missed the start of the school year while waiting for those devices. This created inequity for the low socioeconomic status and African American students in Hermione's school who didn't have their own personal device when the school year started. While some examples were presented involving White students, like not wanting to return to in-person instruction due to family trips or telling parents that they don't understand the material to try and skip an assignment, overwhelmingly the examples discussed involved African American students. While teachers may not have claimed that educational inequity was present solely based on student race, the examples provided and the concerns presented clearly spoke to racial

inequity. It is evident that race was a factor in various forms of inequity as discussed previously in this section.

Summary of Findings

After analyzing the nine interview transcripts and 31 technology artifacts, ten themes emerged in response to my three research questions. For research question one, the themes included level of rigor, length of assignments, class structure, and technology integration. The level of rigor and length of assignments diminished during this past COVID-19 school year. Class structures, similar to class routines, faced many changes. These changes included removing typical items like warm-ups, adding time to teach how to use technology, and changing teaching pedagogies to be more flexible. Technology integration addressed some of the technology features that supported and strengthened student learning. Research question two included the themes of student performance validity, academic dishonesty, and external factors influencing students. Teachers were concerned whether the students' grades and overall math performance were honest reflections of their academic ability. Additional concerns were brought up about cheating and other external factors that may inhibit student learning. Lastly, inequity of device access, inequity of Internet access, and other inequities were the themes for research question three. Most participants felt that the school division supplied all the needed computers and Internet hot spots and, therefore, removed any possible inequity this school year. However, concerns over low socioeconomic status and students' ability to have Internet access did emerge. While race was not explicitly stated as affecting educational equity, the implications of the examples the participants expressed represent inequities for African American students. African American students had the needed devices and Internet, but lacked things like parental support, forums to discuss current events, and motivation to attend school daily.

CHAPTER 5

Conclusions

Through analyzing the nine participant interview transcripts and 31 technology artifacts, I was able to gather rich information about teacher experiences and their perceptions of this virtual school year. I analyzed their interview and artifact data to develop themes based on each research question. When analyzing how the teachers had changed their curriculum, pedagogy, and assessment practices, the themes included level of rigor, length of assessments, classroom structure, and technology integration. Due to loss of instructional time, the level of rigor and length of assignments and assessments were both lessened. With the multiple changes this virtual school year, teachers also had to adjust their classroom structures. One major adjustment to the classroom structure included the removal of typical classroom processes like warm-ups and self-discovery. Due to COVID-19 policies and procedures, teachers also had to remove common classroom structures like the use of manipulatives, group work, or projects. Multiple participants also indicated that the request to see student work was removed from the math classroom. Without having paper-and-pencil assignments, the teachers found it hard to have an effective way for students to show their math work in the virtual learning environment. Teachers also had to modify their classroom structure to include time for teaching the actual technologies being used. Teachers spent large amounts of time instructing students on how to use specific technologies rather than just instructing on math content. Ultimately, as a part of classroom structure, teachers had to be flexible this virtual school year regarding how they traditionally focused on their pedagogy and assessments. Some teachers modified their classroom teaching practices to be self-paced, while others added more guided instruction instead of independent practice. Many participants mentioned being more gracious and allowing students multiple

attempts to successfully complete student work. This change from a traditional one-and-done assessment mindset really shows teacher flexibility during the 2020-2021 school year. The last theme for research question one was technology integration. While teaching technology may have taken up instructional time, the teachers did point out benefits from their new learning management platform. Schoology (2021) allowed the teachers to automatically grade their assignments which provided immediate feedback to the students. The teachers also used these automatic grades to disaggregate the data and plan for future instruction.

When asked about student performance this virtual school year, all participants responded in a negative manner. Overall, the level of math achievement appeared to go down this past school year according to their perceptions. The three themes related to student performance included student performance validity, academic dishonesty, and external factors influencing students. Student performance validity related to if the students were actually learning their intended math content. Without seeing the students in person, the participants struggled to feel that their student data were accurate. Most of the concern about inaccurate data came from students being academically dishonest this virtual school year. Every participant mentioned cheating in one way or another. The academic dishonesty ranged from the use of Photomath (2021), to siblings or parents taking assignments, to students just Googling the answers. With so many outside resources available, it appeared that a lot of students were not completing all of their work on their own. In addition to using outside resources for answers rather than learning the math content, low student performance was also attributed to a number of external factors. These external factors include parent support and the home dynamic, outside responsibilities, age, and the school dynamic. Participants indicated that it would have been beneficial for parents and guardians to check in daily with a student's academic progress. However, due to single

family households, parents having to work, absent parents, or lack of technology knowledge, parents and guardians were not effectively assisting with student performance. Home dynamics also included having homes with multiple children and family plans during instructional time. Having multiple children may have put a strain on the parents' abilities to support their children, as well as the Internet bandwidth. Family plans, especially trips and traveling, sometimes took priority over instructional time and forced students to miss class. Student age for both middle and high school students was discussed as being a possible issue. As young adults, the students may not have the maturity and organizational skills to self-monitor and complete online schooling without parental or guardian support. Lastly, school dynamic, as in how school was organized this past school year, affected student performance. Students faced less instructional time and fewer instructional days of school. They also, in some cases, were unable to return to in-person school, even if needed, due to buildings already being at capacity. The technology level and skills of the teacher also affected student performance. If the teacher was unable to effectively integrate technology into the math classroom, the students' learning would suffer.

