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Assessing the Impact of Online Homework on 8th Grade Students' Mathematical Proficiency and Perceptions: An Action Research Study

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ASSESSING THE IMPACT OF ONLINE HOMEWORK ON 8TH GRADE STUDENTS' MATHEMATICAL PROFICIENCY AND PERCEPTIONS: AN ACTION RESEARCH STUDY

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DEDICATION

Earning a doctorate has been a challenging and fulfilling pursuit. Finding a balance between my home, work, and academic lives sometimes felt impossible and required sacrifices and compromises from all members of my family.

To my wife, Berna, thank you for all your support and love throughout this process. You always reminded me to keep my eye on the prize and remember why I started this journey.

To my children, Beckham and Jagger, thank you for being such unique little humans. Watching you grow, develop, and change brings me joy and gratitude daily. I hope to instill a love of learning and pass on my excitement so that you will pursue higher education later in life.

To my parents, Ingrid and Gary, thank you for your willingness to contribute in multiple ways to support my endeavors. You have always been my biggest cheerleaders; this journey would have never happened without your help.

ABSTRACT

This action research aimed to assess the impact of online homework, delivered via IXL, on thirteen 8th Grade Mathematics students' mathematical proficiency and explored their perceptions of its usefulness. The Cedar Hill Middle School students typically scored below state and national averages in mathematics, necessitating increased rigor and support. Two main questions guided the research in this study. The first question assessed the impact of online homework on students' mathematical proficiency according to the National Council of Teachers of Mathematics (NCTM) definition, looking specifically at strategic competence, conceptual understanding, procedural fluency, and adaptive reasoning. The second question investigated students' perceptions of the usefulness of online homework on their mathematical proficiency. A convergent parallel mixed-method study collected student data from multiple sources, including IXL, a pre- and posttest, student surveys, and student interviews. Quantitative data was analyzed using descriptive (mean, standard deviation) and inferential statistics (paired samples t-test). Qualitative data was collected through student interviews and analyzed using open, axial, and selective coding. Rigor and trustworthiness were maintained using member checking, thick, rich description, peer debriefing, and triangulation. There was a positive correlation between the IXL online homework and the posttest results, showing that IXL has an impact. However, survey results revealed that most students were neutral about the impact and usefulness of the IXL online homework assignments. Analysis of interview transcripts revealed three themes: (a) IXL has many motivating and helpful features

which aided participants' comprehension, but some features were demotivating, (b) remembering and connecting IXL content and classroom instruction to the posttest varied, and (c) videos, lessons, and liking IXL helped the participants to complete assignments and understand the content in IXL. While IXL positively affected mathematical proficiency, student perceptions varied on its helpfulness for the pre- and posttest. It is theorized that the unlimited number of attempts on IXL and students' reading comprehension skills may have affected the innovation's impact. Recommendations for future online homework technology implementations should consider the number of attempts for homework completion and attempt to make more significant connections between lessons, homework assignments, and assessments.

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CHAPTER 1

INTRODUCTION

National Context

For three-quarters of a century, homework has been researched and analyzed to ascertain its academic influence (Bas, Senturk, & Mehmet Ciherci, 2017; Cooper, Robinson, & Patall, 2006; Corno, 2005; Trautwein, Köller, Schmitz, & Baumert, 2002). However, the role of homework has still being deliberated on all levels of education, both nationally and locally, resulting in the need for further investigation of the processes for effective implementation (Fernández-Alonso, Suárez-Álvarez, & Muñiz, 2015; Ladson, 2012; Mahmood, 2018; Maltese, Tai, & Fan, 2012). Students' and parents' complaints have varied over time on length, difficulty, rigor, and homework functionality (Gill & Schlossman, 2005). Positive correlations between traditional pen and paper homework and performance success have been shown in multiple environments (Cooper et al., 2006; Cooper & Valentine, 2001; Fan, Xu, Cai, He, & Fan, 2017; Fernández-Alonso et al., 2015; Cheema & Sheridan, 2015; Keith, 1982; Ladson, 2012). Recent research has shown only a limited relationship between the time spent on homework and academic achievement (Cooper et al., 2006; Ramdass & Zimmerman, 2011). Nevertheless, it is still widely accepted "that homework has a pedagogical value" (Cooper, 1989, p. 85), provided that its length is reasonable and promotes deeper learning (Galloway, Conner, & Pope, 2013).

Homework is assigned to improve and practice skills learned during a lesson, while grading ensures an incentive for completion (Roschelle, Feng, Murphy, & Mason, 2016). A moderately significant mean effect on homework and achievement was found by Paschal and Weinstein (1984) when feedback was received or when an assessment was assigned. Technology's introduction has changed how homework can be delivered, practiced, and evaluated, enacting a sense of optimism for its future role (Kodippili & Senaratne, 2008).

Online technology-based homework is continually being assessed as a means to provide meaningful, instantaneous feedback and management for the grading portion for large-scale populations (Arasasingham, Martorell, & McIntire, 2011). While online homework can alleviate the additional workload of collecting and grading homework for educators, not all online homework has been beneficial. Students' grades and homework scores correlated weakly in an Organic Chemistry course (Chamala et al., 2009). However, the researchers theorized that the difference between the final examination content versus the homework played a prominent role in the outcome (Chamala et al., 2009). Also, no significant effect was found by Cole and Todd (2009) when implementing online homework versus traditional bookwork. The researchers speculated that because the study evaluated the control and experimental groups simultaneously, some cross-communication negated any potential effect outcomes (Cole & Todd, 2003). To counteract prior studies' perceived shortcomings, a comprehensive research plan was developed and executed by Arasasingham et al. (2011) over six years that carefully aligned its content and assessments. The results showed that online homework substantially impacted exam scores (Arasasingham et al., 2011).

Disparities in different studies revealed that considerable thought must be placed on developing learners' conceptual understanding and thorough engagement with online homework to elicit positive change in academic performance (Archer & Olson, 2018; Cheng, Thacker, Cardenas, & Crouch, 2004; Hegedus, Dalton, & Tapper, 2015; James, 2016; Maltese et al., 2012; Rasila, Malinen, & Tiitu, 2015; Zahner, Velazquez, Moschkovich, Vahey, & Lara-Meloy, 2012). For example, in the Dillard-Eggers, Wooten, and Child (2008) study, well-planned online homework enhanced academic performance while garnering positive feedback from its participants.

IXL has been a successful educational tool for implementing online homework in mathematics classes. Schuetz, Biancarosa, and Goode (2018) concluded that the features of IXL enabled students to build mathematical skills and autonomy through the remedial and differentiated feedback provided. In 2013, the Beaverton School District, located in the Pacific Northwest, found that scores on the OAKS math test were positively correlated with IXL practice (Empire Education Inc., 2013). Although IXL does not align perfectly with more rigorous, multi-step assessments, it has tremendous value in building mathematical fluency of essential skills for low-achieving students (Hollands & Pan, 2018). Furthermore, with its availability through a computer or mobile application, it is a medium that can be efficiently utilized for homework and in-class practice to increase student independence and engagement.

The incorporation of online homework in mathematics classes has rapidly grown in the United States. However, the successful implementation was found to be dependent upon several key factors: its use as a formative assessment, it being a minimal portion of the grade, its daily implementation, its use in class discussion, its reinforcement of the

desired outcome, and its connection to classroom assessments (Lunsford & Pendergrass, 2016; Roschelle et al., 2016).

Local Context

The research was conducted at Cedar Hill Middle School (CHMS), a public institution in the southeastern United States serving 6th to 8th graders. CHMS is a pseudonym for the actual school's name, which has been changed to protect those involved with the study. Furthermore, all names of students, colleagues, and administrators have been given pseudonyms or omitted to protect their anonymity. Typically, around 450 students attend CHMS middle school annually. The mathematics teachers used curriculum designed by Math Nation which followed the South Carolina College- and Career-Ready Standards (SCCCR) for mathematics. The math department employed six full-time teachers covering the 6th Grade Math, 7th Grade Math, 8th Grade Math, and Algebra I courses. Eighth-grade students identified by their high 7th-grade Measure of Academic Progress (MAP) test scores were placed in Algebra I during 8th grade. At the same time, the remainder were assigned to 8th Grade Mathematics.

Homework implementation has been discussed at length in mathematics department meetings and in passing conversations with colleagues and administrators. Concerns about students' time spent on homework, the amount of plagiarism, the process of grading, students' practice of improper habits, time spent checking homework, and remediating misconceptions have been discussed. Teachers wanted students to use the homework as additional practice, but mistakes made during homework completion consume valuable class time to reform misunderstandings (Galloway et al., 2013). Grading daily homework for 90 to 110 students was not practical, so homework was

checked for completion and assigned a grade for attempted work. This grading style reinforced the notion that homework was a task to be completed rather than understood (Galloway et al., 2013).

In order to address these issues, the CHMS mathematics department has attempted various techniques to improve performance. Teachers have tried assigning problems at the end of each lesson, which are generally completed during class in groups, or at home individually. Informal polling of students has revealed that homework is not completed with enough consistency to promote meaningful self-evaluation. Other teachers have found assignments on Khan Academy, Wowsers, ALEKS, or other websites that can provide immediate feedback. Still, the homework problems are often not comprehensive enough or do not align with the teacher's lesson and curriculum. Other teachers tried spot-checking homework a few times a unit rather than completing time-consuming daily checks. However, these different techniques still required the teacher to use class time to check homework, subtracting from the valuable time spent on remediation.

There was still a need for a system that provided meaningful feedback that aligned with the Illustrative Mathematics coursework curriculum. The pace of the curriculum had little time built in for remediation. Time spent checking homework completion and correctness could have been used to tackle misconceptions in understanding and processes. Process-based feedback and example problems provided by IXL can support students outside of the classroom. Homework was essential to developing a deeper understanding of the lessons at CHMS. Greater exploration was

needed for an online homework system that provided immediate feedback to students and enabled teachers to analyze and address any misconceptions.

Statement of the Problem

More than half of the 8th-grade students at CHMS scored below grade level in Math on state standardized testing According to the SCCCR on the students' Measure of Academic Progress (MAP) tests, approximately 70% of students scored in the Does Not Meet (DNM) expectations and Almost Met (AM) expectations categories during their Winter MAP testing. Following the winter testing, South Carolina Governor McMaster closed all schools, and we went into a temporary remote situation with students learning from home. A tremendous loss of instructional time occurred at CHMS for many reasons. A significant portion was due to the lack of preparedness by teachers and administration with the sudden and unanticipated lockdown. Online learning was new to both students and staff. Some students had yet to receive improved internet access, so attending virtual school was impossible. Most students had difficulty attending school regularly due to their family's living situation or had never navigated an online platform. The newness of online learning and the lack of district, administration, and teacher preparedness led to a problematic spring of online learning.

Many issues were discussed during the summer months to prepare CCSD for the possibility of remote learning during the 2020-2021 school year. The district adopted Canvas as Learning Management System (LMS), and all teachers had the required training. Wi-Fi access was upgraded and expanded to all students with accessibility difficulties during the Covid-19 lockdown. These changes enabled most students to access all their coursework from home on their school-issued devices.

In order to help CHMS students regain lost instructional time and help students further advance their learning, an online homework innovation was utilized during a unit on functions. Roschelle et al. (2016) showed that students, parents, and teachers believed that homework was a vital part of the learning process to practice the skills acquired during a lesson, which correlated with positive or neutral effects on learning (Roschelle et al., 2016). When graded for correctness, the likelihood of quality work was increased and associated well with test scores, but teachers found this to overload their daily tasks (Lunsford & Pendergrass, 2016). Furthermore, specific feedback had to be swift enough for students to process mistakes and address mislearning patterns (Alexander, 2013). Timely performance feedback has been shown to develop the student-teacher relationship and increase the quality of instruction (Arora, Yun Jin, & Masson, 2013; Babaali & Gonzalez, 2015; Bowman, 2014; Kong & Song, 2013; Roschelle et al., 2016; Tabor & Minch, 2013; Thiet, 2017; Yerushalmy, Nagari-Haddif, & Olsher, 2017). Student academic issues that lingered without remediation hindered the relationship's progression, and instructional quality declined (Husain & Khan, 2016).

Students wanted to know that their time spent on homework was meaningful, purposeful, and aided their classroom performance (Maltese et al., 2012). Students needed the motivation to complete their homework and wanted quality, appropriate responses, but finding a balance was a struggle for teachers (Lunsford & Pendergrass, 2016). Considering the students' potential gain and teachers' perspective of the utility of homework, the research question becomes: Where is the middle ground?

Purpose Statement

This action research aimed to assess the role of online homework on 8th Grade Mathematics students' mathematical proficiency at Cedar Hill Middle School using IXL.

Research Questions

The following research questions guided this research study:

1. **Research Question 1:** How does IXL online homework affect the mathematical proficiency of 8th Grade Mathematics students at Cedar Hill Middle School?
    1. **Sub Question 1**: How does IXL online homework affect the strategic competence of 8th Grade Mathematics students at Cedar Hill Middle School?
    2. **Sub Question 2**: How does IXL online homework affect the conceptual understanding of 8th Grade Mathematics students at Cedar Hill Middle School?
    3. **Sub Question 3**: How does IXL online homework affect the procedural fluency of 8th Grade Mathematics students at Cedar Hill Middle School?
    4. **Sub Question 4**: How does IXL online homework affect the adaptive reasoning of 8th Grade Mathematics students at Cedar Hill Middle School?
2. **Research Question 2:** What are students' perceptions taking 8th Grade Mathematics at Cedar Hill Middle School of the impact of online homework using IXL on their mathematical proficiency?

Statement of Research Subjectivities and Positionality

Without purposeful design, homework's perceived futility eventually overrides motivation and ruins any additional gains in learning. My introduction to the field of Educational Technology began with the discovery of my purpose, something beyond imparting the language of mathematics through lessons, assessments, and homework. I want to understand the future path of technology to make its use impactful and pursue knowledge systematically, building a set of principles for its inclusion. This new foundation will enable me to enhance my craft and open pathways to modern teaching, working, and learning.

Early in my career, when I was still coaching collegiate track, the lessons I learned laid the foundation for my future beliefs. First and most importantly, I realized that feats of amazement never happened by accident. Meticulous planning and sustained dedication were paramount to executing every tremendous athletic performance. As I transitioned from coach to teacher, this idea developed further because of its importance in the classroom. Preparation and organization have always been the backbone of success, but I did not want to get caught up in technology's newer, better, and cooler mantra. After the novelty wears off, the underlying foundation is constantly exposed. Knowing the importance of developing sound pedagogical practices motivates me to keep expanding my knowledge base, ensuring that academic achievement's underlying structures are built on sound principles.

My worldview is filtered through a pragmatic lens, allowing my impression to shift as new information is attained, thereby changing my perception of the situation. Hammond (2013) felt that pragmatism allowed for knowledge to be modified, and the

cyclical aspect of action research was paramount to facilitating this new information in subsequent research cycles. Higham (2018) stated that an ontological perspective could shape my reality by allowing me to see my participants' contradictory viewpoints (Higham, 2018). From a pragmatic epistemological standpoint, my classroom has been its microcosm without needing to reflect on larger society (Garrison, 1995). I must also develop a collaborative relationship with the participants, the administration, the school, and other stakeholders to successfully implement a pragmatist methodology (Frels & Onwuegbuzie, 2013). Furthermore, a keen awareness of my biases or prejudices will guide the research process at all stages to allow a more objective viewing of the information (Morgan, 2013).

The positionality of an individual is derived from two inherent ideas, according to Merriam et al. (2000): philosophy is ever-changing and cultural status is transformative. While Merriam et al.'s (2000) research may hold in a larger schema on a longer timeframe, my positionality will hold steady in the microcosm of my research. I see myself as an outsider in my relationship with the participants because they are primarily of different ethnicities, socioeconomic statuses, and geographic areas and have been indoctrinated with another value system. Although consideration must be given to my microcosm position, since a teacher, no matter how integrated and accepted into a student's life they may become, primarily plays an outsider role to teenagers. He or she is in an authoritarian position in a school's social hierarchy. This role of an outsider will necessitate that I reflect upon the different aspects of the participants' lives. It must be perceived and reflected upon from a position of authority (Giampapa, 2011).

The purpose of the technology, the lesson, the homework, and the activity must precede its implementation to provide meaning. The lens through which I view the importance of homework may be vastly different from the participants. Through this research, I will begin to understand each other's perspectives, and each of us will be molded by the practicality of the environment (Giampapa, 2011). I look to be the transformer and transformed through this process, and it will undoubtedly reveal my positionality with greater clarity and thereby revise my biases.

Definition of Terms

IXL will be defined as the medium by which online homework is delivered to the participants. *IXL* is available through purchase, user-friendly, mobile- and computer-friendly, and can provide questions in many ways, including open response (short and long), multiple-choice, graphs, and tables (www.ixl.com). Analytics were included to assess students' activity, track scores, view practice sessions, and monitor state standards readiness (www.ixl.com).

To understand *mathematical proficiency,* this study analyzed four of the five strands defined by the National Research Council (2001): *strategic competence*, *conceptual understanding*, *procedural fluency*, *adaptive reasoning*, and productive disposition.

The National Research Council (2001) defined *strategic competence* as having the aptitude for expressing and representing ideas to find solutions for mathematical questions. More specifically, at this point in research, it is the students' development of competence "in terms of their ability to construct use and evaluate multiple representations and models of mathematical ideas and establish correspondences between representations" (Suh et al., n.d., p. 475).

Conceptual understanding shaped the students' ability to correspond, describe and theorize arguments mathematically (Zahner et al., 2012). Furthermore, they sensed the relationships, processes, and theories to transfer them across genres (National Research Council, 2001).

Rasila, Malinen, and Tiitu (2015) defined *procedural fluency* as the "ability to use mathematical procedures" (p. 149). Similarly, Andrews (2013) utilized a similar definition and stated that students should be able to execute mathematical tasks with precision, agility, proficiency, and correctness.

In order to understand *adaptive reasoning* in mathematics, the research utilized its expression as the "capacity for logical thought, reflection, explanation, and justification" (National Research Council, 2001). Additionally, it was the students' process by which they analyzed and communicated their thinking (Groth, 2017).

Online homework was defined as a medium to deliver homework via the internet and provide instantaneous feedback (Lunsford & Pendergrass, 2016). Moreover, it offered many advantages over traditional pen and paper homework, including individualized questions, personalized and immediate feedback, automatic grading, worked examples, and increased student satisfaction (Kolmos, 2010).

CHAPTER 2

LITERATURE REVIEW

This action research aimed to assess the role of online homework on 8th Grade Mathematics students' mathematical proficiency using IXL at Cedar Hill Middle School. The analysis of literature concerning online homework concentrates on the following research questions:

1. **Research Question 1:** How does IXL online homework affect the mathematical proficiency of 8th Grade Mathematics students at Cedar Hill Middle School?
    1. **Sub Question 1**: How does IXL online homework affect the strategic competence of 8th Grade Mathematics students at Cedar Hill Middle School?
    2. **Sub Question 2**: How does IXL online homework affect the conceptual understanding of 8th Grade Mathematics students at Cedar Hill Middle School?
    3. **Sub Question 3**: What is the impact of online homework using IXL on students' procedural fluency taking 8th Grade Mathematics at Cedar Hill Middle School?
    4. **Sub Question 4**: How does IXL online homework affect the adaptive reasoning of 8th Grade Mathematics students at Cedar Hill Middle School?

2. **Research Question 2:** What are 8th Grade Mathematics students' perceptions regarding the impact of online homework using IXL on their mathematical proficiency?

A multi-step process was employed to find relevant research for the literature review. First, database searches were executed on pertinent variables for an in-depth understanding of each research question. Essential variables are as follows: (a) online homework, (b) mathematical proficiency, (c) constructivism, (d) performance, (e) attitude, (f) perception, and (g) use of IXL. Next, relevant literature for the review was researched and obtained using *ERIC* and *Education Source*, with occasional sources acquired using *Google Scholar*, *JSTOR*, and *ProQuest*. Combinations of keywords that guided the searches were as follows: *online homework*, *performance, web-based homework, achievement, traditional homework, mathematics, math*, mathematical proficiency, conceptual understanding, conceptual knowledge, strategic competence, mathematical competence, competence, procedural fluency, mathematical fluency, adaptive reasoning, attitude, perception, confidence, constructivism, constructivist theory*, *self-efficacy, autonomy, study time, study effort*, *IXL,* and *positive*. Searches were often limited by selecting "peer-reviewed," "full-text," and "references available" to narrow the field of available research for review. Source recommendations were also acquired from peers and professors and reference sections or bibliographies of more recent literature.

Six sections guide the organization of this literature review and are organized as follows: (a) mathematical proficiency and the influence of the four strands, (b) influence

of online homework, (c) online homework and mathematical performance, (d) effective design of online homework, (e) attitude and perception, and (f) use of IXL.

Section 1 will introduce literature on online homework to offer background knowledge and descriptions of what it means to be mathematically proficient. The second section will detail the purpose of online homework and its influence on learning outcomes and student performance. Important design components of online homework that maximize student performance will be discussed in section three. The fourth section will discuss literature related to online homework and its influence on student attitude and motivation. The last section will analyze research on IXL's use to deliver online homework. Each section of the literature review will be investigated and debated regarding online homework and mathematical proficiency.

Mathematical Proficiency and the Influence of the Four Strands

To improve mathematical proficiency in students, each of the contributing components must first be understood. The following sections will define mathematical proficiency and its strands while highlighting research in each area. The sections will be ordered as follows: (a) mathematical proficiency, (b) strategic competence, (c) conceptual understanding, (d) procedural fluency, and (e) adaptive reasoning.

Mathematical Proficiency

Over the last few decades, the United States has focused on improving mathematical proficiency. According to Olson, Martin, and Mullis (2008), U.S. students' mathematics scores were deficient compared to other countries during international studies, revealing a need to improve mathematical proficiency. Researchers of the U.S. Department of Education's National Center for Education Statistics (2011) also found that

less than 40% of fourth and eighth graders' mathematics scores were proficient for their grade level. Unfortunately, young students' low mathematical proficiency can have a compounding effect as they continue their education. Those who struggled with mathematics early are much more likely to fall and remain behind grade-level expectations (Nelson, Parker, & Zaslofsky, 2016). Data is even more concerning when examining the achievement gaps between racial/ethnic groups. For example, Hispanic and African American students were far more likely to outperform in mathematics than their Asian and Caucasian peers (Guglielmi & Brekke, 2018). Therefore, leaders in U.S. schools and classrooms must improve mathematical proficiency in all students, especially those in underperforming racial/ethnic groups.

Proficiency in mathematics has a multitude of contributing factors. Hudson, Kadan, Lavin, and Vasquez (2010) suggested that mathematical proficiency comes from students' abilities to estimate and compare magnitudes, recognize an unreasonable answer, and represent an answer in various forms. When presented with new material, mathematical proficiency has been shown to demonstrate students' confident command of fundamentals (Bottino & Robotti, 2007; Kulik, Kulik, & Bangert-Drowns, 1990). Additionally, proficiency was improved the most when teachers used student performance data, had students collaborate, gave process-based feedback about errors, and provided specific instruction in the classroom about math theories and processes (Sheldon, Epstein, & Galindo, 2010). Knowing and addressing these factors can positively contribute to mathematical proficiency, a more concise understanding can underscore the interplay of skills that may not have been attended to otherwise.

The definition of mathematical proficiency emphasizes the interplay of different influencing abilities. The National Research Council on Mathematics (2001) has defined mathematical proficiency as five interconnected strands that involve students' strategic competence, conceptual understanding, procedural fluency, adaptive reasoning, and productive disposition. Cozean (2011) and James (2016) suggested that these strands are imperative to developing independent learning for mathematics proficiency. Of the five strands, the online homework innovation will not address productive disposition. Instead, the student surveys and interviews will clarify their perceptions of the online homework and whether that influenced their feelings towards mathematics.

Classrooms must shift their focus to all strands to allow students to improve their mathematical proficiency (Allsopp, Lovin, & van Ingen, 2017). To fully understand mathematical proficiency, grasping the contributing strands and their interconnections is vital. In more detail, the following sections will review strategic competence, conceptual understanding, procedural fluency, and adaptive reasoning.

Strategic Competence

The ability to correctly grasp mathematics problems has been associated closely with strategic competence. It has been described as the ability to perform mental calculations flexibly (Bottino & Robotti, 2007; Hudson, Kadan, Lavin, & Vasquez, 2010). Nicholls (1984) defined strategic competence as the capacity to evaluate and implement problem-solving strategies for mastery. It still holds in the year 2020, as evidenced by Hernández, Perdomo-Díaz, and Camacho-Machín. A more widely accepted and utilized definition stated that strategic competence was the ability to formulate, represent, and solve mathematical problems (Andrews, 2013; Groth, 2017; Rasila et al.,

2015; Suh et al., 2012). Commonalities across definitions highlight a learner's ability to digest and solve mathematical problems using fluidity and resilience strategies.

Strategic competence development comes from proper planning. In order to build strategic competence, opportunities to express and analyze mathematical thought must be routinely administered with feedback (Chickering & Gamson, 1987; Groth, 2017; Suh et al., 2012). Among the five strands, strategic competence was most deficient in mathematics classrooms (Andrews, 2013). When implemented in a classroom with regularity, focusing on strategic competence has been shown to impact and empower learners to solve real-world problems that are increasingly complex and changing (Brisson et al., 2017; Morris, 2019). Correctly implementing feedback with strategically challenging problems can build learners' strategic competence.

Conceptual Understanding

Conceptual understanding is foundational for building mathematical knowledge (Rasila et al., 2015). It has been widely accepted, researched, and defined as the comprehension of mathematical concepts, operations, and relations (Andrews, 2013; Bokhove & Drijvers, 2010; Groth, 2017; Hudson et al., 2010; Kulik et al., 1990; Rasila et al., 2015). Building learners' conceptual foundations were found to be fundamental for the introduction of new ideas (Rasila et al., 2015; Steif, Lobue, Kara, & Fay, 2010) and a critical bridge for the development of representational fluencies (Capraro, Capraro, Carter, & Harbaugh, 2010; Suh et al., 2012). The backbone of mathematics learning begins with solid fundamentals to expand and acquire future knowledge later.

Many studies have correlated increased learners' conceptual understanding through improved knowledge and connection. When presenting new material,

simplifying and breaking down the procedural processes used to solve mathematical problems deepened participants' conceptual understanding (Hegedus et al., 2015; Steif et al., 2010). Improvements in conceptual understanding were correlated to experiments that enabled learners to focus on modern world expressions of mathematics in various representational forms (Hegedus et al., 2015; James, 2016; Rasila et al., 2015) and included purposeful interactions with participants that probed for comprehension (Capraro et al., 2010; Hegedus et al., 2015; James, 2016). Focusing on meaningful collaborations and associations can construct and grow learners' conceptual understanding.

Procedural Fluency

The definition of procedural fluency centers on learners' abilities to organize and execute ascertained mathematical behaviors. Hernández et al. (2020) described procedural fluency as the "ability to know how and when to carry out the steps in a mathematical procedure such as reasonable deductions, geometric formations, symbolic conversions, or solving equations" (p. 211). Foster (2013) and Leinwand et al. (2014) defined it as an aptitude for using different methods interchangeably to demonstrate rich mathematical thought over various problems. The most commonly used description expressed procedural fluency as using mathematical procedures such as simplifying formulas (Andrews, 2013; Bokhove & Drijvers, 2010; Groth, 2017; Hudson et al., 2010; Rasila et al., 2015). Procedural fluency can be summarized as knowing the appropriate uses for mathematical formulas and processes.

Procedural fluency in mathematics can be developed with routine and appropriately skilled activities. Andrews (2013) found that the development of learners'

procedural fluency was addressed regularly in classrooms. Rather than discouraging learners with highly complex problems, reasonable and solvable tasks enhanced procedural fluency (Foster, 2013; Rasila et al., 2015). This method continued Nicholls' (1984) research, which claimed that mastery of procedural fluency through enhanced skills and abilities must be through specifically developed exercises requiring incrementally increased efforts. Consistent mathematical tasks and routines that match the learners' current level of understanding can build procedural fluency rather than implement more challenging activities, leading to frustration and apathy.

Adaptive Reasoning

Adaptive reasoning can be recognized and studied as learners' ability to restructure their mathematical thinking fluidly. It is often distinguished as how learners represent their aptitude for presenting their logical thoughts, reflections, explanations, and justifications (Andrews, 2013; Bokhove & Drijvers, 2010; Groth, 2017; Hudson et al., 2010; Rasila et al., 2015). Regrettably, Andrews' (2013) research showed that it is another strand that has received less attention in mathematics classrooms. In responsive learning environments focused on developing adaptive reasoning, learners were able to show improvements in pattern and symbol recognition (Bokhove & Drijvers, 2010; Cosio & Williamson, 2019) and adjustments to conjectures through the utilization of different problem-solving techniques (Hernández et al., 2020; Stahl, Çakir, Weimar, Weusijana, & Ou, 2009). Prioritizing research on adaptive reasoning can improve how learners think about and explain their comprehension of mathematical situations.

Adaptive reasoning can be trained using problems that require situational thinking. Samuelsson (2010) found that teachers significantly improved learners' adaptive

reasoning after using a problem-based curriculum. When students have to use problems to develop their adaptive reasoning, they must construct their knowledge and reveal the imparted concepts (Mahendra et al., 2017; Ostler, 2011). Creativity and adaptability are trained by using new and unique ideas once students encounter unfamiliar problems (Muin et al., 2018). Ostler (2011) indicated that using various approaches to solve tasks strengthened adaptive reasoning in learners. Students' ability to analyze and solve problems using multiple methods develops when students have to navigate unfamiliar situations with familiar knowledge.

Influence of Online Homework

Homework has long been used to extend learning outside of the classroom. Delivering and receiving homework through the internet has been and will continue to be explored by researchers regarding its influence and effectiveness. This section will define online homework, relate it to constructivist theory, and detail how it has influenced mathematical performance.

Definition of Online Homework

Online homework uses the internet as a distribution mechanism for various purposes**.** Prior research has defined it as a computer-based grading system delivered via the internet (Ali Alshehri, 2017; Bonham, Deardorff, & Beichner, 2003; Leong & Alexander, 2013). Additionally, its design should provide immediate and corrective feedback (Gönülateş & Kortemeyer, 2017; Leong & Alexander, 2013; Lunsford & Pendergrass, 2016) and be delivered in varying forms such as multiple-choice to open-ended type questioning (Gönülateş & Kortemeyer, 2017). Homework implemented

online has evolved to be more complicated than just a virtual textbook, often offering strategic feedback coupled with varied questioning styles.

Constructivist Theory

Constructivist theory can augment the effectiveness of online homework and learning. "Successful models of engaged learning in online education are based on constructivist principles" (Hoskins, 2012, p. 53). The theory contends that new knowledge is constructed by expanding or amending existing knowledge through interactions and experiences (Alsulami, 2016; Keengwe, Onchwari, & Agamba, 2014; Koohang, R., Smith, J., & Schreurs, 2009; Miller-First & Ballard, 2017; Richardson, 2003; Vidmar, 2011). The learning and processing of knowledge can be affirmed or challenged through social interactions (Miller-First & Ballard, 2017; Sang, 2010; Stefan & Popsecu, 2014) and active and meaningful experiences (Alsulami, 2016; Keengwe et al., 2014; Miller-First & Ballard, 2017; Richardson, 2003; Vidmar, 2011). Constructivist theory pairs well with online homework, provided experiences and interactions are designed to promote discussion, collaboration, and significance.

Promotion of Discourse and Learning

Connections and profound insights are paramount for building a constructivist environment. Constructivist theory in pedagogical practices should focus on the depth of understanding of teachers and students (Dongho Kim & Lim, 2018; Richardson, 2003). Interactions among learners have promoted in-depth discussions and connections to enhance the comprehension of content (Chickering & Gamson, 1987; Kim & Lim, 2018; Li & Ma, 2010) and motivated students to learn through their intellectual discourse with each other (Chickering & Gamson, 1987; Kim & Lim, 2018). All meaningful interactions

have been shown to promote learning (Chickering & Gamson, 1987; Einfield, 2014; Yerushalmy, Nagari-Haddif, & Olsher, 2017). Technology has been an effective means to implement constructivist pedagogy online (Li & Ma, 2010; Einfield, 2014). Intellectual discourse creates constructivist environments that can connect or restructure knowledge online or in person.

Performance

Online homework and traditional pen and paper methods have been shown to produce similar performance effects under certain circumstances. Statistical differences in performance, detailed in Table 2.1, were not found between online homework and traditional pen and paper homework (Cole & Todd, 2003; Demirci, 2007; Hauk, Powers, & Segalla, 2015; Mathai & Olsen, 2013; Stickles, 2017). Using an online delivery system as an alternative method to deliver content yielded no significant effects (Cole & Todd, 2003; Hauk, Powers, & Segalla, 2015; Mathai & Olsen, 2013). Feedback on correctness was not enough to affect performance, although researchers stipulated that additional process-based responses may positively influence performance (Mathai & Olsen, 2013; Stickles, 2017). However, the Demirci (2007) study showed some improvements in exam performance in the online homework group, but the effect was minimal and therefore not significant. More pertinent feedback may be needed for online homework results to indicate statistical significance over traditional pen and paper homework.

Table 2.1 *Traditional Homework versus Online Homework: No Statistical Significance*

Study	Participants	Method	Prevalence
Cole and Todd (2003)	Two hundred participants were from first-year general chemistry at a large midwestern university. Additionally, 14 student interviews (12 females and two males) were conducted.	It was a mixed-methods study with quantitative and qualitative data. Data was collected on all class homework, labs, and exams. A Group Assessment of Logical Thinking (GALT) test was administered and scored. Both pre- and post-attitude tests were gathered. Data from semi-structured interviews were analyzed.	No significant difference was found in student performance. However, high GALT students' attitude was more negative than low GALT students. Researchers suggest that merely putting homework online does not affect the outcome.
Demirci (2007)	103 students (54 male and 49 female) enrolled in a physics-1 course at a university	The study was a quantitative experiment that used student surveys and homework and exam data collected over the semester.	No significant differences were found between the treatment and control of their performance. However, significant improvements were noted in exam scores after the online homework intervention. Participants also had a higher perception of web-based homework.
Hauk, Powers, and Segalla (2015)	Four hundred thirty-nine students participated in the study from 19 moderately sized college algebra sections at large public universities. Three hundred two students were in the treatment group, and 137 were in the control group.	It was a quantitative study with pre- and posttest data gathered on a 25-item multiple-choice test. The online homework treatment used WeBWork as the platform to deliver content. The treatment group used the WeBWork homework system, and the control group used traditional pencil and paper.	Results were as follows: $t(302) = 17.41$, $p < 0.0005$ for the WeBWork group, $t(137) = 11.86$, $p < 0.0005$ for the traditional homework group, and $t(439) = 21.09$, $p < 0.0005$ for the combined group. While the WeBWork did show slightly higher scores, it was not statistically significant.
Mathai and Olsen (2013)	Seventy-seven students participated in a college algebra course — 48 participants in the treatment group (in two sections) and 29 participants in the control.	The study used a convenience sample to collect quantitative data on all participants using their MPT, Math SAT, mean semester exam score, final exam score, mean homework score, and final grade in the course.	According to the exam data, no significant difference was found between the online and traditional homework groups, with a p-value = 0.2756. However, there was also some slight interaction between better algebra skills and online homework, with a p-value = 0.0094 for a one-sided two-sample *t*-test.