The third research question focused on educational inequity based on student race. However, most of the participants did not feel that race was a factor in educational inequity this past school year. When it came to having a computer device, all students, no matter the race, had access since the school division went one-to-one. Some inequity was mentioned regarding Internet access, which then tied in with student socioeconomic status. The participants who mentioned race as a factor for Internet access inequity aligned it with low socioeconomic status. After discussing inequity of device access and inequity of Internet access, the concept of other forms of inequity was discussed. Other factors related to educational inequity were brought up that didn't necessarily focus on race combined with education and technology concerns. A

concern was brought up about African American students lacking supervision and the needed materials at home. It was also seen as inequity that African American students had no forum or safe space to discuss current events of the Black Lives Matter movement, like the death of George Floyd. Additionally, African Americans face educational inequity when they are unable to receive their education from people who look like them. While this concept is not new to virtual education, I still found it a valuable portion of Belle's perspective. Lastly, the concern over language inequity for ELL students who have not had full day English instruction for over a year was discussed.

The nine interview transcripts and 31 artifacts from this case study provided insight into how secondary math teachers in the Marvel School Division had to change their typical ways of schooling due to virtual instruction. Teachers were forced to reconfigure their lessons, curriculum, and assessment due to time and technology constraints.

Discussion

Technology

The nine participants in this study drastically changed their teaching methods and strategies during the 2020-2021 school year. Some teachers had previous technology experience, while others learned most of their technological knowledge this past school year. Although the participants provided rich descriptions of their experiences during their virtual school year, the findings did not represent strong technology integration as defined by Mishra and Koehler (2006). Through the lens of Technological Pedagogical and Content Knowledge (TPACK), technology integration would be characterized as technological pedagogical knowledge, or the use of technology to specifically support and strengthen instruction. While the participants were now fully using technology in their classroom and removing all paper products from the class, it

was not always clear that technology was being used to strengthen instruction. Most of the examples provided by the participants of technology integration actually represented simple technology use. The technology was serving simply as a replacement for a paper-and-pencil version of a worksheet, assignment, or notes. The difference between technology use and technology integration would be giving a paper-and-pencil test online versus using an online assessment that would disaggregate data for future instruction. A few of the participants discussed their use of the auto-grade feature to provide immediate feedback for students on their math assignments. However, not every teacher explained that this feedback was then put into use for future instructional improvement. Captain America specifically spoke about using data for future review sessions, but most participants simply used the auto-grade feature for quick grading and immediate correct or incorrect feedback for the students. While immediate feedback could support student learning, it only supports learning if the student understands why they got something incorrect. If the technology support just tells them they got it wrong, or marks the problem in red, the student is not really gaining any knowledge about their mistakes.

Most of the artifacts submitted also failed to present technology integration. A majority of the artifacts were just online versions of traditional math work. Instead of completing questions on a paper worksheet, the same type of question was now just embedded into a Google Doc. Teachers also used Schoology (2021) to provide online questions, quizzes, and tests for their students. By simply modifying math assignments to digital templates, teachers were only using technology rather than truly integrating it. The teachers tapped into their technological knowledge and technological content knowledge, but failed to reach pedagogical change. The teachers researched the online programs that existed and would help them in the virtual learning environment; however, not every online program served to strengthen student learning. While

this virtual school year created the need to have homework and classwork assignments online, not every Google Slide or Google Sheet assignment represented true technology integration. Technology was used much more during this virtual school year, but it was used more to facilitate math instruction rather than strengthen instruction. Now that this virtual school year is behind us, teachers have the opportunity to move from technology use to technology integration. Teachers can take the online math activities and use them in a more proactive way to remediate, enrich, or strengthen future secondary math classroom instruction.

During the participant interviews, multiple online programs were referenced that allowed teachers to communicate in real time with their students, such as Nearpod (2021) and whiteboard.chat (2021). Teachers also used new online platforms such as Schoology (2021) and Zoom (2021). However, the use of these online applications as technology integration was inconsistent when analyzing them through the TPACK framework. This is where a limitation to the applied theory should be noted. The TPACK framework was created in 2006, which is before the first iPhone was even released. With such drastic changes to available technologies in 2020-2021, the definitions of the TPACK framework became more difficult to differentiate during my data analysis. A lot of teachers spoke about their instruction in a way that appeared as technology use at first, but their application of the technology could push it into technology integration. With my initial technology integration conceptualization from the TPACK framework, the use of Edpuzzles (2021), Nearpods (2021), and Google (2021) assignments were forms of simple technology use. Teachers were taking the same content and presenting it in a new, virtual way. However, when looking at how Mishra and Koehler (2006) defined technological pedagogical knowledge, the use of these programs may have been considered integration. When teachers were able to communicate in real time during the lesson and clarify questions or fix errors, I

would argue those actions are strengthening instruction. However, it only strengthens instruction for the students who are present and communicating with the teacher.

The initial assumption that online programs represented technology use was also challenged by the simplified definitions of TPACK from Cox and Graham (2009). These two researchers added the word *emergent* to technological pedagogical knowledge and explained that new technology resources used within a teacher's pedagogy are considered technological pedagogical knowledge until they are no longer new within the field of education. For this past virtual school year all of the new online technologies and platforms were emergent for most of the participants and since they were used for math instruction, they would meet the definition of technological pedagogical knowledge. Overall, the participants in this study used many new technologies this school year. While some of them were just to recreate a paper-and-pencil version of an assignment, other platforms were used in a technology integration format. Teachers used technology to provide instant feedback and help remediate struggling students. Teachers also used online programs to chat in real time with students and address any challenges or concerns. This past school year represents a large shift from math content knowledge to math technological pedagogical knowledge.