Study	Participants	Method	Prevalence
Stickles (2017)	One hundred four college algebra students, 40 participants in the control group, and 42 participants in the treatment group completed the study.	The study used a convenience sample with a mixed-methods design, a technology survey, five exams, and a final. In addition, Hawkes Learning System was used to deliver online homework content.	No statistically significant difference was found in performance between the two groups on their semester exam average or final exam score.

When comparing online homework with traditional homework, research that showed positive effects on performance had additional helpful features. Online homework interventions have been shown to elicit positive statistical significance, as detailed in Table 2.2, on students' performances (Martorell, & McIntire, 2011; Archer & Olson, 2018; Arora, Yun Jin, & Masson, 2013; Babaali & Gonzalez, 2015; Bowman, 2014; Burch & Kuo, 2010; Dodson, 2014; Doorn, Janssen, & O'Brien, 2010; Jonsdottir, Bjornsdottir, & Stefansson, 2017; Roschelle, Feng, Murphy, & Mason, 2016a; Schubert, 2013). Online homework was correlated with increased time on task with improved student performance (Babaali & Gonzalez, 2015; Bowman, 2014), and also attributed the positive effects to the self-empowerment given by the programs to the learners (Arasasingham et al., 2011; Archer & Olson, 2018; Arora et al., 2013). Comprehension was able to be increased when feedback data was used to tailor classroom instruction (Jonsdottir et al., 2017; Roschelle et al., 2016) and provide consistently tailored assignments to the needs of the learners (Dodson, 2014; Doorn et al., 2010; Schubert, 2013). Statistically significant results suggest that learners improve performance when online homework enables increased time on task, self-empowers learners, improves instruction based upon data, and adjusts homework based on feedback.

Table 2.2 *Influence of Online Homework on Performance: Statistical Significance*

Study	Participants	Method	Prevalence
Arasasingham, Martorell, and McIntire (2011)	3,806 students' data was used from six years in general chemistry courses taught by five instructors	This study was a mixed-methods study that assessed achievement based on participants' placement scores, final exam scores, and online homework scores. Participants were in the treatment group.	The study found that online homework provided an overall benefit to student learning. In addition, students replied positively to the implementation of the online homework.
Archer and Olson (2018)	Two thousand four hundred thirty-one online students participated in an entry-level economics course at a university. Participants were split into Group A – no homework support; Group B – Microsoft Excel templates; Group C – Online homework management system.	A quantitative study used descriptive statistics to compare the three groups' means for exam and homework scores.	The study shows that Group C had the highest mean for both homework scores at 78.92% and exam scores at 68.24%. So, the increase in student support shows statistical significance for gains in student learning.
Arora, Yun Jin, and Masson (2013)	One hundred ten participants were used to compare the study, with 51 from 2008 and 59 from 2009. Only data was gathered from the 2008 course, and the treatments were applied to 2009.	The study was quasi-experimental, with pre- and posttests used for comparison, midterm and final exams, and an attitude survey. In addition, *Mastering Engineering* delivered online homework.	The online system had a statically significant improvement of 0.7 ($\pm$ 0.2) compared to the pen and paper homework. Students who used traditional pen and paper averaged 70% on the final exam, while the online homework group averaged 79%.
Babaali and Gonzalez (2015)	Two hundred twenty-five students taking pre-calculus courses are split into eight sections. The control group had 122 (19.5% dropped) students, and the treatment group had 123 (20.5% dropped).	It was a quantitative quasi-experimental study that used the final exam to compare the treatment and control groups. The exam was broken down and analyzed by question. The treatment group used the Hawkes Learning System to facilitate the delivery of the online homework system.	The treatment group scored an average of 15 points higher on the exam than the control with a p-value of 0.00003, using a 95% *t*-test with unequal variance. The treatment group completed more homework assignments and received more feedback, possibly contributing to the increase in final exam average

Study	Participants	Method	Prevalence
Bowman (2014)	Eight hundred seventy general chemistry students from Fall 2009 participated.	Researchers used OWL (Online Web-Based Learning) assignments in this quantitative experiment to deliver homework. Homework analysis was done by topic, and students were classified into four categories per topic based on performances on the in-term and final exams.	The researchers suggested that online homework activity correlated to participants' final course grades, specifically time spent per question. The "r-value is about .090, with a 95% confidence interval of .019 to .160" (p. 55). A negative relationship between the number of attempts and the final course grade.
Dodson (2014)	This study used two sections of an upper-level high school environmental science class as the treatment and control groups.	This quantitative action research used an unknown online homework system to compare homework completion rate and grades, class participation, and final grades to pen and paper homework. Twelve assignments were used as a comparison.	The study results show that homework completion rates were nearly identical for both groups and the treatment had a 9.5% average increase in their final grade. The researcher suggested that online homework had significance, but it was not statistically shown.
Burch and Kuo (2010)	One hundred twenty-six participants in a College Algebra course at a state university in Pennsylvania participated. Sixty-five were in the control group; 61 students were in the treatment group. Twenty-one students from the control group and 31 from the treatment group were used in the final comparison.	The quantitative comparative study was conducted over two semesters, with the first semester having pencil and paper homework and the second semester getting the treatment using MyMathLab. MyMathLab is an online homework and tutoring service that allows three attempts per try and then switches problems. Exam scores from both semesters were used as a means of comparison.	The study results showed that the treatment group's mean scores were higher than the control group's. The p-values from the four exams were as follows: · Exam 1, $p = 0.000$ · Exam 2, $p = 0.006$ · Exam 3, $p = 0.014$ · Final Exam, $p = 0.0685$ In all but the final exam, there was sufficient evidence at 5% significance to conclude that the treatment group's mean scores were higher.

Study	Participants	Method	Prevalence
Doorn et al. (2010)	Six hundred eighty-seven students participated in this study in the fall semester of 2008.	This qualitative experiment used online homework systems (Aplia, WebVista, MyEconLab, and Cengage) to deliver content to participants. In addition, a survey was administered on attitude, perception, comparative views, prior online homework experience, use, textbook, course resources, and demographic information.	The study found that online homework delivery systems positively affect exams and understanding. In addition, strong, positive attitudes toward online homework were associated with higher Grade point averages (GPA) and coursework motivation.
Roschelle et al. (2016)	Forty-three schools participated, with 40 randomly assigned pairs for treatment and control groups. Two were given the treatment in the remaining three schools, and one became a control.	The study was a randomly assigned quantitative experiment that studied 7th-grade classrooms. The treatment groups used an online homework system named ASSISTments, and the control used textbook homework problems. In addition, the TerraNova standardized test was administered to assess the study's effectiveness.	Schools that used the online homework program ASSISTments had higher achievement scores (+8%) than the control and found that students with initially lower mathematics scores benefitted the most.
Jonsdottir, Bjornsdottir, and Stefansson (2017)	60% female and 40% males, and approximately 84 -130 students participated per year for four years	It was a repeated, randomized crossover experiment. Each year, classes were split into treatment and control groups. Again, exam and test scores were analyzed.	Significant positive differences in learning were found in 2011 and 2014 between the treatment and control groups ($p = 0.012$), with a difference in effect size being 0.634. In addition, a significant effect was found in 2014, comparing the treatment and control ($p = 0.009$) with an effect size of 0.416.

Study	Participants	Method	Prevalence
Schubert (2013)	95 9th grade Algebra students	Action research mixed methods study used three online tutorials through MathXL, pre- and posttest on Regents material, surveys, and interviews.	Pre- and posttest results showed that online tutorials were practical with a mean increase of 4.96 and ($t = 7.835$, $df = 94$, $p < .05$). No significant difference in attitude was shown between the pre- and posttest. Interviews revealed that students had a positive attitude towards the math tutorials.

Certain performance improvements occurred in specific subsets of learners in the larger population. For example, while the online homework intervention was not statistically significant overall, as detailed in Table 2.3, breakdown analysis showed that weaker mathematical students benefited with statistically significant improvements demonstrated in their exams (Brewer, 2009; Goehle & Wagaman, 2016). Indications for the improvements in comprehension have been suggested to be from the nontraditional approach (Brewer, 2009) or the built-in achievement system that rewards accuracy and completion (Goehle & Wagaman, 2016). While rewards systems and alternative strategies may positively affect specific population subsets, the intervention protocol was not substantial enough to affect all learners.

The Effect of Online Homework on Mathematical Proficiency

While online homework can influence mathematical performances, it is also essential to realize how each strand might be affected. This section will discuss how online homework has affected (a) strategic competence, (b) conceptual understanding, (c) procedural fluency, and (d) adaptive reasoning.

Table 2.3 *Influence of Online Homework on Performance: Subset Statistical Significance*

Study	Participants	Method	Prevalence
Brewer (2009)	Nine sections of college algebra at a large, western community college with four treatment sections (81 students) and five sections (122) for the control	The study used a quasi-experimental pretest/posttest factorial design. The achievement was measured with the final exam, self-efficacy was measured using the Mathematics Self-Efficacy Scale, and demographic information was collected via a survey.	No significant differences between the mean final exam scores or mean self-efficacy change were found. Data suggests that students with lower incoming skill levels benefited more from the online homework intervention.
Goehle and Wagaman (2016)	One hundred twenty students participated, with 60 in the control group and 60 in the treatment group.	It was a quantitative study using student surveys and results from exam performance.	The study showed no significant positive effect on achievement with $p = 0.0351$. However, it is suggested that some elements of web-based homework may have benefitted weaker mathematical students.

Strategic Competence

Building strategic competence correlates with individualized feedback in online environments. Differentiated feedback and support enabled self-directed learning, cultivating learners' strategic competence (Lai & Hwang, 2016; Morris, 2019). Personalized feedback and active learning online empowered learners to control their depth of understanding (Lai & Hwang, 2016; Morris, 2019) and improved in-class interactions and participation (Lai & Hwang, 2016). Specific feedback builds learners' strategic competence by catering to students' needs and increasing positive classroom behaviors.

Specific problem selection and mathematical conversations are cornerstones in developing strategic competence from online homework. Prior research has shown that homework items that can elicit students' recognition of their thinking through a reciprocal construction and evaluation process have increased strategic competence (Ozdemir &

Pape, 2012; Suh, Seshaiyer, Leong, Freeman, Corcoran, Meints, & Wills, 2012). Also, homework items that created classroom conversations, which increased the usage of mathematical terms and procedures, have developed students' strategic competence (Suh, 2007; Suh et al., 2012; Cartwright, 2018). Furthermore, homework items will improve strategic competence when students' problem-solving processes are grounded in their mathematical understandings (Suh, 2007; Ozdemir & Pape, 2012; Suh et al., 2012). Developing strategic competence in an online homework environment requires meaningful problem selection that allows students to understand their thought processes and initiates mathematical conversations in follow-up classes.

Conceptual Understanding

Customized feedback using technology correlates to higher levels of conceptual understanding. Online homework interventions that provided automatic feedback allowed classroom teachers to assess vital information on knowledge acquisition for future lessons (Cheng et al., 2004; Lin, Zhi-Feng Liu, & Yuan, 2008; Rasila et al., 2015; Yerushalmy et al., 2017). Kapur (2012) showed that students improved their conceptual understanding faster by learning from online homework feedback than through direct instruction. Similarly, positive correlations were found between the structured feedback given to learners and increased conceptual understanding (Archer & Olson, 2018; Cheng et al., 2004; Hegedus et al., 2015; James, 2016; Rasila et al., 2015). Halcrow and Dunnigan (2012) concluded that online homework could promote understanding and problem-solving skills by engaging more students. Customized feedback and data-based classroom decisions from online homework enabled more significant support from

instructors and opportunities for individual learners to increase their conceptual understanding.

Students' connection with an expression of mathematical understanding can be augmented with online homework. Online homework has improved conceptual understanding by connecting and transferring knowledge outside the classroom (Rasila, Malinen, & Tiitu, 2015; Riegel & Branker, 2019). More significant increases in conceptual understanding were shown when online homework allowed differences in individuals' expression of knowledge, accepting a variety of open-ended answers (Kanive, Nelson, Burns, & Ysseldyke, 2014; Rasila, Malinen, & Tiitu, 2015; Riegel & Branker, 2019) and data was used to improve classroom teaching pedagogies (Abramovich, 2015: Riegel & Branker, 2019). Problems that were appropriately leveled based on students' abilities or provided scaffolded feedback based upon answer submissions improved conceptual understanding (Kanive et al., 2015; Abramovich, 2015). Students who can connect knowledge learned in the classroom through unique expressions can augment their conceptual understanding.

Procedural Fluency

The level of task difficulty in online homework affects learners' procedural fluency in mathematics. Developments in procedural fluency were possible when online homework tasks were less challenging (Foster, 2013; Rasila et al., 2015). Improvements were shown by Rasila et al. (2015) with more manageable tasks that provided immediate corrective feedback and by Foster (2013) with tasks that required incrementally increased efforts to master content. Laswadi, Kusumah, Darwis, and Afgani (2016) showed that students who were given work online using manipulatable models of real-world objects

had higher success and enhanced their procedural fluency. Contrasting other research, Bautista (2013) concluded that while task selection is essential, developing procedural fluency was still primarily influenced by students' mathematical abilities and skills. Research indicates that successful practice and mastery of mathematical procedures require strategically designed problems that are appropriately leveled.

Improving students' procedural fluency with online homework coincides with their analysis and knowledge harmonization. Online homework questions that allow students to explore multiple solutions, using a variety of answer representations helped to develop procedural fluency (Laswadi, Darwis, & Afgani, 2016; VanDerHeyden & Codding, 2020) and improved their flexibility in simplifying complex tasks into manageable segments (VanDerHeyden & Codding, 2020). Strategically chosen virtual manipulatives in online homework allowed students to investigate a question from multiple perspectives, deepened their connections with the material, and linked procedures with mathematical understanding (van Es & Conroy, 2009; Laswadi, Darwis, & Afgani, 2016). Feedback should aid students' general knowledge of the current task to naturally form connections (Laswadi, Darwis, & Afgani, 2016; VanDerHeyden & Codding, 2020). Online homework problems that allow for the manipulations and explorations of situational possibilities through manipulatives will increase students' procedural fluency by giving them a space to make connections.

Adaptive Reasoning

The design of feedback changes learners' adaptive reasoning skills in mathematics. Multiple opportunities and constructive feedback have enabled learners to guide their learning and improve adaptive reasoning (Haddad & Kalaani, 2014;

Linnenbrink, 2005). Learners' ability to negotiate various strategies to find solutions to mathematical problems was investigated by Haddad and Kalaani (2014) with ongoing formative feedback and Linnenbrink (2005) with opportunities to recognize learning achievement. Ichinose and Martinez-Cruz (2018) found that environments that encourage learners to take different approaches to solve problems and connect unrelated topics can improve mathematical perseverance and adaptive reasoning. Cunningham, Dias, and Angulo (2011) showed that increasing student interest in active problem-solving helped improve mathematics performance, including adaptive reasoning.

Online homework can provide more opportunities for developing learners' adaptive reasoning skills, which requires a back and forth between attempting and receiving feedback on mathematical problems.

Exploration and answer rationalization are keys to students' adaptive reasoning growth. The development of adaptive reasoning, through the use of online homework, utilized questioning that required students to make connections using prior knowledge and mathematical ideas (Gonzalez & DeJarnette, 2013; Kastberg & Frye, 2013) and encouraged the exploration of different avenues (Ally & Christiansen, 2013; Gonzalez & DeJarnette, 2013). Questions should be created to promote examination using both intuitive and deductive reasoning (Ally & Christiansen, 2013; Kastberg & Frye, 2013), enabling students to challenge or affirm possible solutions to the problem (Ally & Christiansen, 2013; Gonzalez & DeJarnette, 2013). Therefore, questions aiming to grow students' adaptive reasoning should guide different exploratory avenues to steer thought trajectories rather than provide immediate solutions.

Effective Design of Online Homework

The significance of the effect of online homework implementation is contingent on design aspects that promote mathematical proficiency. The pertinent features that will be discussed are (a) varied feedback, (b) multiple submission opportunities, (c) self-pacing, and (d) performance.

Varied Feedback

Variations in the type of feedback given by online homework produced different effects on student learning and comprehension. For example, basic comprehension was evaluated with online homework programs that provided the learner with a response on correctness (Anderson, 2019; Chamala et al., 2006) or that used a numerically rated score to compare homework answers to a predetermined standard (Anderson, 2019; Bokhove & Drijvers, 2012; Nicol & MacFarlane-Dick, 2006). More significant results came when online homework included process-based feedback that assisted learners by providing exemplary work or step-based analysis. This type of feedback enhanced comprehension (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006) and empowered students to manage their level of understanding through self-regulation (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006; Yerushalmy et al., 2017). While task feedback is essential to gauge general understanding, process-based feedback provides a much richer online environment that can further comprehension and self-empowerment.

Multiple Submission Opportunities

Careful consideration must be given to the number of online homework submission attempts and how it will be used to gauge mathematical proficiency. Data

from online homework suggested that the most robust performance and conceptual understanding outcomes only correlated with the first attempt when multiple attempts were allowed (Kortemeyer, 2015; Yourstone, Kraye, & Albaum, 2010). It has been shown that as the number of attempts increased, the relation to learning and performance decreased (Bowman, 2014; Gönülateş & Kortemeyer, 2017; Kortemeyer, 2015; Yourstone et al., 2010). Furthermore, in multiple-attempt scenarios, data suggested that the maximum number of attempts be limited to five before random guessing and learning regression increased significantly (Kortemeyer, 2015). While more attempts give students opportunities to learn from their mistakes, data from the first attempt provides the most insight into how students improve their mathematical proficiency.

Self-Pacing

Online homework can be designed for the learner to learn autonomously. Exploration and learning increased in digital environments, allowing learners to self-regulate pace (Kong & Song, 2013; Stefan & Popsecu, 2014; Tabor & Minch, 2013). The creation and interaction with the online content also cultivated participants' knowledge acquisition (Stefan & Popsecu, 2014; W. Tabor & P. Minch, 2013). Further research showed that self-pacing in online homework allowed learners to become primarily responsible for the self-regulation of their understandings and analyses (Alsulami, 2016; Glancy & Isenberg, 2013; Keengwe et al., 2014; Miller-First & Ballard, 2017), while also building self-awareness through metacognition of their learning (Arora et al., 2013; Babaali & Gonzalez, 2015; McLoughlin, Lee, & Chan, 2006; Seo & Engelhard, 2014). Learning online can be cultivated by building individual awareness of knowledge acquisition and comprehension in a self-analytic environment.

Performance

Increases in performance correlated to crucial features included in the design of online homework. The mathematic performance was improved with online homework when learners engaged with the assignment, received internet-based support (Ali Alshehri, 2017; Gönülateş & Kortemeyer, 2017; Mathai & Olsen, 2013), and participated actively with process-based feedback (Ali Alshehri, 2017; Richards-Babb, Drelick, Henry, & Robertson-Honecker, 2011). Performance increases were also shown when data-driven decisions were made using learners' time on task and completion rates from the online homework to alter classroom teaching practices (Arora et al., 2013; Babaali & Gonzalez, 2015; Bowman, 2014; Kong & Song, 2013; Roschelle et al., 2016; Tabor & Minch, 2013; Yerushalmy et al., 2017) through restructuring and refining future homework assignments (Archer & Olson, 2018). A multi-faceted approach to improving performance should ensure that online homework includes features that support and engage learners while allowing for meaningful data collection for instructors' future decision-making.

Online Homework's Influence on Learners' Attitude and Perception of Mathematics

The introduction of online homework can impact learners' attitudes and perceptions. The interaction between attitude and perception with learners' mathematical proficiency will be discussed in the next section. The following sections will guide the discussion: (a) attitude and (b) perception.

Attitude

Online homework can be a persuasive element to learners' attitudes. Positive correlations between attitude and understanding were found as a result of learners'

gratification from being able to complete assignments more independently (Ali Alshehri, 2017; Wooten & Dillard-Eggers, 2013; Xu & Wu, 2013), increased understanding due to feedback (Doorn et al., 2010; Hodge, Richardson, & York, 2009; Leong & Alexander, 2013), and increased motivation to complete homework assignments (Doorn et al., 2010; Hagger, Sultan, Hardcastle, & Chatzisarantis, 2015; Lin et al., 2008). In contrast, little correlation was found between high-achieving students' attitudes and online homework interventions due to their preexisting high intrinsic motivation levels (Leong & Alexander, 2013; Taylor, 2019). In two action research studies, learners' attitudes had no statistical significance when comparing traditional to online homework, but instant feedback on homework submission accuracy was valuable (Schubert, 2013; Taylor, 2019). Online homework can positively influence learner satisfaction and comprehension through feedback and enthusiasm, provided intrinsic motivation levels are not already high.

Perception

Online homework can increase learners' perception of a mathematics course. Some learners felt online homework was a motivator that increased completion rates and time on task (Hagger et al., 2015; Hodge et al., 2009; Kolmos, 2010; Richards-Babb et al., 2011), while others stated it was a reason to remain enrolled in a course (Burch & Kuo, 2010). Lower- and middle-achieving students found that online homework increased their overall satisfaction (Leong & Alexander, 2013). Demirci (2007) suggested that online homework influenced learners' attitudes towards technology usage, while Hoskins (2012) found that it boosted quality interactions and increased engagement. Learners' motivation, interaction, enrollment, engagement, time on task, and satisfaction

can all be influenced by online homework to improve the quality of the course experience.

IXL

The delivery mechanism of an online homework innovation will need to contain features that enhance learning and feedback. This section will discuss the attributes and benefits of IXL, highlighting the functions that will make it excellent for online homework.

Description

The usefulness of an online homework system depends on its attributes. IXL is purchasable with practice problems containing free-response, multiple-choice, tables, graphs, process-based feedback, and example problems (Kolmos, 2010). Few resources are as comprehensive and aligned with Illustrative Mathematics as IXL for instructors to personalize homework content that fits the needs of the learners in a course.

Implications

While rigorous, peer-reviewed research has not been studied using IXL, some doctoral dissertations and masters' theses have investigated its effectiveness. Fourth-grade student performance on the California State Standardized Test showed statistical significance when IXL was used to learn multiplication facts (Donawerth, 2013). Improvements in seventh-graders mathematical proficiency growth were shown using IXL, with greater significance in the female population (Arms, 2019). Attitudes towards using IXL were positive since learners felt more in control of their successes and adapted to their learning level (Sullivan, 2020). Improvements in both attitude and performance are vital indicators that IXL will be an effective means to deliver online homework

content and feedback. The data gathered alters course instruction and future homework designs.

Chapter Summary

Impacting learners' mathematical proficiency is explicitly linked with five intertwined strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (Andrews, 2013; Bokhove & Drijvers, 2010; Groth, 2017; Rasila et al., 2015; Suh et al., 2012). While production disposition is not directly addressed as a research question, focusing on learners' attitudes and perceptions of the online homework will provide insight into how innovation influenced their work ethic. In addition, researchers have shown that increasing each strand is possible with strategic opportunities that use proven methods.

Homework has traditionally been completed at home with pen and paper. However, the internet has now enabled homework to be put online in a responsive, interactive environment (Gönülateş & Kortemeyer, 2017; Leong & Alexander, 2013; Lunsford & Pendergrass, 2016). Therefore, this study will investigate how online homework, designed with constructivist theory principles, can promote the communications and collaborations needed to build upon existing knowledge (Alsulami, 2016; Keengwe et al., 2014; Koohang et al., 2009; Miller-First & Ballard, 2017; Richardson, 2003; Vidmar, 2011) and promote learning (Chickering & Gamson, 1987; Einfield, 2014; Yerushalmy, Nagari-Haddif, & Olsher, 2017).

Numerous studies that used online homework found the positive statistical significance of learners' mathematical performance. Given the demographics of the population that will be studied, Brewer (2009) and Goehle and Wagman (2016)

demonstrated that weaker mathematical students could have their mathematical proficiency influenced the most through an online homework innovation. Improving mathematical proficiency depends primarily on quality feedback to change learners' mathematical comprehension.

The design of online homework is vital in order to elicit increases in learners' mathematical proficiency. Process-based feedback had the most influence on student learning by enhancing comprehension (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006) and improving self-regulation (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006; Yerushalmy et al., 2017). Multiple homework attempts did allow for more chances for success, but only the first attempt accurately reflected performance outcomes (Kortemeyer, 2015; Yourstone, Kraye, & Albaum, 2010). Learners will use process-based feedback based on their responses to self-reflect on their understanding and make corrections on subsequent answers.

Learners' attitudes and understandings were increased when online homework was enjoyable (Ali Alshehri, 2017; Wooten & Dillard-Eggers, 2013; Xu & Wu, 2013), provided meaningful feedback (Doorn et al., 2010; Hodge et al., 2009; Leong & Alexander, 2013), and was motivating (Doorn et al., 2010; Hagger et al., 2015; Lin et al., 2008). In addition, positive perceptions of online homework helped augment learners' completion rates and time on task (Hagger et al., 2015; Hodge et al., 2009; Kolmos, 2010; Richards-Babb et al., 2011), and course satisfaction (Burch & Kuo, 2010).

The key takeaway from this literature review is that online homework has the potential to increase mathematical proficiency, but without the crucial design features

mentioned, it may only be as effective as traditional homework (Cole & Todd, 2003; Demirci, 2007; Hauk, Powers, & Segalla, 2015; Mathai & Olsen, 2013; Stickles, 2017). Therefore, implementing IXL must include processes that facilitate the most significant growth and performance results to maximize learner outcomes.

CHAPTER 3

METHODS

This action research aimed to assess the role of online homework using IXL on mathematical proficiency on 8th Grade Mathematics students at Cedar Hill Middle School in South Carolina. It utilized action research with a convergent parallel mixed-methods design to incorporate quantitative and qualitative research elements. This chapter discusses the research design, settings and participants, action/innovation, data collection methods/sources, data analysis, rigor and trustworthiness, and a plan for sharing and communicating findings.

The following research questions guided the design of this study:

Research Question 1: How does IXL online homework affect the mathematical proficiency of 8th Grade Mathematics students at Cedar Hill Middle School?

> **Sub Question 1**: How does IXL online homework affect the strategic competence of 8th Grade Mathematics students at Cedar Hill Middle School?
>
> **Sub Question 2**: How does IXL online homework affect the conceptual understanding of 8th Grade Mathematics students at Cedar Hill Middle School?
>
> **Sub Question 3**: How does IXL online homework affect the procedural fluency of 8th Grade Mathematics students at Cedar Hill Middle School?

Sub Question 4: How does IXL online homework affect the adaptive reasoning of 8th Grade Mathematics students at Cedar Hill Middle School?

Research Question 2: What are 8th Grade Mathematics students' perceptions regarding the impact of online homework using IXL on their mathematical proficiency?

Research Design

A classroom pedagogical modification must be grounded in theory, academics, and practice interwoven with reflective processes (Maksimović, Osmanović, & Đekić, 2018). The research environment and population designated for implementation were unique (Mertler, 2017). A change in classroom procedures, such as implementing online homework, alters the delivery and focus on how students typically complete assignments. To study how its implementation affects students' outcomes, there was no way for me as a classroom teacher to retain a role as a non-participatory objective researcher. Considering the small sphere of influence that a classroom teacher commands (Wisniewska, 2011), action research is best suited to improve educational practices by systematically addressing localized issues to improve outcomes (Maksimović et al., 2018).

Action research is a methodical investigation of school functions, teacher practices, and student knowledge acquisition in which a school’s teachers, administrators, and counselors have a vested interest (Mertler, 2017; Mills, 2011). Unlike a qualitative or quantitative researcher, who seeks to answer questions through generalizations as an objective observer (Mertler, 2017; Schmuck, 1997), an action researcher has the desired

outcome for a localized problem while being an active participant (Bradbury-Huang, 2010). Through this process, action research creates a situational narrative by understanding the environment, the researcher's positionality, and the participants' role (Heikkinen, Huttunen, & Syrjälä, 2007).

Many traits and advantages of action research have made it a valuable process for teachers to advance their professional practice (Mertler, 2017). According to Bradbury-Huang (2010), excellent action research has to include four components: a partnership between researcher and participants, roots in local pragmatism, stakeholders that are integrated and informed, and the construction of a foundation for future change. Heikkinen et al. (2007) further detailed that action researchers should establish the root causes and intentions of participants' actions, consider their own worldview in the reflective narratives, feature both discordant and amenable interpretations of the treatment, analyze whether there were positive social transformations, and be mindful to new and different methods of rationalization. The main benefits of action research reside in its smaller size, cyclical nature, collection of information, and reflective practices, allowing the researcher to alter future iterations to meet situational demands (Mertler, 2017). Action research allowed me, as the teacher-researcher, to make a meaningful change while considering my positionality and my students' voices.

A convergent parallel mixed method design was utilized to answer the two overarching research questions. The study used quantitative and qualitative data findings to complement and compare sources (Edmonds & Kennedy, 2017), thus enhancing the interpretation of the innovation's effect (Edmonds & Kennedy, 2017). A mixed-method researcher's objective is to elaborate and fortify the study's ability to answer the research

questions wholly and conclusively (Schoonenboom & Johnson, 2017). An in-depth understanding of the process from many perspectives enabled me to understand beyond the quantitative data to reveal any biases or perspectives, further explaining the how and why of this research setting (Creswell & Creswell, 2018; Collins, Onwuegbuzie, & Sutton, 2006). For example, the student perspectives enabled me to understand potential reasons why they thought the online homework was ineffective or exceptional beyond the normative results (Schoonenboom & Johnson, 2017).

Settings

The action research took place at Cedar Hill Middle School (CHMS), a publicly funded Title I school that teaches students from grades sixth through eighth. The homework was delivered via IXL through the internet. All students had access to the internet via a home computer, tablet, cell phone, or mobile computing device through Wi-Fi or an internet service provider. Access was ensured by Charleston County School District (CCSD) due to the Covid-19 pandemic, where free internet access was given to all students through Wi-Fi buses, internet service providers, and other means.

The 2019-2020 school year was the pilot year that Cedar Hill Middle School (CHMS) became a one-to-one school, where every student was assigned either a Chromebook or Dell computer. Initially, students were not allowed to remove school-issued computers from campus, but that changed once the pandemic lockdown began during the school year. Many students were doing assignments at home on their computers for the first time since they now had virtual access to coursework. The district adopted Canvas, a Learning Management System (LMS), to build modules, assign work,

and submit assignments. It was an adjustment for the students, teachers, administration, and district to be virtually integrated and dependent.

In prior years, homework was rarely assigned since students could not take home their workbooks or laptops. However, a new principal and many new faculty members tried changing that narrative by setting higher expectations for the students, one being homework's regular occurrence. The idea for online homework was to provide students a medium to complete it while receiving process-based assistance outside the classroom. Many of these students were very intuitive and intelligent but often succumbed to obstacles rather quickly. Online homework innovation tried to offset these initial tendencies to give up and instead build some self-efficacy by providing more avenues of support in an online environment.

Due to the Covid-19 pandemic, two of my classes were taught in person and the other two synchronously through Zoom. The number of in-person and temporary remote classes changed as the Covid-19 infection positivity rates fluctuated up or down. Class periods four and seven were my in-person classes with sizes 35 and 18, respectively. The class of 35 students was taught in the Gymnasium, with the students sitting at lab tables approximately six feet apart. There was one whiteboard, a projector and screen, Wi-Fi access, a microphone, and a speaker system, and each student had a laptop. The physical distance between the first and last rows was immense; therefore, the microphone was necessary for the students in the back to hear correctly and save the teachers' voices. The class with 18 students was in a standard CHMS classroom with a SmartBoard and document camera. Also, each student had a school-issued laptop. The students' desks

were arranged in groups of three throughout the room, with plexiglass barriers dividing the students.

The larger class had a co-teacher due to the number of students with accommodation plans and IEPs. While students with IEPs and accommodation plans were excluded from the study, the co-teacher, Ms. Silverstein, played a significant role in helping deliver mathematics content and support students in the classroom. Ms. Silverstein has a Special Education degree and was primarily responsible for ensuring that all students' IEP and accommodation plans were followed.

Each section met daily for one hour, and the students' ranged in age from 13 to 15 years old, with all being eighth-graders. Average class sizes for these sections ranged from 13-35 students and the demographics varied ethnically, with the majority being African American. In the 2019-2020 school year, the classes were approximately 60% African American, 25% Latino/ESL and 10% Caucasian, and 5% other (Williams, C., 2019).

Participants

Participants were selected through purposeful sampling since I was the primary teacher and researcher of most 8th Grade Mathematics sections. The persuasive argument for selecting these students was their low state-mandated testing scores. After analyzing state testing results, these issues were identified during the 2019-2020 school year. As per school policy, this course was assigned to 8th-grade students who did not qualify for Honors Algebra I. The students in this course mirrored the school demographics and were predominantly African American in the 2019-2020 school year, with the ratio of African Americans to other students being approximately 3:1 (Williams, 2019).

Cedar Hill Middle School also had a significant and growing English as a Second Language (ESL) population. ESL students often needed modifications to assignments and assessments in 8th Grade Mathematics to help with comprehension, note-taking, and assessments. Strategies such as simplifying text, using Google Translate, reading directions aloud, and partnering with the English as a Second Language (ESL) teacher were methods to assist those students. Of the 95 students enrolled in 2019, only two had Individualized Education Plans (IEPs; Williams, 2019). Alterations to seating, testing time, calculator use, and class notes were the most common in IEPs.

Students in my periods four and seven classes were invited to participate in the study. Of the 53 students, 34 were African American, six were Caucasian, 12 were Latino American, and one was a native Portuguese speaker. Students' Measure of Academic Progress (MAP) scores typically were below grade level. Unfortunately, due to the Covid-19 pandemic, MAP data was not gathered during the spring of 2020, when the students would typically have been tested. In addition, learning during that time was limited by internet access, disorganization, and unpreparedness. As a result, there was a loss of learning for many students.

One class was significantly larger than the other. However, the class with 35 students has a co-teacher; therefore, the student-teacher ratio was approximately 18:1. Hopefully, this should have mitigated any possible advantage that may have been gained due to the disparities in class sizes.