Inequity

My personal teaching experiences during the COVID-19 school year vastly differed from the perceptions of my participants in regard to inequity, specifically based on race. I, personally, experienced students of color struggling much more with virtual learning due to Internet concerns, multiple people in their homes, lack of educational workspace, and lack of parental support to focus on the importance of education and attendance. The participants didn't feel any educational inequity had taken place this past school year in terms of having access to devices.

Additionally, most participants felt that Internet access had also been provided. However, as explained in the findings section, while the participants stated that no racial inequity occurred this past school year, most of the examples provided focused on African American students. The participant examples were in line with my personal experiences of Internet concerns, multiple people in the home, and lack of parent support. Internet concerns were discussed more often in terms of socioeconomic status, but low socioeconomic status tended to align with African American students as well.

The five tenets of Critical Race Theory (CRT) did not explicitly come to light during my data analysis. As someone well researched in CRT, I can see how inequity for our African American students stems from a historically racist country. However, most secondary math teachers are not trained in CRT or understand systemic racism deeply and its effects on public education. The first tenet, racism is normal (Delgado & Stefancic, 2001), would most likely not come up in teacher interviews because it is the norm. If differences based on race are seen as typical and normal, then racial inequity in education may exist, but may not be noticed. Interest convergence and intersectionality were two tenets not addressed in this study. I do feel that a few comments from the participants touched on the face that race is socially constructed and the idea of counter-narrative. One participant discussed that very few students of color were in the classroom, which caused more focus and attention to go to those students because they stood out more. Since the students of color stood out more, it is obvious that race as a social construct happened within that classroom. Another teacher noted that virtual learning helped some of the habitual troublemakers to focus on school and their education. While this isn't necessarily a counter-narrative for how African American people are perceived, the student is still producing a counter-narrative for how they are typically perceived.

The lack of coded interview data and artifact representations under the umbrella of CRT and inequity does not mean that inequity based on race does not exist, but rather it was not mentioned by the participants. The lack of racial discussion alongside the fact that eight of the nine participants were White begs for a closer analysis. Mazzei (2004) presented how to deconstruct discourse by examining the unspoken, or silent, words. Instead of overlooking the lack of racial inequity as seen by the participants, there needs to be a focus on why the silence was present. Alongside the lack of explicit discussion about race, it is important to note how quickly the participants answered the interview questions about educational inequity and inequity based on race. For the first six interview questions, the participants gave specific examples and elaborated on their responses. However, on questions seven and eight, the responses were much shorter and to the point. Mazzei (2004) stated that this "silent voice was evoked to avert calling attention to oneself" (p. 30). Perhaps the participants were uncomfortable stating their opinions as White educators regarding any discrepancies or educational inequities with students of color.

When starting this study, I was sure that racial inequity would be a large discussion point with all of the participants. The findings did not support that teachers perceived racial inequity was occurring this past virtual school year. Even though the findings did not support racial inequity, our country as a whole continues to be inequitable based on race.

Implications for Practice

The themes for research question one were level of rigor, length of assignments, classroom structure, and technology integration. Each of these themes presents implications for practice within public education and the secondary math classroom. Both the level of rigor and length of assignments were reduced within the curriculum and assessments this past school year.

The first implication would address the fact that students will have learning gaps and content missing this upcoming school year. With public education returning to in-person teaching, educators must be aware that the amount of material and level of math content were reduced in the previous school year. Teachers will need to have a plan for how to address this missing math content, as well as work with students to obtain a more rigorous math curriculum. The second implication is for secondary math teachers to really assess what level of math content is needed for students to be successful, as well as how many times that student needs to demonstrate that math content. The findings demonstrated that teachers re-evaluated how long their assessments were, and when and why they needed to actually assess. Moving forward, teachers can create more meaningful assignments and assessments that are focused on the most needed skills without overwhelming the students with too many questions. A positive to this past virtual school year is that, with limited time, teachers had to prioritize and focus on the most important math content. Teachers also had to prioritize how they used their classroom teaching time. I hope that teachers will continue to re-evaluate their assessment practices for the benefit of student learning, rather than remaining in a traditional mindset of lengthy assessments.

The change of classroom structure included removing typical items like warm-ups, adding time to teach technology, and becoming more flexible as a teacher. Like the implication for assessments, the change in classroom structure forces teachers to evaluate what is really needed in the classroom. The two teachers who had to remove warm-ups saw a decline in student math knowledge retention. These data support the return of warm-ups at the start of each class period this upcoming year. Other teachers discussed removing self-discovery activities and math projects. If these teachers did not see a drastic decline in student performance, I would argue the benefit of these classroom structures. If removing self-discovery and projects did not lessen

student achievement, are they worth returning to the curriculum? The overall implication for classroom structure is for teachers to really evaluate what they do or don't do during class time and how it supports or strengthens student learning.

The removal of class structure items, as well as rigor and length of assignments, was not only due to shortened instructional time, but also due to the increase of classroom time spent teaching technology. For all of the new platforms the participants decided to use during math class, there was time needed for that teacher to learn the platform, as well as class time needed to teach and instruct the students. The implication for teaching technology is that teachers need to plan their upcoming year with math content instruction and time set aside for technology teaching or troubleshooting. There is potential that students may have not really learned the technology during this past school year and still need assistance with things like Schoology (2021), email, and submitting Google assignments.