Role of the Researcher

The researcher and teachers' roles were navigated with skill and self-awareness since I was both the study's disseminator and an authority figure in the classrooms.

Teachers have an established power differential, which was taken under consideration when publishing the results. Furthermore, collaboration and cooperation were essential to understanding how online homework affected the participants' achievement. Reflection and consideration were given to the possibilities of obligatory participation and positive opinions based upon the need to please the teacher. Great care was taken to analyze my own potential biases based on the relationships built with the participants, which might have hindered my judgment.

Action/Innovation

My action research focused on using online homework, created and delivered via IXL, to increase 8th Grade Mathematics students' mathematical proficiency and assess their perception of the innovation. Mathematics homework is primarily used as practice for students (Roschelle et al., 2016). Online homework will be used for this exact purpose and provide valuable feedback to students in an appropriate and accommodating manner (Azevedo & Bernard, 1995; Butler & Winne, 1995; Shute, 2008; Roschelle et al., 2016). IXL was selected because it contains features that research has shown to elicit positive correlations with mathematical proficiency.

A few features of IXL online homework are vital for increasing learners' mathematical proficiency. See Table 3.1 to see how the feature of IXL is connected to research-based practices. Of utmost importance is that IXL offers process-based feedback when questions are answered incorrectly. Process-based feedback has been shown to have a positive influence on student learning by enhancing comprehension (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006) and improving self-regulation (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol &

MacFarlane-Dick, 2006; Yerushalmy et al., 2017). Hopefully, learners will use process-based feedback to enhance their understanding and regulate their learning.

Table 3.1 *IXL Features and Connected Theories*

IXL Feature	Connected Theory
Processed-based feedback	Enhanced comprehension (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006) and improved self-regulation (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006; Yerushalmy et al., 2017)
Positive reinforcement	Increased learners' attitudes and understandings (Ali Alshehri, 2017; Wooten & Dillard-Eggers, 2013; Xu & Wu, 2013), motivated (Doorn et al., 2010; Hagger et al., 2015; Lin et al., 2008), improved completion rates and time on task (Hagger et al., 2015; Hodge et al., 2009; Kolmos, 2010; Richards-Babb et al., 2011), and enhanced course satisfaction (Burch & Kuo, 2010)
Modeled work	Boosted comprehension (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006) and self-regulation (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006; Yerushalmy et al., 2017)
Homework Data	Assessed learning and used to increase understanding (Lunsford & Pendergrass, 2016) and also used to alter future instruction (Jonsdottir et al., 2017; Roschelle et al., 2016)

Another feature of the IXL online homework is the positive reinforcement displayed after answering questions. Prior research has shown that enjoyable online homework increases learners' attitudes and understandings (Ali Alshehri, 2017; Wooten & Dillard-Eggers, 2013; Xu & Wu, 2013) and also motivates the students (Doorn et al., 2010; Hagger et al., 2015; Lin et al., 2008). Furthermore, students that have perceived online homework positively have been shown to increase completion rates and time on task (Hagger et al., 2015; Hodge et al., 2009; Kolmos, 2010; Richards-Babb et al., 2011) and experience greater course satisfaction (Burch & Kuo, 2010).

A third important feature of IXL online homework is that it displays modeled mathematics work. Prior studies have shown enhanced comprehension when online homework contains modeled work (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006). Students also experienced greater self-regulation of their understandings when modeled work was present (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006; Yerushalmy et al., 2017).

IXL was also selected because Cedar Hill students typically scored below grade level on state testing. Students with low achievement scores typically respond very well to online homework innovations (Roschelle, 2016). Daily online homework assignments can assess students' learning of the lesson's objective while increasing understanding of the material and classroom discussions (Lunsford & Pendergrass, 2016). Additionally, data from online homework can be used to alter instruction in subsequent lessons based on learner needs (Jonsdottir et al., 2017; Roschelle et al., 2016). A similar effect was hopefully replicated and observed during the treatment. The following sections will guide the Action/Innovation section: (a) online homework design, (b) classification of homework questions into four strands, and (c) online homework implementation.

Online Homework Design

The IXL online homework assignments supported the Illustrative Mathematics curriculum by assessing the standards covered in the daily lesson. Each lesson had one or two online homework assignments focused on student mastery. Students were required to achieve a SmartScore above 80 to achieve full marks for the homework. From prior experience teaching this course, students' time to complete homework varied widely.

Longer variations in completion time for online homework were expected since mastery would be the focus.

The online homework innovation consisted of ten lessons and 17 IXL assignments. In addition, an introductory unit on functions was taught during the research period. The lessons covered various topics on functions, including inputs, outputs, equations of functions, tables, graphs, linear equations, and piecewise functions (Illustrative Mathematics, 2018). Table 3.2 contains a more in-depth look into the lessons, the number of questions, and the types of responses required.

Table 3.2 *Online Homework Lesson Topic, Number of Assignments, and Types of Answers*

Lesson	Topic	Number of Assignments	Types of Answers
1	Inputs and Outputs	2	Short answer, table fill-in
2	Introductions to Functions	1	Multiple-choice
3	Equations for Functions	2	Short answer, table fill-in
4	Tables, Equations, and Graphs of Functions	2	Short answer and multiple choice
5	More Graphs of Functions	2	Multiple-choice, short answers, and graphs
6	Even More Graphs of Functions	2	Short answer, table fill-in, and graphs
7	Connecting Representations of Functions	1	Multiple-choice
8	Linear Functions	1	Multiple-choice
9	Linear Models	2	Multiple-choice
10	Piecewise Linear Functions	1	Short answer

Types of question styles and answer submissions were diverse according to the information needed. Homework questions required students to select from pre-determined answers, fill missing data into tables, plot points on graphs, and give short numerical answers. Visual sketches and graphs of mathematical concepts and procedures in algebra and geometry were easily manipulated with the IXL software.

Homework was incentivized by being assigned a grade, but feedback on correctness and processes was instantaneous for the participants, unlike textbook work. For students to receive a maximum score on the homework assignment, they must have achieved a SmartScore above 80; every 8 points below lowered the grade by 10%. Mathematical proficiency was improved when process-based feedback on errors was given, and the homework performance data can alter instruction (Sheldon, Epstein, & Galindo, 2010). Immediate correction with process-based instruction helped improve mathematical proficiency, especially for students who were lower achieving in mathematics (Arasasingham et al., 2011; Roschelle et al., 2016). If students answer homework questions incorrectly, IXL displays a model worked example to show students how to continue completing the problem. Model work demonstrated to students in online homework feedback has been proven to enhance comprehension (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006) and improve self-regulation of their learning (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006; Yerushalmy et al., 2017). This self-analysis process should improve students' meta-awareness of their mathematical understanding (Alsulami, 2016; Glancy & Isenberg, 2013; Keengwe et al., 2014; Miller-First & Ballard,

2017). Subsequently, online homework was a formative assessment, allowing students to complete the assignment until mastery was achieved.

A standard protocol for homework weight from the CHMS mathematics department was 10%, maintained throughout the study for course consistency. Homework assignments were accepted after the assignment's initial due date to emphasize learners' mastery and the importance of comprehension over completion.

Classification of Homework Questions into the Four Strands

IXL assignments and alignment with Illustrative Mathematics were predetermined by the IXL Skill Alignment for Illustrative Mathematics – 8th Grade. See Appendix BB for the curriculum alignment and recommended assignments. Therefore, the homework assignments could not be altered but instead categorized by strands according to the type of questioning. In order to ensure the validity of the categorizations of the questions, a fellow mathematics colleague at Cedar Hill was asked to categorize each assignment as well (Mertler, 2017). For my fellow mathematics colleague to classify a given question, a mutual agreement on the definition for each of the four mathematics strands (i.e., conceptual understanding) was essential for consistency. Each assignment was analyzed and categorized as "conceptual understanding," "adaptive reasoning," "procedural fluency," or "strategic competence" in accordance with the line of questioning. An assignment fell into multiple categories if it was determined to assess more than one strand. After comparing my categorizations with one of my colleagues, we formed a consensus to establish reliability (Mertler, 2017). Any disagreements were discussed until an agreement was found. A breakdown of the classification of each online homework was detailed in Table 3.3. A similar process was also used for the pre- and posttest.

Conceptual Understanding

Assignments classified as conceptual understanding were problems that utilized the comprehension of mathematical concepts, operations, and relations (Andrews, 2013; Bokhove & Drijvers, 2010; Groth, 2017; Hudson et al., 2010; Kulik et al., 1990; Rasila et al., 2015). Due to the broad interpretations that likely occurred, it was anticipated that many questions were applicable in this category.

Procedural Fluency

Assignments categorized as procedural fluency needed to require that a participant use mathematical procedures, such as the simplification of a formula (Andrews, 2013; Bokhove & Drijvers, 2010; Groth, 2017; Hudson et al., 2010; Rasila et al., 2015). Assignments that required actionable steps to find a solution fell into this category. Students should have demonstrated how to use a process or formula from the lesson's objective in an unfamiliar situation (Hernandez et al., 2020).

Adaptive Reasoning

Assignments classified into the adaptive reasoning category asked the learner to describe their approach. It required that the learner showcase mathematical finesse through logic, contemplation, clarification, and rationale (Andrews, 2013; Bokhove & Drijvers, 2010; Groth, 2017; Hudson et al., 2010; Rasila et al., 2015). While these were attributes that a student used to solve many problems, an adaptive reasoning assignment required an encounter with something unfamiliar (Muin et al., 2018). In addition, the path to solving the problem was not straightforward and was approached and solved from many directions (Ostler, 2011).

Strategic Competence

The last classification category was strategic competence, a type of mathematical problem seldom used (Andrews, 2013). Therefore, close attention was paid to the number of assignments aligned with the category. Strategic competence was considered the ability to construct, represent, and answer a mathematical problem (Andrews, 2013; Groth, 2017; Rasila et al., 2015; Suh et al., 2012). An assignment in the strategic competence category needed the student to demonstrate mastery of a topic (Nichols, 1984; Hernández, Perdomo-Díaz, & Camacho-Machín, 2020) and was often very challenging and elaborate (Brisson et al., 2017; Morris, 2019).

Table 3.3 *Breakdown and Classification of Online Homework Items into Mathematics Strands*

Lessons	Online IXL Homework Strand Addressed			
	Conceptual Understanding	Procedural Fluency	Adaptive Reasoning	Strategic Competence
Lesson 1 - What's the Rule	1	1		
Lesson 2 - Wait Time	1	1	1	1
Lesson 3 - The Value of Some Quarters	1	1		1
Lesson 4 - Subway Fare Card	1	1	1	1
Lesson 5 - Diego's 10K Race	1	1	1	
Lesson 6 - Walking Home from School	1		1	1
Lesson 7 - Comparing Different Areas	1	1	1	1

Lessons	Online IXL Homework Strand Addressed			
	Conceptual Understanding	Procedural Fluency	Adaptive Reasoning	Strategic Competence
Lesson 8 - Beginning to See Daylight	1	1	1	1
Lesson 9 - Board Game Sales	1	1	1	1
Lesson 10 - Lin's Phone Charge	1	1		
Totals	11	8	8	10

Note: A number in the column means that the question was determined to assess that strand, while the number represents the number of points allocated for grading. The total represents the total amount of points possible for each strand on the pre- and posttest.

Online Homework Implementation

Each homework assignment was linked to the lesson module on Canvas, the Learning Management System (LMS) used by CCSD. Every lesson taught had a multi-step module that took the students through the various parts of the task. Each embedded link at the end of the module led to an IXL homework assignment that assessed one or more of the objectives. Homework data was analyzed and used to alter future lessons and teaching. The proper use of online homework data to transform education has been shown to positively impact student performance (Arora et al., 2013; Babaali & Gonzalez, 2015; Bowman, 2014; Kong & Song, 2013; Roschelle et al., 2016; Tabor & Minch, 2013; Yerushalmy et al., 2017).

After the students' homework was assigned and completed, the data was extracted from IXL into an Excel document. The Excel document was used to record individual and overall mathematical proficiencies analyses. A macro was then used to extract the

strand data from the mathematical proficiency data and recorded. Each participant's mathematical proficiency on the homework was based on students' SmartScores. The macro then extrapolated the proficiency data and classified it into the mathematical strands of conceptual understanding, adaptive reasoning, procedural fluency, and strategic competence. Special attention was paid to how well the students scored in the strategic competence and adaptive reasoning categories since these strands were typically addressed the least in mathematics classrooms (Andrews, 2013).

Students were allowed to attempt online homework until their SmartScore was above 80. The IXL SmartScore increased with every correct answer and decreased with every incorrect answer, thus encouraging students to use process-based feedback and worked examples to improve their scores. In addition, participants were highly encouraged to take their time on each question since learning and performance typically decreased as attempts increased (Bowman, 2014; Gönülateş & Kortemeyer, 2017; Kortemeyer, 2015; Yourstone et al., 2010).

Instructional Objectives

The homework's instructional objectives were aligned with the instructional objectives for the test questions, and the rationale was the same. A breakdown of the lesson number, lesson objectives, and online homework was provided in Table 3.3 (Illustrative Mathematics, 2018). Each online homework focused on one objective from each lesson, even if the lesson covered multiple objectives or had multiple assignments. Table 3.4 shows how each lesson addressed an objective and how that lesson aligned with the online homework. All instructional objectives taught from the unit were evaluated during the online homework except for 8.F.A. Although this objective was not

directly assessed, it was assessed indirectly through the homework problems that checked for understanding using sub-objectives.

Table 3.4 *Alignment between Research Questions and Data Collection Methods*

Research Questions	Data Collection Methods
RQ1: How does IXL online homework affect the mathematical proficiency of 8th Grade Mathematics students at Cedar Hill Middle School?	Pre- and Posttest Data Online Homework Data
RQ2: What were Eighth Grade Mathematics students' perceptions regarding the impact of online homework using IXL on their mathematical proficiency?	Student Interviews Student Surveys

Note: RQ = Research Question

Question Validation

All Illustrative Mathematics homework was created and aligned with the standards for each lesson. Ten lessons covered the seven standards taught during the online homework innovations. Six of the seven standards had at least one online homework assignment to address that question. Similar to the pre- and posttest, standard 8.F.A was not assessed during the online homework innovation. The online homework questions aligned well with the pre- and posttest since both emphasized the number of questions per standard. For online homework to be a reliable source for students to study and learn from, the substance and structure of the problems should mirror that of the assessments (Green & Johnson, 2010).

Data Collection Methods

Qualitative and quantitative data were collected in this convergent parallel mixed-method approach. This research method provided in-depth detail and reinforced the study's conclusions by explaining the anomalous phenomenon (Schoonenboom & Johnson, 2017; Mertler, 2017). The research questions and data collected were

summarized in Table 3.4. Quantitative data was gathered from the pre- and posttest and online homework. Qualitative data were collected from student interviews. Finally, qualitative and quantitative data were collected from student surveys. The following sections highlighted the essential parts of the data collection plan: (a) pre- and posttest, (b) online homework, (c) student interviews, and (d) student surveys.

Pre- and Posttest

A pre- and posttest's primary emphasis was to evaluate the innovation's effect (Dimitrov & Rumrill, 2003). This method was excellent in assessing change over time (Creswell & Creswell, 2018) and determining the degree of change (Mertler, 2017). The following sections guided the pre- and posttest section: (a) description of pre- and posttest and (b) description of the implementation of pre- and posttest.

Description of Pre- and Posttest

Participants' incoming skill level of mathematical proficiency was established through a pretest of seven questions, detailed in Appendix B. Each question assessed one of the instructional objectives using various question-and-answer styles. The assessment utilized multiple-choice items, graphs, tables, functions, and open-ended items to determine participants' knowledge.

Instructional Objectives. The Illustrative Mathematics textbook was aligned with both the Common Core State Standards (CCSS) and the South Carolina Career and College Readiness Standards (SCCCR) (Illustrative Mathematics, 2017). There were seven standards covered in this unit on functions: 8.F.A, 8.F.A.1, 8.F.A.2, 8.F.A.3, 8.F.B, 8.F.B.4, and 8.F.B. Each standard was listed and defined in Table 3.4. Objectives focused

on students mastering skills related to functions and relationships between two quantities (Illustrative Mathematics, 2017).

Test validation. All Illustrative Mathematics assessments were created and developed following each unit's South Carolina State Standards. Seven standards were covered in the ten lessons during the online homework innovation. The pre- and posttest assessed six of the seven standards, as detailed in Table 3.5. Therefore, it could be rationalized that the textbook was designed to assess standard 8.F.B after additional lessons with that skill. The Illustrative Mathematics textbook implemented a spiral model, where it introduced topics, became increasingly harder, and revisited skills at multiple points during the year (Illustrative Mathematics, 2018).