A consistent concern brought up during the interviews was lack of time and lack of technology training on how to effectively integrate technology into the secondary math classroom. As public education continues to advance technologically, educators need to be more aware of these concerns. From the perspective of the teachers working during this year of virtual instruction, it was clear that time was needed to convert paper-and-pencil material over to virtual resources, create digital assignments and assessments, and really learn the workings of the new technologies. With such a need for planning time, the secondary setting did add one asynchronous day each week to help with this time constraint. Both in middle and high school, the Marvel School Board decided to have direct instruction four days per week and then have one virtual student support day each week. This allowed for students to get caught up on assignments and receive more individualized teaching and support from their teachers. The

teachers also now had a day without live instruction where they could schedule student support meetings and have allotted time to plan for their upcoming virtual math instruction. Moving forward, school divisions should continue to allot time, even if less than once per week, for teachers to not have live instruction and be able to learn, plan, and implement new technologies in the classroom. Additionally, time needs to be reserved for adequate training of new technologies. One of the limitations of TPACK is that teacher training focuses on what the technology is versus how to really integrate the technology. Each school should have a technology specialist who really works with teachers on how to appropriately use technology as an integrative tool in their classroom. Instead of thinking that online assessments just grade themselves, how can educators grow to really use those assessment data for improved instruction? How can online data disaggregation guide future learning? The participants in this study were all math teachers who generally know how to disaggregate data as a part of their content knowledge base. An important implication for practice would be to ensure that all teachers, of all contents, have this same data analysis content knowledge.

The final implication under research question one is to continue using technology to support student success in ways that seem non-traditional from the typical face-to-face school year. Specifically, teachers should continue providing multiple attempts on assignments, using auto-grade features, and using technologies to help provide meaningful immediate feedback to the students. The most noted change from all participants in pedagogical practices was from giving one-and-done assessments to providing multiple attempts. Students should be able to try their best, receive help on areas of weakness, and then try again. With multiple attempts on assignments, teachers and students can work towards true mastery of a subject. The auto-grade and immediate feedback features can assist with the review and remediation process of these

multiple attempts, as well as provide data for the teacher on how to move forward with secondary math instruction. The different ways that teachers chose to assess and provide student feedback this past virtual year can increase student achievement moving forward. I hope that public school teachers continue with this gracious mindset and helping each student wherever they are in their math content knowledge.

The themes related to the second research question on changes to student performance addressed student performance validity and academic dishonesty. Both themes have large implications for this upcoming school year. All secondary math teachers must be aware that students may be moving forward in the math curriculum and not have the basic math content knowledge from the previous math subject. Even if a student received an A this past virtual school year, there is potential that that student really doesn't know the math they should have learned. Teachers will need to start this upcoming school year with some form of pre-assessment or data collection to gain accurate knowledge of their students' current level of math ability. Not only will this upcoming school year require a lot of reteaching math, but it will also require reteaching acceptable school behavior, such as completing all work honestly. With so many outside sources for assistance with the math work, secondary math teachers will need to be diligent in their teaching and remediation practices for struggling students. I also hope that secondary math teachers can go into the next school year with a helpful mindset rather than a frustrated mindset that their current students are mathematically behind.

When discussing all of the external factors that may have negatively influenced student success, the implication is that teachers and schools are aware of these factors and can start the school year with supports in place to help the students. While most students will probably have a learning gap in some subject, there will be students who have a much larger gap than others. As

educators, we need to realize that this may not be the fault of the student. Public educators need to enter this upcoming school year with grace, rather than frustration, and have systems in place to assist student learning. Schools should work to openly communicate with parents about what the school is doing and how that parent can support. Schools can also set up mentorship programs and use their guidance departments to follow up and assist struggling students. In general, schools just need to be ready for an in-person school year like no other and understand that more support and various levels of support may be needed for students in comparison with the 2018-2019 regular school year.

The final research question uncovered themes of inequity. Since the participants did not feel that inequity was prevalent due to the school division providing devices and Internet access, an implication would be for the school division to remain diligent in providing resources and ensuring that students have their needed technologies. As discussed in the findings, racial inequity was not present in the data analysis, which may stem from lack of training and understanding about what racism and inequitable education may look like. The fact that teachers may not fully understand CRT and how it relates to our systemically racist country implies that training is needed. Teachers should understand how Whiteness as property during the critical legal studies movement directly relates to inequity in education, from funding to the curriculum to discipline practices. With more historical knowledge, teachers may be able to see inequity in ways they originally didn't realize existed. Other than training teachers and school divisions on CRT and culturally responsive pedagogy, the implications for inequity based on race are beyond the scope of public education. While I hope more training can help change the experiences of our students of color, when our country remains inequitable it is difficult to make a change in only the realm of public education.

Implications for Research

Based on this study, I see the need for four main avenues of future research. The first avenue of research involves operationally defining and distinguishing between technology use and technology integration. With so many new technologies being developed, it is important to revisit the TPACK framework and definitions with a more current technological lens — particularly after this pandemic year in which so much innovation in virtual instruction occurred. By having a more current idea of what makes technology use and integration different, educators can locate their current level of performance and have an idea about how to move more towards an integration approach that supports and strengthens instruction. The second area of research would be to look at technology use and integration in other content areas. This research would also tie into the previously discussed research topic because integration may look different in science, English, and history than it does in math. The third area of research would focus on inequity based on race. While this study did not present findings to support racial inequity during virtual learning, it is important to continue to investigate this area. A research study focused solely on inequity would be beneficial. This research may need to start with a training portion to ensure that the participants understand inequity, how it started based on race, and how it is presented in current educational practices. Lastly, research needs to be conducted on how students experienced virtual learning. Did students feel like the technology was supporting and strengthening their instruction? This research may show more areas of possible inequity once student experiences and student perspectives are analyzed. Additionally, using a CRT framework, student voice and narrative is a necessity. The fifth tenet of CRT is the use of counter narrative for racial justice (Ladson-Billings, 2013). These counter narratives would be used to bring the experiences of minoritized people into our systemically racist world. By

researching inequity from a student perspective, we can gather rich stories as they have been lived in virtual public education, which may be drastically different from how their teachers perceived virtual instruction. This research would be extremely important to give voice to students of color who are traditionally being educated by White females (Howard, 2003).