Table 3.5 *Standards and Pre- and Posttest Item Alignment*

Standards	Pre- and Posttest Items
8.F.A - Define, evaluate, and compare functions.	• Item 1
8.F.A.1 - Understand that a function is a rule that assigns to each input exactly one output. The graph of a function is the set of ordered pairs consisting of an input and the corresponding output. Function notation is not required in Grade 8.	• Item 5 • Item 7
8.F.A.2 - Compare properties of two functions, each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). For example, given a linear function represented by a table of values and a linear function represented by an algebraic expression, determine which function has the greater rate of change.	• Item 7
8.F.A.3 - Interpret the equation y = mx +b as defining a linear function whose graph is a straight line; give examples of functions that are not linear. For example, the function $A = s^{2,}$ giving the area of a square as a function of its side length, is not linear because its graph contains the points (1,1), (2,4), and (3,9), which are not on a straight line.	• Item 5
8.F.B - Use functions to model relationships between quantities	

Standards	Pre- and Posttest Items
8.F.B.4 - Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x,y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models and its graph or a table of values.	• Item 3 • Item 7
8.F.B.5 - Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function described verbally.	• Item 2 • Item 4 • Item 6

Description of the Implementation of Pre- and Posttest

The pre-test was administered before the innovation began, and the posttest after the unit's last lesson. The pre- and posttest were delivered through an educational technology resource called ASSISTments, which allowed the students to take the assessments in class and remotely on a computer with Wi-Fi access. The ASSISTments program automatically graded the multiple-choice questions, but the open-ended responses were manually scored. The pre- and posttest data section was divided into parts, including (a) grading and (b) classification of questions into four strands.

Grading. The pre- and posttest were graded using a point system. Items one to four were graded by awarding points for the correct solutions chosen. See Appendix D for a full breakdown of the grading system and how the tier system was implemented. The maximum number of points to be awarded was sixteen. Items five and six used a three-tier grading system that awarded three points as the maximum possible for each question. Item seven was graded on a four-tier system, with the highest possible points being four. The pre- and posttest used the maximum number of points awarded to the

student and divided that by the total number of points possible, which was 16. To maintain grading validity and reliability, a mathematics colleague graded the pre- and posttest (Mertler, 2017).

Classification of Questions into Four Strands. Math Nation created the assessment for this course, *8th Grade Illustrative Mathematics* (2016). Like the online homework classifications, the items have been classified into the four major strand categories of strategic competence, conceptual understanding, procedural fluency, and adaptive reasoning to assess the student's skill level in each area. Appendix C highlights the breakdown and classification of each question into four strands. The second evaluation, the posttest, followed the innovation to assess the effects and compare the pretest results.

Online Homework

With the online homework scores being both the innovation and a data collection instrument, most of the information on design and implementation has been detailed in the Action/Innovation section. The following section details the data collection process: Description of online homework.

Description of Online Homework

Assignments were selected from the recommendations in IXL Skill Alignment for Illustrative Mathematics – 8th Grade. Question items on the online homework were very similar to the pre- and posttest. Students filled in tables, read tables, analyzed graphs, created graphs, evaluated functions, and provided short answers. Some questions required a single answer using a formula, while others had multiple parts and used multiple steps and formulas. All assignments and curriculum alignment can be found in Appendix BB.

Online homework was delivered using IXL. Correct answers advanced participants to the next question and increased their SmartScore until it reached 100, while incorrect answers led them to process-based feedback prompts and decreased their SmartScore. Each prompt guided students through the process required to solve the problem since process-based feedback have been shown to advance student comprehension (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006).

Data collected from online homework was compared with students' results from the posttest to evaluate effectiveness. In addition, data were analyzed for correlations between online homework items and test items aligned to the same SCCCR standard. For example, students scoring well on the homework items from lessons 1-4 should have had correlative scores on the posttest problems 1 and 5, as detailed in Table 3.5 and Table 3.6.

IXL analytics allowed for analysis of individual student questions, displayed the number of questions answered, showed the time spent on the assignment, and gave a SmartScore. The IXL data was used for instructional revisions based on statistical results from the individual assignments (Marsh, Pane, & Hamilton, 2006; Means, Chen, DeBarger, & Padilla, 2010; Roschelle et al., 2016).

Table 3.6 *Instructional Objectives, Lessons, and Online Homework*

Standards	**Lessons**	**IXL Online Homework Assignments**
8.F.A - Define, evaluate, and compare functions.	• Lesson 3 - Equations for Functions	• Complete an Input/Output Table using an Equation • Find the Rule: Word Problems • Identify Independent and Dependent Variables

Standards	Lessons	IXL Online Homework Assignments
8.F.A.1 - Understand that a function is a rule that assigns to each input exactly one output. The graph of a function is the set of ordered pairs consisting of an input and the corresponding output. Function notation is not required in Grade 8.	• Lesson 1 - Inputs and Outputs • Lesson 2 - Introduction to Functions • Lesson 3 - Equations for Functions • Lesson 4 - Tables, Equations, and Graphs of Functions • Lesson 5 - More Graphs of Functions	• Complete an Input/Output Table • Input/Output Tables: Find the rule • Identify Functions: Tables • Complete an Input/Output Table using an Equation • Find the Rule: Word Problems • Identify Independent and Dependent Variables • Interpret Points on a Graph of a Linear Function • Identify Functions: Graphs • Identify Functions • Complete a Table and Graph of a Linear Function
8.F.A.2 - Compare properties of two functions, each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). For example, given a linear function represented by a table of values and a linear function represented by an algebraic expression, determine which function has the greater rate of change.	• Lesson 7 - Connecting Representations of Functions • Lesson 8 - Linear Functions	• Compare Linear Functions: Tables, Graphs, and Equations • Compare Linear Functions: Graphs and Equations
8.F.A.3 - Interpret the equation y = mx +b as defining a linear function whose graph is a straight line; give examples of functions that are not linear. For example, the function $A = s^{2,}$ giving the area of a square as a function of its side length, is not linear because its graph contains the points (1,1), (2,4), and (3,9), which are not on a straight line.	• Lesson 4 - Tables, Equations, and Graphs of Functions • Lesson 7 - Connecting Representations of Functions • Lesson 8 - Linear Functions	• Compare Linear Functions: Graphs and Equations • Compare Linear Functions: Tables, Graphs, and Equations

Standards	Lessons	IXL Online Homework Assignments
8.F.B - Use functions to model relationships between quantities	• Lesson 10 - Piecewise Linear Functions	• Identify Functions • Complete a Table and Graph of a Linear Function
8.F.B.4 - Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x,y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models and its graph or a table of values.	• Lesson 8 - Linear Functions • Lesson 9 - Linear Models • Lesson 10 - Piecewise Linear Functions	• Compare Linear Functions: Graphs and Equations • Identify Linear and Nonlinear Functions: Tables and Graphs • Identify Functions: Graphs • Rate of Change: Graphs
8.F.B.5 **-** Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function described verbally.	• Lesson 5 - More Graphs of Functions • Lesson 6 - Even More Graphs of Functions • Lesson 10 - Piecewise Linear Functions	• Find Values using Function Graphs • Complete a Table for Function Graph

Note: All standards are taken from the SCCCR standards for Mathematics. All lessons and assessment questions are from the *Illustrative Mathematics* textbook (Illustrative Mathematics, 2018). Online homework assignments are from correlated IXL practice assignments.

Grading. The online homework, like the pre- and posttest, used a point system for grading. All online homework assignments can be found in Appendix BB. The maximum possible points students could earn on all the homework was 100. A score at or above a SmartScore of 80 received 100 out of 100 possible points. Every 8 points below an 80 SmartScore dropped the grade book score an additional 10.

Consequently, a 72 SmartScore was worth 90 out of 100 points, a 64 SmartScore was equivalent to 80 out of 100, and so on. Students were allowed as many attempts as needed to complete the assignment, and correct answers increased their score, while

incorrect answers lowered their score. Students were allowed to reattempt any assignment prior to the posttest. Seventeen IXL online homework assignments were part of the innovation yielding a 1700-point total.

Student interviews

After analyzing the posttest results and online homework data, interviews were conducted with purposefully selected students to understand the online homework interview's effect fully. This section will detail the (a) description of student interviews and (b) description of the implementation of student interviews.

Description of Student Interviews

Each semi-structured interview was guided by a specific set of questions with the option for probing questions if needed (Mertler, 2017). Questions for the interview were newly crafted to ensure that they were age-appropriate, neutral, and specific to the online homework innovation (Creswell& Creswell, 2018; Mertler, 2017). The interview questions with research justification are detailed in Table 3.7. Each interview had a scripted beginning and ending, with open-ended questions driving the discussion (Jacob & Fergurson, 2012). Not all follow-up questions were listed, but probes were used to allow for a more emergent design (Creswell & Creswell, 2018). The interview's language was simple, with direct and brief questions (Mertler, 2017).

Given the participants' age, the semi-structured model allowed for more clarification and exploration to elicit a thorough response. Different students needed to be asked for clarification during other portions of their answers, so it was necessary to retain some flexibility (Mertler, 2017). Each person and situation could be unique, and the

information sought must be adaptable and varied (Leedy & Ormrod, 2005; Mertler, 2017). The interview script and questions can be found in Appendix A.

Table 3.7 *Interview Questions and Research Alignment*

Research Question	Interview Questions	Justification
What were 8th Grade Mathematics students' perceptions regarding the impact of online homework using IXL on their mathematical proficiency?	1. Tell me about yourself.	This question was designed to gain demographic information and background on the student. Prompts about race, age, family, where they grew up, likes, and dislikes. In addition, this question aimed to build rapport and establish comfortability (Jacob & Fergurson, 2012).
	2. What are your thoughts about completing the homework using IXL?	This question was designed to get the students thinking about online homework and their initial perception. The tone was neutral to ensure that the question remained neutral and did not lead the participant (Mertler, 2017). Probes about likes, dislikes, features, feedback, submissions, aspects, usefulness, motivation, attitude, and feelings may be given.
	3. How do you think doing the IXL homework online impacted your learning and score on the posttest?	This question delved into the heart of the research question, trying to build upon the second question and make the students think about the specific aspects that they found effective or ineffective. Again, clarification was needed to explain what I meant by impact to the participant. Probes were given about definitions, concepts, formulas, similarities in questioning, scores, and language.
	4. Is there anything about online homework you have not mentioned but want to discuss?	This question allowed the participant to talk openly about anything they may have thought about but did not specifically mention. Questions that enable interviewees to revisit previous questions or provide open-ended thoughts can help an interviewer probe more deeply (Jacob & Fergurson, 2012).

The interviews lasted approximately 6–12 minutes and were completed through Zoom outside school hours. The goal was to keep the interviews short since younger students could lose interest quickly (Jacob & Furgerson, 2012). Meeting times and dates were arranged with each participant and their parent after the conclusion of the posttest. Considering the time it took to interview, transcribe, and examine the results of four participants, the interviews were kept brief (Boyce & Neale, 2002). Participants were selected for interviews based on their mastery of the content. The goal was to select at least one high, average, and low achieving student.

Description of the Implementation of Student Interviews

To gain a complete picture of students' perceptions of the effects of online homework on their mathematical proficiency, 8-10 students were asked to interview — this number of students allowed for a broad picture of the innovation. The criteria for selection were two-fold. First, students had to be willing to be interviewed. Given the participants' age and the possibility of being apprehensive about interviewing with their teacher, students were reluctant to sit for an interview. Many students at Cedar Hill were still developing their social-emotional awareness, and a one-on-one interview might have felt too invasive. To combat this, I offered incentives such as future homework passes to encourage students to provide me with their perspectives. Second, once enough students assented, students were selected out of the pool on their differing mathematical proficiency levels. Ideally, some 8–10 students selected for interviews should have demonstrated mastery. The second set of students should have struggled or declined during the innovation. The last few students should have shown little to no improvement. These three groups of students provided a complete picture of the innovation and gave

me an in-depth analysis of student perceptions. Unfortunately, of the potential pool of students, only four were willing to participate.

Interviews were conducted on Zoom after school hours. The interview's opening reaffirmed the assent of the interviewee and verified that consent had been given by a parent or guardian (Jacob & Fergurson, 2012). The early part of the interview was more relaxed to build trust and allowed the interviewee to feel comfortable talking about their experience (Mertler, 2017).

Interviews were recorded on an audio device and later transcribed using the speech-to-text function of Otter.ai to gather a complete picture of the words and mannerisms present. Students were given a copy of the interview transcript to complete a member check to ensure they were accurate and representative of their answers (Metler, 2017).

Student Perception of Online Homework Survey 2020-2021

Surveys are a tool that can be used to collect quantitative and qualitative data information using a set of questions or statements (Mertler, 2017). In order to understand the various perceptions of online homework, an anonymous survey was administered to participants after completing the posttest. Hopefully, the anonymity of the survey improved the honesty of the participants' answers (Creswell & Creswell, 2018). The following topics guided the student survey section: (a) survey and (b) description of the implementation of student surveys.

Survey

The *Student Perception of Online Homework Survey 2020-2021* was created and delivered using Google Forms after completing the posttest. The survey was a modified

version of the survey created by Gutierrez (2017), which compared online homework to pen and paper. The survey questions are in Appendix I, and the original survey can be found in Appendix H.

The survey was composed of nine statements, each requiring the student to rate their answers using a 5-point Likert scale. The survey length and the questions' language were based on participants' age. The survey design ensured that it was appropriately lengthened, easy to understand, contained non-repetitive questioning, and used non-leading statements (Mertler, 2017). The ratings consisted of the following typical Likert scale ratings: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree (Mertler, 2017). Consideration for the inclusion or exclusion of a neutral answer was extensive. Still, I thought it best to include one if students truly felt no inclination towards one view or another (Mertler, 2017). Table 3.8 shows the survey questions and their alignment with research question two.

Table 3.8 *Student Survey Questions and Research Alignment*

Research Question	Student Survey Questions
What were 8th Grade Mathematics students' perceptions regarding the impact of online homework using IXL on their mathematical proficiency?	1. Online math homework provides me with resources that help me solve my math problems. 2. I earn higher test grades after I have online math homework. 3. I think that online math homework helps me to do the math. 4. When completing online math homework, I use the online resources provided.

Research Question	Student Survey Questions
	5. Online math homework does **NOT** provide me with resources that help me solve my problems. 6. I do **NOT** think online math homework helps me learn how to do math. 7. I do **NOT** use the online resources provided when I am completing online math homework. 8. Online math homework is more good than bad. 9. Online math homework is more bad than good.

Note: RQ2 = Research Question two. Questions 5, 6, and 7 were reversed coded for analysis.

Description of the Implementation of Student Surveys

A link was provided to the students' survey embedded in the same Canvas module as the posttest. Students were asked to complete the survey after completing their posttest, and it was delivered electronically using Google Forms. The survey remained open for 24 hours if any student needed additional time to complete the survey. All survey responses were downloaded into an Excel document for descriptive statistics analysis.

Data Analysis

Analysis of data collected involved both quantitative and qualitative processes. Pre-and posttest data, online homework data, and student surveys were analyzed quantitatively. The qualitative data analysis results were checked for complementarity to explain the outcomes from the quantitative data (Greene, Carcelli, & Graham, 1989; Schoonenboom & Johnson, 2017). Student interviews were analyzed through qualitative

means. Table 3.9 describes each research question's research questions, data sources, and analysis method. The following sections highlighted the essential parts of data analysis: (a) online homework data, (b) pre- and posttest data, (c) student interview data, and (d) student survey data.

Table 3.9 *Outline of Research Questions, Data Sources, and Analysis Methods*

Research Questions	Data Sources	Analysis Methods
How does IXL online homework affect the mathematical proficiency of 8th Grade Mathematics students at Cedar Hill Middle School?	• Pre- and Posttest Data • Online Homework Data	• Inferential statistics (paired samples *t*-test) • Descriptive Statistics (*M, SD*)
What were 8th Grade Mathematics students' perceptions regarding the impact of online homework using IXL on their mathematical proficiency**?**	• Student Interviews • Student Surveys	• Inductive Analysis • Descriptive Statistics (*M*, *SD*)

Online Homework Data

Online homework data used IXL to compile data into an Excel spreadsheet and was analyzed using descriptive statistics to consolidate and review sizable data quantities (Mertler, 2017). Data were summarized by detailing means and standard deviations for the assignments individually and collectively.

Further analysis was conducted after applying the macro to the mathematical proficiency scores individually and collectively, breaking the homework questions down by strand proficiency. The four strands of mathematical proficiency have been defined by the National Research Council (2001): strategic competence, conceptual understanding,

procedural fluency, and adaptive reasoning. In addition, descriptive statistics were used for analysis and comparison (Mertler, 2017).

Pre- and Posttest

Data from the pre- and posttest was used to assess students' changes in mathematical proficiency, conceptual understanding, strategic competence, adaptive reasoning, and procedural fluency by comparing results from both assessments. Pre- and posttests assessed the students' ability to use the strands on topics relevant to functions, tables, graphs, and linear equations. In addition, descriptive statistics gave insight into a measure of central tendency (mean) and measures of dispersion (standard deviation) to understand collective performances and individual variations (Mertler, 2017).

Inferential statistics have also been utilized on pre- and posttests to assess the hypothesis that online homework innovation will positively impact mathematical proficiency for 8th Grade Mathematics students at CHMS. A paired samples *t*-test was performed on pre- and posttests to compare both groups' outcomes (Creswell & Creswell, 2018). The *t*-test assessed the null hypothesis (i.e., any difference in scores is due to chance) and an alternative hypothesis (i.e., 95% confidence that the increase in scores was not due to chance) to see if the mean scores from the posttest results were reliably greater than the mean of the pretest results (Mertler, 2017). Additionally, internal consistency was assessed using Kuder-Richardson Formula 20 (abbreviated as KR-20, and scores above 0.70 are considered reliable and repeatable) (Creswell & Creswell, 2018).