Overall, this case study addressed the pedagogical changes within the secondary math classroom within the Marvel School Division, teachers' perspectives on changes in student performance, and the effect of the COVID-19 pandemic on educational inequity. The participants felt that they were integrating technology to support student learning, even with the struggles of a lowered level of rigor and shortened assignments. Teachers were unsure if the grades during the 2020-2021 school year were accurate due to academic dishonesty and external factors that affected student learning. Educational inequity was discussed as it related to device access and Internet access. While the participants stated that this educational inequity was not a racial factor, the examples provided about struggling students or student concerns mainly focused on students of color. Additional research is needed to further analyze technology integration, racial inequity in education, and the student experience during virtual learning.

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APPENDIX A
Interview Protocol

Teacher Interview Protocol

Person Interviewed (Pseudonym):
Position:
Date and Time:
Interview Location:

Introduction: "My name is Lauren Bellamy and I am a student in the Curriculum and Instruction program at Old Dominion University. I am conducting a research study on the pedagogical changes within the math classroom due to virtual learning. The purpose of this research is to explore potential curriculum and assessment changes made within the math classroom, examine student performance changes, and discuss potential educational inequities due to the digital divide. You are being asked to participate in this study because you were identified as a teacher with successful technology integration in the math classroom.

This interview will last about 60 minutes. You will be asked to discuss your experiences as a math teacher during the COVID-19 pandemic. We will discuss technology use in the classroom before and during the pandemic, any modifications to your teaching practices, and your perception on student performance and possible digital inequities. Your participation in the research study, including this interview, is completely voluntary and confidential. You do not have to answer any questions you do not wish to answer and you may choose to leave the interview at any time.

This interview will be audio recorded so that I can accurately transcribe what is discussed. The audio recordings will only be reviewed by members of the research team and the transcription service. With your permission, I would also like to record the video zoom meeting. Study information, including audio and visual recordings, will be kept in a secure location. The results of the study may be published or presented at professional meetings, but your identity will not be revealed. Pseudonyms will be used in any reporting.

There are no expected negative effects of participating in this interview. I will be happy to answer any questions you have about the study."

If the participant(s) has agreed to be audio/video recorded, state: "since you have agreed to be audio/video taped, I will now turn on the zoom record feature." If the interview participant did not agree to audio recording, written notes will be taken. I will have a paper and pen at the interview location in case there is an audio recording malfunction or in case a participant wishes not to be recorded.

Start the interview.

1. Please start by telling me about yourself, such as why you became a math teacher and what you enjoy most about your job.

2. Describe how you incorporated technology into your math classroom prior to COVID-19.

3. How has your incorporation of technology changed during this virtual school year? Please provide specific examples.

4. How, if at all, have your teaching methods and assessment practices been modified this school year? Why did you feel these modifications were necessary?

5. How, if at all, has your perception of student performance changed due to virtual instruction? Please provide specific examples.

6. Have technology concerns or inequities affected your students this school year? In what ways?

7. Do you feel that virtual instruction has created any educational inequity for your students? Please explain.

8. Is there anything else related to math instruction during the pandemic that you think I should know?

9. If you feel comfortable, please share with me how you identify as far as ethnicity, gender, age range (i.e., 30-40, 40-50) and years of teaching.

APPENDIX B

Codebook

Code	Definition	Examples
Technology use	Directly related to the use of some form of technology without mentioning its impact on student learning	• I mean we practiced a lot of, you know, a lot of those those application, you know IXL and you know, then we had quizizz and kahoots and they were able to see it together on that big projector screen. • I did use near pod, you know, as I used near pod like one time and the kids was like we don't like this. • I would do occasionally the Google slides. • So I fell in love with edpuzzle, and they fell in love with ED puzzle.
Technology integration	Technology directly included in improving or supporting instruction or student learning	• So I can say that was a benefit of them not using a handheld because I can show them how to use those desmos, you know, strategies. • I gave them multiple choices of how to do things, um, and that was one of the things that my kids loved, um, about this activity was on the slides they could choose whether they want to do use foil or box or double distribute and then, as they picked it up, um, knowing that, then it gave them an individualized video for that method. • And I could type that right there on the document and nobody in the classroom knows I'm talking to somebody else. • I would use them for formative assessments, like warm ups and stuff, something quick at the very beginning, because it helps with that immediate feedback the kids so desperately want all the time.
Pedagogy/ Teaching methods	Descriptions of how the teacher presents material or the lesson to the class	• Like you should be able to do a warm up and you should be able to do the notes with me and do the homework and everything is due the next day. • So I think, by it being in person, I was able to walk around and show them, you know how to do it. • One of my, typically, I like to do warm ups just to help with spiraling.

		• I'll do it guided instruction and then I'll say okay you go do three through seven on your own and then I'll let them work independently, we come back, we check our answers and I've done that ever since my day, this is my sixth year teaching, and I've done that, since day one.
Pedagogical change	Specific examples that state a prior teaching method or strategy and the new/changed method of teaching	• So it got to a point where a lot of the practice, the independent practice, now became guided practice. • So that's changed as well, and then you know, the number of attempts. • So I can say, you know, in hindsight, you know, showing them how to use that desmos especially getting ready for the SOL test has been a benefit because before then, I didn't, I didn't use desmos, I use my handheld because it was just, it was tactile. • And then, a lot of times to, I've realized in math when it comes to an activity or a lesson or a homework assignment, um, the simpler, the better. • And they recognize that if you hold them accountable still, but you're willing to modify a little bit, then it's still important, but sometimes life is more important, you know.
Content knowledge	Specific mention of the math content	• but I think my my thing this year is my my kids came to me with little foundation, little foundation. • So then based off of that they would tell me, like they're x and y titles, the name of their graph • Well so something like solving two step equations, we would, without even hands down would throw in something that was all fractions.
Assessment	How the teacher is determining the academic progress of the students	• You know, so that's really changed my assessments, you know and giving multiple attempts, you know to do well, because I, because this year to me now, it was more about a student's confidence.
	How the teacher determines if the students	• Now when it comes to my assessments there has been a lot of grace now, then what I had in the beginning.

	understood and learned the intended outcomes	• I think the other thing that has been really big is realizing that 50 question tests or 25 question tests are just really something that we don't have to do, every day. • Because I'll be honest, well, no I tell you what, our assessments have been a little less rigorous.
Student performance	The student output, looking at both student process and outcome	• And you see students who don't even attempt to do it. • But they're really ones who are working they're, they are, they are working so hard and even if they don't pass that test in two weeks, I know that they tried and they did their best and I'm okay with that. • I think it definitely increased more student participation, I can say that. • So, the one thing that I noticed with my students, not that this was a per se bust kind of active… you know assignment, but I noticed that my students were struggling when it came to the simplification. • My virtual kids seem to be very engaged, um, ready, working, never chasing after missing work from them.
Student performance validity	How well does the student output actually represent the knowledge level of the student	• Ummm, and I say that now, you know, because when I go home each night, you know, I'm like what did they learn anything. • So it just gave me a, a, a tainted picture, because the ones who are in person, on and that's why, when it came to do quizzes and tests now, what I, you know, they used to have the quizzes and tests on their asynchronous day, which is that, which is Monday for us. Um, I don't know what you're doing all I get is a score. • I think sometimes it's harder to gauge what kids know. • But the assessments I'm a little iffy with and see if it actually measures their true academic ability. • So, um, that made it quite difficult without, you don't, I was talking to my principal about the fact that the first monitored assessment the entire school year for me to

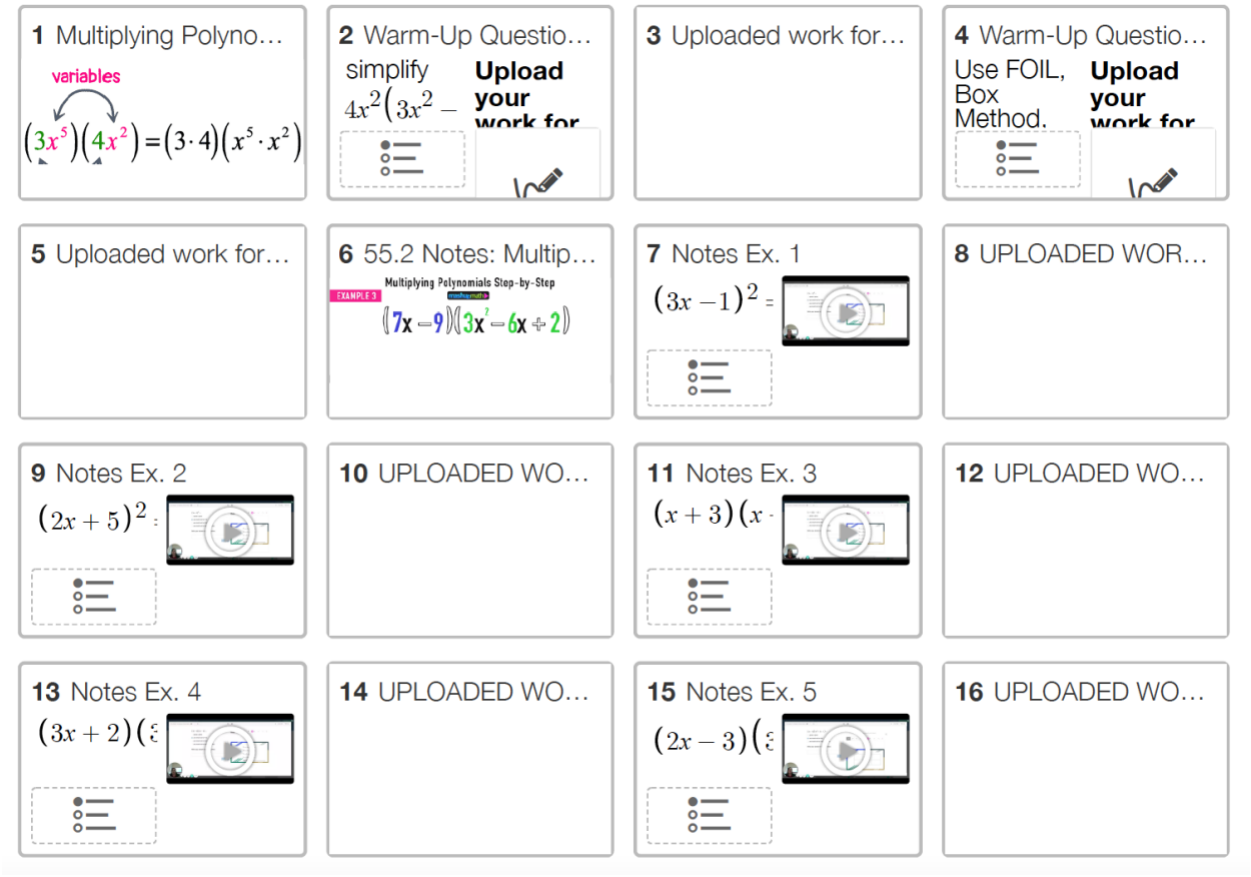
		know what the students own ability level was going to be, would be the SOL.
Digital concerns	General concerns focused around technology	• Because, although I'm sharing my screen, it doesn't mean that they're looking at it or they're even paying attention. • Now… when it comes to them being home, I have seen a lot of Wi-Fi issues, I can say that if you got more than maybe one child in your household and you're trying to share this little hotspots, you know, access, that has become a challenge and that and I think some of my kids actually ran, ran into that as well. • Multiple students trying to use that one hotspot or, you know, you gotta use it this day, you have to use it, you know, during this time period and that that was tough for some of them. • Um, but with math, it's very hard to do a lot of things without pencil paper because I want them to work it out. • It's harder in a virtual world, um, because you don't have the constant interaction with them.
Inequity based on race	Discrepancies in education based on student race	• You know just thinking about like my student makeup I don't really see as, as you know, you know the, the black white you know, I have more white students here, in my opinion, you know, my African American students, as or you know per se. I don't really see it that way here. • Like I said the, just because our school provided everything, um so there really was no, no race factor involved, which is a good thing. • You know, with your ELL kids they're learning, the biggest inequity they have this year is they have no forum to talk English and be around people who are speaking English, all day long. • Absolutely. Um so typically the students who were mostly affected that I, that I can call from my particular students were African American students.