Student Interviews

Inductive analysis was used to analyze student interviews to develop an in-depth understanding of the quantitative data results and participants' perceptions of online homework's impact on mathematical proficiency. First, a thematic analysis was conducted to create a rich description of how the data will be compacted, organized, and interpreted (Raskind et al., 2019), thus authenticating emerging themes (Mertler, 2017). Next, the initial round of open coding developed concepts for evaluation and further examination using "in vivo" coding, which uses descriptions in the style of the interviewee or journalist (Glaser & Strauss, 1967). Then, open coding was interpreted to develop emergent coding based on the language, thoughts, and implications found in the interviewee's words and phrases (Stuckey, 2015). This analysis style follows the Grounded Theory methodology, in which the researcher uses the data to develop the theory rather than trying to impose any codes or themes (Blair, 2015). After that, further rounds of axial coding were applied to the data to form linkages between categories and subcategories, fine-tuning connections and explanations (Blair, 2015). Finally, selective coding was applied to all codes and themes to reveal the data's central structure and theory (Blair, 2015).

Student Surveys

Data from the student surveys were used to analyze student perceptions of the online homework on their mathematical proficiency**.** Each of the 11 questions was analyzed using descriptive statistics. Means and standard deviations gave insights into the participants' individual and collective scores (Mertler, 2017). Cronbach's Alpha was calculated on the entire survey to assess the pilot survey's reliability. Data from

participants and the collective group was discussed through means and standard deviations.

Procedures and Timeline

The innovation study was divided into four phases: Participant Identification, Data Collection and Innovation, Descriptive Statistics and Student Interviews, and Data Analysis. Table 3.10 provides further details on expectations and time frames for each phase.

Table 3.10 *Timeline of Participant Identification, Data Collection, and Data Analysis*

Phase	Expectations	Time Frame
Phase I: Participant Identification	1. Identify Participants 2. Distribute and Collect Assent and Consent Forms 3. Review Assent and Consent Forms 4. Administer Pretest	Two weeks
Phase II: Data Collection and Innovation	1. Online Homework Innovations (11) a. Ongoing Online Homework MP analysis (*M, SD*) 2. Administer Student Perception Survey a. End of week 2 3. Instruct Classes 4. Deliver Posttest 5. Administer Student Perception Survey a. End of week 4	Four weeks
Phase III: Descriptive Statistics and	1. Pretest and Posttest MP analysis (*M, SD*) 2. Student Survey Analysis (*M, SD*)	Two weeks

Phase	Expectations	Time Frame
Student Interviews	3. Interview 8–10 Students (10 minutes each) 4. Transcribe Student Interviews with G Suite	
Phase IV: Data Analysis	1. Member Checking of interviews 2. Thematic Analysis and Coding Student Interviews 3. Online Homework Strand Analysis (*M, SD*) a. SC, CU, PF, AR 4. Pretest and Posttest Strand Analysis (*M, SD*) a. SC, CU, PF, AR 5. Pretest/Posttest (paired samples *t*-test) a. MP, SC, CU, PF, AR 6. Internal Consistency Check (KR-20)	Four weeks

Note: MP = Mathematical Performance, SC = Strategic Competence, CU = Conceptual Understanding, PF = Procedural Fluency, and AR = Adaptive Reasoning.

In Phase I of the study, participants were asked to volunteer for the study from two of the four sections of 8th Grade Mathematics. Once identified, participants were given an invitation to participate in the study, detailed in Appendix F. Participants were then asked to complete assent forms with their parents completing a corresponding consent form. A copy of the assent form and consent form can be found in Appendix G, and Appendix H. All forms were reviewed to ensure that all documentation had been correctly filled out and signed. Once all documents were verified, participants took the pretest to assess their current level of understanding.

During Phase II, the online homework innovations were administered on 11 homework assignments during the first half of Unit 5 in the 8th Grade Mathematics

course. Individual homework assignments were analyzed using descriptive statistics to help tailor daily instructional activities to the students' needs. At the end of the unit, a posttest was administered to all participants. In addition, two student perception surveys were distributed during the data collection. The first occurred at the halfway point and the other at the end of the unit, following the posttest.

Phase III opened with an analysis of the students’ pre- and posttest mathematical performance and the student surveys using descriptive statistics. The pre- and posttest analysis and the student survey analysis provided pertinent information to select 8–10 students for interviews and the data analyses from the online homework. Students were selected based on their varied performance and survey data to be interviewed. Four students agreed to participate, helping obtain a varying view of the innovation: those who improved significantly, those who improved moderately, and those who showed little to no improvement from the pre- to posttest. Interviews probed student perceptions of the innovation, and students were asked to comment on their pre- and posttest results. During this time, interviews were audio-recorded and transcribed with Otter.ai, an online speech-to-text program.

At the beginning of Phase IV, students conducted member checks of their interviews to ensure the transcriptions' accuracy. Once accuracy was verified, each interview was coded and analyzed thematically. Online homework and the pre- and posttest were further analyzed using descriptive statistics by breaking down mathematical performance into each of the four strands: strategic competence, conceptual understanding, procedural fluency, and adaptive reasoning. Finally, using a paired samples *t*-test, mathematical performance, strategic competence, conceptual

understanding, procedural fluency, and adaptive reasoning were analyzed to compare the pre- and posttest. K-R 20 levels (Kuder-Richardson Formula 20) were also determined for the *t*-tests to ensure the tests had reliability.

Rigor and Trustworthiness

Numerous methods were available to authenticate a qualitative study. Creswell (2012) recommends that a minimum of two be instituted. Concerns arose during qualitative inquiry due to the relationship between the researcher, participants, and data for several reasons: the free gathering of data through communication and observation, subjective analyses and interpretations, and a lack of standard checks and balances, as in journalism (Morse, 2015). Qualitative inquiries should have “accuracy and believability” (Mertler, 2017, p. 140) to determine whether the research has measured what has been intended, been described richly for context, and has an established protocol (Shenton, 2004).

To ensure the rigor and trustworthiness of the qualitative portion of the study, four methods were used: (a) member checking, (b) thick, rich description, (c) peer debriefing, and (d) triangulation.

Member Checking

Member checking was a means to portray the participants' perceptions and intentions through meetings and discussions (Hays, Wood, Dahl, & Kirk-Jenkins, 2016). Interview transcripts and researcher analyses were shared with the participants to ensure they were represented accurately (Mertler, 2017). Participant intentions were vital for accurately representing emerging theories or inferences (Shenton, 2004). Interview

analyses were provided to all interviewees to check emerging theory development, ensuring all data interpretations and conclusions have been verified.

Thick, Rich Description

Thick, rich descriptions were used to convey the details of the research circumstances and surrounding perspectives (Shenton, 2004). Notes, observations, interpretations, and assumptions were utilized to portray a vivid picture and allow other researchers to reproduce the study or use its verdicts (Hays et al., 2016). All interviews described participants’ online homework perceptions, thoughts, reactions, and surrounding circumstances and environment. This recursive activity provided details about the researcher's theories and associations (Hays et al., 2016).

Peer Debriefing

Methodology and findings were reviewed through peer debriefing to offer a critical lens of the research process (Hays et al., 2016). Procedures were taken to collect data, examine results, and make inferences, which were scrutinized through alternative perspectives to ensure that each stage had proper execution and detailed explanation (Mertler, 2017). A collaborative effort of analyses ensured the interpretations had consensus (Liao & Hitchcock, 2018). Members of my cohort, my dissertation chair, peers, and colleagues from work who had previously completed research provided an outside perspective grounded in qualitative processes. Most of the peer debriefing was conducted by my dissertation chair, who analyzed and critiqued my coding process. We met and discussed how and why specific codes were applied to interview transcripts, ensuring that my codes conveyed the interviewees' thoughts. Periodic emails, phone calls, and meetings were also conducted with colleagues and members of my cohort to ensure

my process and analysis were sound. Analysis of information as an external reader critiqued the vividness of my descriptions (Liao & Hitchcock, 2018; Shenton, 2004). Peer debriefs helped check the validity of the initial codes for researchers to adjust and provide analysis on the revised codes before they were finalized (Richards & Hemphill, 2018). All necessary background information was provided, and all questions about the study were answered to ensure any critiques contained details needed to receive advice.

Triangulation

Multiple perspectives and data sets were used to increase validity through triangulation in qualitative studies (Mertler, 2017; Morse, 2015). Limitations often exist through a single means of data collection; therefore, supporting data through multiple perspectives can strengthen the analyses to overcome individual research shortcomings (Shenton, 2004). Any contradictory data was used for alternate conclusions (Mertler, 2017). Interview and survey data were analyzed and compared with the quantitative data from the pre- and posttests and the online homework to verify the accuracy and provide insight into the qualitative data.

Plan for Sharing and Communicating Findings

This action research was implemented to assess the impact of online homework on mathematical proficiency. Once the study concluded, it was essential to communicate the results to show the theoretical and practical relationship when implementing an innovation (Mertler, 2017). Research sharing provided other educators and research practitioners the opportunity to see the importance of my work and share similar sentiments or concerns (Mertler, 2017). A three-part plan for sharing and communicating my findings was detailed in this section, starting with (a) Cedar Hill Middle School, then

(b) Charleston County School District (CCSD), and finally a national-level conference, such as the (c) National Council Teachers of Mathematics.

Cedar Hill Middle School

The findings of this research were shared with study participants utilizing their pre- and posttest scores and the data collected from interviews and surveys. To protect and secure the participants' anonymity, each person was assigned a random generic pseudonym (i.e., Bob, Susan, Carl, etc.) with the cipher stored away, obtainable only by the classroom researcher (Mertler, 2017). Formal and informal feedback forms helped redesign the research process per action cycle. Once each cycle was complete, all data and conclusions were presented via PowerPoint. This short 10 to 15-minute presentation was shared with the math department and administrators at Cedar Hill Middle School during faculty meetings with all identifying information of the participants removed. During these brief presentations, colleagues and administrators learned the following: contextual information, the purpose of the study, methodology, outcomes, and action plan. Time was also allotted for questions and answers (Mertler, 2017).

Charleston County School District

Each spring, there is a weeklong professional development conference for the Charleston County School District (CCSD). The research findings will be shared in a more extended version, around 50–60 minutes, giving more insight into its design, implications, and further implementations. The aim will be to present the first set of findings during the spring of 2023. The deadline to register to present during the June 2023 sessions is in January 2023, so a short description is necessary to acquire a conference spot. During all meetings, feedback will be obtained using an informal survey

or polling to gather my colleagues’ perspectives on the findings and the presentation's nature.

NCTM National Conference

In 2023, the National Council of Teachers of Mathematics (NCTM) will have a regional conference in March/April, and a proposal will be submitted approximately six months prior. Therefore, this final presentation will be expanded to accommodate the 90-minute session, including more student work examples and in-depth analysis, and allow additional time for questioning.

CHAPTER 4

FINDINGS AND INTERPRETATIONS

This action research aimed to assess the effect of IXL online homework on students' mathematical proficiency in 8th Grade Mathematics at Cedar Hill Middle School in South Carolina. It utilized action research with a convergent parallel mixed-methods design to incorporate quantitative and qualitative research elements.

Two mathematics sections in 2020-2021 were asked to participate in the research. Among the 57 eligible students, 22 initially agreed to participate in the study. However, only 13 fully participated by completing both surveys and pre- and posttests. Four of those students also participated in one-on-one interviews.

The following questions guided the research:

Research Question 1: How does IXL online homework affect the mathematical proficiency of 8th Grade Mathematics students at Cedar Hill Middle School?

Sub Question 1: How does IXL online homework affect the strategic competence of 8th Grade Mathematics students at Cedar Hill Middle School?

Sub Question 2: How does IXL online homework affect the conceptual understanding of 8th Grade Mathematics students at Cedar Hill Middle School?

Sub Question 3: How does IXL online homework affect the procedural fluency of 8th Grade Mathematics students at Cedar Hill Middle School?

Sub Question 4: How does IXL online homework affect the adaptive reasoning of 8th Grade Mathematics students at Cedar Hill Middle School?

Research Question 2: What are Eighth Grade Mathematics students' perceptions regarding the impact of online homework using IXL on their mathematical proficiency?

This chapter will discuss the findings from quantitative and qualitative data collected from IXL homework assignments, the pre- and posttests, student surveys, and student interviews.

Quantitative Findings and Interpretations

Students were asked to complete IXL homework, take a pre- and post-test knowledge assessment, and complete a survey to measure the impact of the online homework delivered via IXL. The 13 students who fully participated ranged from 13 to 14 years old. Of those 13, seven were male, six were female, two were Caucasian, four were English as a Second Language, and seven were African American. The following sections will guide the Quantitative Results section: (a) Student Perceptions of Online Homework Survey, (b) Pre- and Post-test Knowledge Assessment, (c) IXL Online Homework Descriptive Statistics using the SCCCR Standards, and (d) Post-test and IXL Online Homework Descriptive Statistics according to the Four Strands.

Student Perceptions of Online Homework Survey

The *Student Perceptions of Online Homework Survey 2020-2021* was created and delivered using Google Forms at the study's midpoint and after the post-test. The survey was a modified version of the survey created by Gutierrez (2017), which compared online

homework to pen and paper. The survey questions are in Appendix I, and the original survey is in Appendix H.

The survey was composed of nine statements, each requiring the student to rate their answers using a 5-point Likert scale with 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. Both survey length and language of the questions were based upon participants' ages and research questions. The survey design ensured that it was appropriately lengthened, easy to understand, contained non-repetitive questioning, and used non-leading statements (Mertler, 2017). Items were divided into two smaller subscales (use of resources and impact on student learning) to assess students' beliefs about the impact of IXL on their learning and use of the resources. Data were analyzed using JASP, the open-source statistical analysis software program. Items framed negatively were reverse coded to enable the calculations of composite means.

Cronbach's alpha test for reliability was performed on the aggregate data to test for the internal consistency of the results. Cronbach's alpha scores typically range from zero to one, with higher scores correlating with higher consistency. Results below 0.7 should be viewed with skepticism as the results are slightly less reliable (Hair, Black, Babin, & Anderson, 2010). This study's results ($\alpha = 0.696$) had enough consistency to make valid conclusions.

Descriptive Statistics

Descriptive statistics were used to explore the students' perceptions of the online homework innovation and students' changes in perceptions from the midpoint to the post-test survey. Table 4.1 provides descriptive statistics for the surveys administered on March 11, approximately two weeks after data collection, and on March 23, immediately

after the students took the post-test. The midpoint survey had a composite mean (*M* = 2.65) close to neutral, leaning slightly towards disagree. The standard deviation for the midpoint survey *(SD* = 0.84) was sizable, so individual students had various experiences. Composite posttest survey statistics showed that the mean (*M* = 2.94) and (*SD* = 1.02) changed from the study's middle. The mean of the post-test gained 0.33 points above neutral, and the standard deviation increased by 0.22.

Table 4.1 *Descriptive Statistics for Student Perception of Online Homework Survey 2020-2021 for all Student Participants (n = 13)*

	Midpoint Survey		**Posttest Survey**	
	M	***SD***	***M***	***SD***
Online Homework Items	2.65	0.83	2.94	1.02

When analyzing the ratings of a few statements on an individual level, several made significant changes from the midpoint survey to the post-test survey. For example, in the second item, *I earn higher test grades after I have online math homework,* and participants' ratings changed the most from the midpoint (*M* = 2.71) to the post-test (*M* = 3.54) survey, with an increase of 0.83. The second highest move from the midpoint (*M* = 3.00) to the post-test (*M* = 3.67) survey, with an increase of 0.67 on the second survey, was the statement, *Online math homework provides me with resources that help me solve my homework problems*. Other statements had little to no change at all. For example, item 7, *I do NOT use the online resources provided when I am completing online math homework,* had a minor change from the midpoint (*M* = 2.29) to the posttest (*M* = 2.23) survey.

Subscale: Use of Resources. The following is a further analysis with descriptive statistics (mean and standard deviation) on the statements that rated students' impact on

learning and use of resources. Details for the Use of Resources subscale can be found in Table 4.2. Subscale composite means for the post-test (*M* = 2.92) showed the students were almost neutral regarding the resources provided by IXL, which improved over the midpoint survey mean (*M* = 2.52), which leaned more towards disagree. However, the variation in post-test survey responses (*SD* = 0.98) and midpoint survey responses (*SD* = 0.72) was moderately high, so the students' individual experiences varied on their perceived effectiveness of the online resources.

Table 4.2 *Descriptive Statistics for Use of Resource Items 2020-2021 (n = 13)*

	Midpoint Survey		**Posttest Survey**	
Items	***M***	***SD***	***M***	***SD***
Online math homework provides me with resources that help me solve my homework problems.	2.92	0.96	3.67	0.95
When completing online math homework, I use the online resources provided.	2.92	0.50	3.54	0.97
Online math homework does NOT provide me with resources that help me solve my math problems.	2.00	0.57	2.23	0.83
I do NOT use the online resources provided when I am completing online math homework.	2.23	0.73	2.23	1.17
Subscale Combined	2.52	0.72	2.92	0.98

Subscale: Impact on Student Learning. This subscale assessed the participants' perceptions of the impact of online homework on their learning. As detailed in Table 4.3, composite means for this subscale from the post-test survey responses (*M* = 2.96) and the midpoint survey responses (*M* = 2.75) showed a slight increase towards neutral with an increase of 0.14. However, relatively high standard deviations on the post-test survey responses (*SD* = 1.05) and midpoint survey responses (*SD* = 0.94)

showed that while the averages were neutral, each student may have had different experiences with the impact IXL had on their student learning.