Inequity based on socioeconomic status	Discrepancies in education based on student socioeconomic status	• but as far as an access, you know, um, I haven't really seen any of the, you know, the socioeconomic you know issues regarding students not having, you know, access to their schooling. • Um, so I think that's been harder and I think a lot of our kids who are at the lower socioeconomic status, have a lot more responsibilities than students who maybe aren't. • So I think that has been the biggest inequity, um, which will probably follow along socioeconomic lines, you know, parents that could be home for their kids versus parents that are going to have to go to work, um has been probably an issue with being able to keep up with the school. • And that's if the, like when the school provided them, before the school provided them if they didn't have one or have the money to get one that would have been an issue as well.
Racism in normal (Delgado & Stefancic, 2001)	Examples that support how our country was founded on laws that support Whiteness above all other races	Not coded in data analysis
Interest convergence	When White people seek some type of racial justice solely for personal benefit	Not coded in data analysis
Race is socially constructed	Humans are not genetically different so the differences seen between ethnic groups have been socially constructed	• And noticing the demo, with the demographics I teach, because I only have the two to three and each classroom they're easy to point out that I can easily see them, they don't blend into the group, so perhaps I'm noticing that a little bit more. (not used in data analysis)
Intersectionality	How race, gender, class, and sexual orientation interact in different	Not coded in data analysis

	settings – These interactions cannot be separated from one another	
Counter-narrative	Bringing cultural viewpoints to the forefront of our hegemonic society	• There's not the peer pressure or I need to misbehave because that's what everybody expects me to do. • Um, and so you've had some kids who habitually have been troublemakers, who are thriving in this environment. (neither used in data analysis)
Academic dishonesty	References to cheating or not completing work unassisted by an outside source	• Yes, so that changed just how I look at these things, and another thing is, um, with the parents, you know, I, you know, I'm all for parental involvement, but not to the point where you are doing it for your child and not with your child. • I've had personally issues of siblings taking quizzes and tests. • Speaking very honestly, I believe that a lot of students are, it's been more evident in my opinion, that a lot of students are cheating and copy and down things from websites, um, or having, they could also be having somebody else complete the assignments for them. • Um, students, we have honestly had to have this conversation, legit conversation with students, about they do not understand that photo math is not acceptable method of showing work.
Environment/contextual factors	Factors that may be affecting the student's education such as family obligations or home environment	• And will you be taking trips in the middle of the week? • so a lot of a lot of my students, I see that their parents have to work, we got to work. • So that's where we've seen a big deficit as well, um if they do not have that support at home or someone kind of following up. • One way is for students that are not able to, or not, I don't want to say allowed, but because our building is at capacity. • Or they had a lot of kids and they were all on at once, it like, it couldn't support all of the, you know, computers that needed that Wi-Fi.

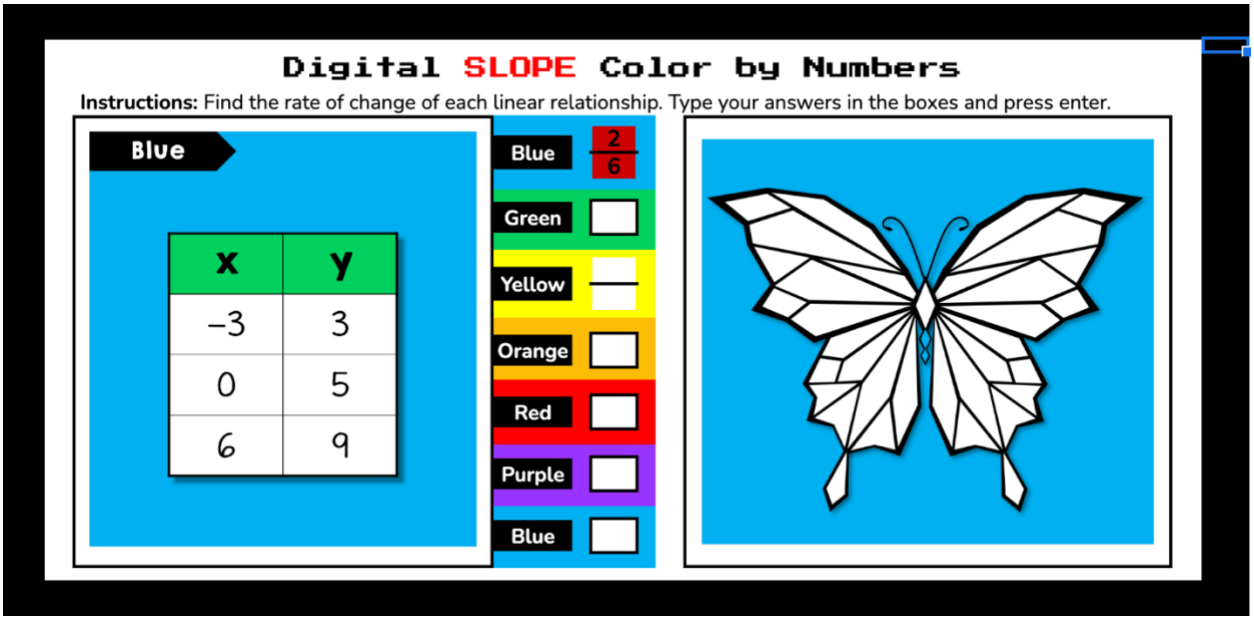
APPENDIX C

Technology Integration Artifact: Student Choice



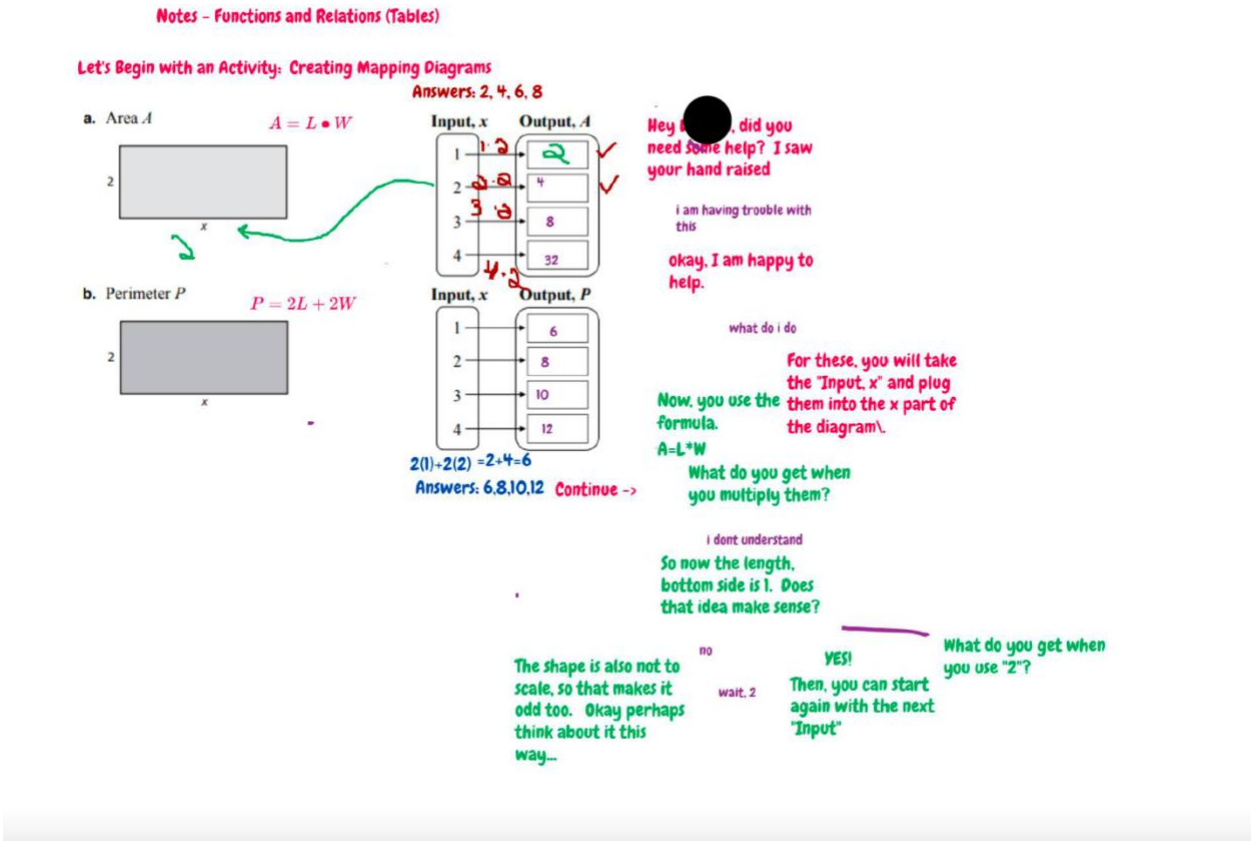
APPENDIX D

Technology Integration Artifact: Color by Number Student Assignment



APPENDIX E

Technology Integration Artifact: Teacher and Student Conversation



APPENDIX F

Technology Integration Artifact: Online Assignment that Provided Immediate Feedback