Table 4.3 *Descriptive Statistics for the Impact on Student Learning Items (n = 13)*

	Midpoint Survey		**Posttest Survey**	
Items	***M***	***SD***	***M***	***SD***
I earn higher test grades after I have online math homework.	2.69	0.95	3.54	0.78
I think that online math homework helps me to do my math.	3.31	0.63	3.69	1.11
Online math homework is more good than bad.	3.31	0.75	3.54	1.20
I do NOT think that online math homework helps me learn how to do my math.	2.23	1.17	2.08	0.95
Online math homework is more bad than good.	2.23	1.23	1.92	1.19
Subscale Combined	2.75	0.94	2.96	1.05

The degree to which the standard deviations were close to one throughout the survey shows the variety in each student's opinions and experiences with the IXL program. However, overall, the aggregate data of the means showed that the students reported that the IXL online homework was neither beneficial nor detrimental to their learning.

Inferential Statistics

Knowing that the data was reliable, inferential statistics were calculated to assess the implications of the quantitative data. First, the Shapiro-Wilk test was performed to tell if the sample had a normal distribution. According to Field (2013), *p*-values greater than 0.05 on a Shapiro-Wilk test shows no evidence of non-normality. In

other words, p-values greater than 0.05 fall within the normal range. However, values below that threshold indicate that data has begun to deviate significantly from the norm.

Given that the Shapiro-Wilk determined the data were normally distributed (p = .10), a paired samples t-test was used to analyze the two survey data sets. The paired samples t-test compares the means of the data to assess whether there is a statistically significant difference between the two data sets. There was a slight difference in the mean scores on the midpoint survey (M = 2.65, SD = 0.84) than those of the post-test survey (M = 2.94, SD = 1.02), t(12) = -0.864, p = 0.420. Further analysis of the impact on student learning subscale showed a lesser increase in means between the midpoint survey (M = 2.75, SD = 0.93) and post-test survey (M = 2.96, SD = 1.05), t(12) = -1.309, p = 0.369, than the use of resources subscale, which had the midpoint survey (M = 2.52, SD = 0.72) and posttest survey (M = 2.92, SD = 0.98), t(12) = -0.503, p = 0.45. Results from the paired samples t-test can be found in Table 4.4.

Table 4.4 *Paired Samples t-Test for Midpoint and Posttest Surveys (n=13)*

	Midpoint Survey Mean (SD)	**Posttest Survey Mean (SD)**	***t***	***df***	***p***
Composite	2.65 (0.84)	2.94 (1.02)	-0.864	12	0.420
Impact on Student Learning	2.75 (0.94)	2.96 (1.05)	-1.309	12	0.369
Use of Resources	2.52 (0.72)	2.92 (0.98)	-0.503	12	0.457

When multiple tests are run, the likelihood of a Type I error increases (Armstrong, 2014). Therefore, to decrease the likelihood of a false positive, a Bonferonni adjustment was made to the alpha-level, $\alpha = .017$ ($\alpha = .05/3 = .017$). Since the p-values from the three tests are all above .017, the results of the tests will not be considered

significant. Statistically, there was no difference in scores from the midpoint to the post-test survey.

Pre- and Post-test Knowledge Assessment

The pre- and post-test knowledge assessments were delivered to the students using the ASSISTments program that works in conjunction with the Illustrative Mathematics curriculum. A fellow CHMS mathematics colleague and I graded each assessment within the program to ensure consistency in the open-ended responses; any discrepancies were discussed, and a single score was recorded. Once graded, the scores were downloaded into Microsoft Excel spreadsheets for analysis using JASP. The post-test (Appendix B) assessed the students' ability on functions as they related to tables, graphs, word problems, and linear equations.

A Kuder-Richardson Formula 20 test for reliability was attempted on the post-test data to ensure internal consistency. An aggregate score of 1 indicated that the test was reliable and had conclusive results (Creswell & Creswell, 2018).

Descriptive Statistics

Descriptive statistics were used to describe the means and standard deviations of the pre- and post-test knowledge assessment. Table 4.5 provides pre-test data administered prior to the start of the IXL online homework, and the post-test was administered after the conclusion of the 10-lesson content. Pre-test data showed a mean (M = 21.92) and (SD = 9.23), while the post-test showed a mean (M = 31.34) and (SD = 7.83). The mean increased by approximately 9.42 points, and the standard deviation decreased by 1.40 from the pre-test to the posttest.

Table 4.5 *Descriptive Statistics for Pre- and Posttest (n = 13)*

	Pretest		**Posttest**	
	M	***SD***	***M***	***SD***
Knowledge Assessment	21.92	9.23	31.34	7.83

Inferential Statistics

A paired samples *t*-test was planned to compare the pre- and post-test results for students who used the IXL online homework. Due to the small sample size, establishing the pre- and post-test distribution was important for choosing an appropriate statistical method. Therefore, a Shapiro-Wilk test was performed; it did not show evidence of non-normality (p = 0.57). The planned *t*-test was conducted with results showing significance. Students who used the IXL online homework scored higher on the posttest (*M* = 31.34, *SD* = 7.83) than on the pretest (*M* = 21.92, *SD* = 9.23), *t*(12) = -3.201, p = 0.008. The instructional part of the IXL online homework innovation improved math content knowledge, and this conclusion was verified using the Kuder-Richardson Formula 20 test for reliability. Results from the paired samples *t*-test can be found in Table 4.6.

Table 4.6 *Paired Samples t-Test for Pre- and Post-test (N=13)*

Pre-test Mean (SD)	**Post-test Mean (SD)**	***t***	***df***	***p***
21.92 (9.23)	31.34 (7.83)	-3.201	12	0.008

Post-test Descriptive Statistics using the SCCCR Standards

Descriptive statistics were used to understand the South Carolina College and Career Ready (SCCCR) standards that coincided with post-test questions and results to understand how the IXL online homework impacted students' mathematical proficiency. This section will analyze the sub-questions and four strands (conceptual understanding,

strategic competence, procedural fluency, and adaptive reasoning). This section was added due to the abundance of overlapping data sets because post-test items and IXL online homework assignments assessed multiple strands. In Chapter 3, Table 3.4 shows how each SCCCR standard assessed correlated with each posttest question. Some questions had multiple parts and assessed multiple standards. Problems 1, 2, 3, 4, 6 were single questions, problem 5 contained three questions (5A, 5B, and 5C), and problem 7 had eight separate questions (7A, 7B, 7C, 7D, 7E, 7F, 7G, 7H). Six standards are aligned with the post-test: 8.F.A.1, 8.F.A.2, 8.F.A.4, 8.F.B, 8.F.B.4, and 8.F.B.5.

SCCCR Standard 8.F.A.1. Item 1 and 5A on the post-test assessed SCCCR standard 8.F.A.1, which states that a student should be able to "understand that a function is a rule that assigns to each input exactly one output. The graph of a function is the set of ordered pairs consisting of an input and the corresponding output." Table 4.7 contains descriptive statistics for post-test problems 1 and 5A. Item 1 on the post-test assessment had a mean score of 0.31 out of 4 points (*SD* = 1.10). Problem 5 was a three-part question, with each part being assessed separately out of 4 points. Item 5A had a mean score (*M* = 3.11) and (*SD* = 1.82).

Table 4.7 *Descriptive Statistics Posttest SCCCR Standard 8.F.A.1 (n = 13)*

	1		**5A**		**Average**	
	M	***SD***	***M***	***SD***	***M***	***SD***
Knowledge Assessment	0.31	1.10	3.11	1.82	1.71	1.46

SCCCR Standard 8.F.A.2. Problems 7G and 7H on the post-test assessed SCCCR standard 8.F.A.2, which states that a student should be able to "compare properties of two functions, each represented in a different way (algebraically,

graphically, numerically in tables, or by verbal descriptions)." Table 4.8 contains descriptive statistics for post-test problems 7G and 7H. Question 7G had a mean (*M* = 2.52) score out of 4 points and (*SD* = 2.03), and question 7H had a mean (*M* = 1.55) score out of 4 points and (*SD* = 1.51).

Table 4.8 *Descriptive Statistics Posttest SCCCR Standard 8.F.A.2 (n = 13)*

	7G		**7H**		**Average**	
	M	***SD***	***M***	***SD***	***M***	***SD***
Knowledge Assessment	2.52	2.03	1.55	1.51	2.04	1.77

SCCCR Standards 8.F.A.3 and 8.F.B. Problems 5B and 5C on the post-test assessed SCCCR standards 8.F.A.3 and 8.F.B. Standard 8.F.A.3 states that a student should be able to "interpret the equation y = mx +b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear." Standard 8.F.B states that students should be able to "use functions to model relationships between quantities." Table 4.9 contains descriptive statistics for post-test problems 5B and 5C. 5B had a mean score (*M* = 0.62) and (*SD* = 1.54), and 5C had a mean score (*M* = 1.93) and (*SD* = 0.96).

Table 4.9 *Descriptive Statistics Posttest SCCCR Standards 8.F.A.3 and 8.F.B (n = 13)*

	5B		**5C**		**Average**	
	M	***SD***	***M***	***SD***	***M***	***SD***
Knowledge Assessment	0.62	1.54	1.93	0.96	1.28	1.24

SCCCR Standard 8.F.B.4. Problems 3, 7A, 7B, 7C, 7D, 7E, and 7F on the post-test assessed SCCCR standard 8.F.B.4, which states that a student should be able to

"construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, in terms of its graph or a table of values." Descriptive statistics for problems 3, 7A, 7B, 7C, 7D, 7E, and 7F can be found in Table 4.10. Problem 3 had a mean (*M* = 2.24) score of 4 points and (*SD* = 2.15). Questions 7A and 7B both had a mean (*M* = 0) score of 4 points and (*SD* = 0). Question 7C had a mean (*M* = 0.63) score of 4 points and (*SD* = 1.27). Question 7D had a mean (*M* = 1.94) score of 4 points (*SD* = 2.16). Question 7E had a mean (*M* = 0.98) score of 4 points and (*SD* = 1.81). Question 7F had a mean (*M* = 2.16) score of 4 points and (*SD* = 1.44).

Table 4.10 *Descriptive Statistics Posttest SCCCR Standard 8.F.B.4 (n = 13)*

	3		**7A**		**7B**		**7C**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Knowledge Assessment	2.24	2.15	0	0	0	0	0.63	1.27
	7D		**7E**		**7F**		**Average**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Knowledge Assessment	1.94	2.16	0.98	1.81	2.16	1.44	1.14	1.26

SCCCR Standard 8.F.B.5. Problems 2, 4, and 6 on the posttest assessed the SCCCR standard 8.F.B, which states that students should be able to "describe the functional relationship between two quantities qualitatively by analyzing a graph" and also "sketch a graph that exhibits the qualitative features of a function that has been described verbally." Descriptive statistics of problems 2, 4, and 6 can be found in Table

4.11. Problems 2 and 4 had a mean (*M* = 0.31) score out of 4 points and (*SD* = 1.12). Problem 6 had a mean (*M* = 0.85) and (*SD* = 1.5).

Table 4.11 *Descriptive Statistics Posttest SCCCR Standard 8.F.B.5 (n = 13)*

	2		**4**		**6**		**Average**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Knowledge Assessment	0.31	1.12	0.31	1.12	0.85	1.52	0.49	1.25

IXL Online Homework Descriptive Statistics using the SCCCR Standards

Descriptive statistics were used to understand that IXL online homework coincided with SCCCR standards. Overall, 17 different assignments reinforced the Illustrative Mathematics 8th grade Math course standards. The names, means, and standard deviations of IXL online homework assignments can be found in Table 4.12. Each assignment was scored out of 100 points. In addition, six standards are aligned with the IXL online home: 8.F.A.1, 8.F.A.2, 8.F.A.4, 8.F.B, and 8.F.B.4, and 8.F.B.5.

Many IXL online homework assignments assessed multiple strands (conceptual understanding, strategic competence, adaptive reasoning, and procedural fluency), leading to overlapping data sets. The SCCCR standards were used to present the data more clearly. Further evaluation of the strands will be found in the analysis section.

Table 4.12 *Descriptive Statistics for IXL Online Homework Assignments (n=13)*

IXL Online Homework Assignments	***M***	***SD***
Complete an Input/Output Table	92	28
Input/Output Tables: Find the rule	96	14
Identify Functions: Tables	85	38
Complete an Input/Output Table using an Equation	100	0

Find the Rule: Word Problems	87	33
Identify Independent and Dependent Variables	87	30
Interpret Points on a Graph of a Linear Function	92	28
Identify Functions: Graphs	85	38
Identify Functions	92	19
Complete a Table and Graph of a Linear Function	74	33
Compare Linear Functions: Tables, Graphs, and Equations	65	29
Compare Linear Functions: Graphs and Equations	68	28
Identify Independent and Dependent Variables in Tables and Graphs	78	39
Find Values Using Function Graphs	86	34
Complete a Table for a Function Graph	85	38
Identify Linear and Nonlinear Functions: Tables and Graphs	81	38
Rate of Change: Graphs	81	38
Composite	84	30

SCCCR Standard 8.F.A.1. The following IXL online homework assignments were given to prepare for SCCCR Standard 8.F.A.1: Complete an input/output table, input/output tables: find the rule, identify functions: tables, complete an input/output table using an equation, find the rule: word problems, identify independent and dependent variables, interpret points on a graph of a linear function, identify functions: graphs, identify functions, complete a table and graph of a linear function. The IXL online homework data analysis showed a mean score (M = 89) and (SD = 26). Descriptive statistics for SCCCR Standard 8.F.A.1 can be found in Table 4.13.

Table 4.13 *Descriptive Statistics for SCCCR Standard 8.F.A.1 (n = 13)*

	8.F.A.1	
	M	***SD***
Knowledge Assessment	89	26

SCCCR Standard 8.F.A.2. The following IXL online homework assignments were given to prepare for SCCCR Standard 8.F.A.2: Compare linear functions: tables, graphs, and equations, and compare linear functions: tables and equations. IXL online homework data analysis showed a mean score (*M* = 66) and (*SD* = 28). Descriptive statistics for SCCCR Standard 8.F.A.2 can be found in Table 4.14.

Table 4.14 *Descriptive Statistics for SCCCR Standard 8.F.A.2 (n = 13)*

	8.F.A.2	
	M	***SD***
Knowledge Assessment	66	28

SCCCR Standards 8.F.A.3 and 8.F.B. The following IXL homework assignments were delegated to the students to prepare for SCCCR Standards 8.F.A.3 and 8.F.B: Identify functions, complete a table and graph of a linear function, compare linear functions: tables, graphs, and equations, and compare linear functions: tables and equations. IXL online homework analysis showed a mean score (*M* = 75) out of 100 and (*SD* = 27). Descriptive statistics for SCCCR Standard 8.F.A.3 and 8.F.B can be found in Table 4.15.

Table 4.15 *Descriptive Statistics for SCCCR Standard 8.F.A.3 and 8.F.B (n = 13)*

	8.F.A.3 and 8.F.B	
	M	***SD***
Knowledge Assessment	75	27

SCCCR Standard 8.F.B.4. The following IXL homework was assigned to prepare for the posttest assessment: Compare linear functions: graphs and equations, identify linear and non-linear functions: tables and graphs, identify functions: graphs, rate of change: graphs, compare linear functions: tables, graphs, equations. The IXL online homework analysis showed a mean score (*M* = 77) out of 100 (*SD* = 34). Descriptive statistics for SCCCR Standards 8.F.A.4 can be found in Table 4.16.

Table 4.16 *Descriptive Statistics for SCCCR Standard 8.F.B.4 (n = 13)*

	8.F.B.4	
	M	***SD***
Knowledge Assessment	77	34

SCCCR Standard 8.F.B.5. The following IXL homework was assigned to prepare for the posttest assessment: Find values using function graphs and complete a table for a function graph. The IXL online homework analysis showed a mean score (*M* = 85) out of 100 and a standard deviation (*SD* = 36) for both assignments. Descriptive statistics for SCCCR Standard 8.F.B.5 can be found in Table 4.17.

Table 4.17 *Descriptive Statistics for SCCCR Standard 8.F.B.5 (n = 13)*

	8.F.B.5	
	M	***SD***
Knowledge Assessment	85	36

Posttest and IXL Online Homework Descriptive Statistics According to the Four Strands

This section will provide descriptive statistics for the posttest and IXL online homework assignments according to the National Council for Teachers of Mathematics (NCTM) mathematical proficiency strands. The Illustrative Mathematics curriculum

associates each lesson with one or multiple SCCCR standards, and corresponding IXL online homework assignments assess the understanding of that standard. Table 4.18 provides information on the alignment of the IXL online homework assignments and the associated strand. Appendix C also presents details about the posttest questions and their alignment with one or more strands. The following sections will guide this portion: (a) conceptual understanding, (b) procedural fluency, (c) adaptive reasoning, and (d) strategic competence.

Table 4.18 *IXL Online Homework Assignment Strand Alignment (n=13)*

IXL Online Homework Assignments	***CU***	***PF***	***AR***	***SC***
Complete an Input/Output Table	Y	Y		
Input/Output Tables: Find the rule	Y	Y		
Identify Functions: Tables	Y	Y	Y	Y
Complete an Input/Output Table using an Equation	Y	Y		Y
Find the Rule: Word Problems	Y	Y		Y
Identify Independent and Dependent Variables	Y	Y		Y
Interpret Points on a Graph of a Linear Function	Y	Y	Y	Y
Identify Functions: Graphs	Y	Y	Y	Y
Identify Functions	Y	Y	Y	
Complete a Table and Graph of a Linear Function	Y	Y	Y	
Compare Linear Functions: Tables, Graphs, and Equations	Y	Y	Y	Y
Compare Linear Functions: Graphs and Equations	Y	Y	Y	Y
Identify Independent and Dependent Variables in Tables and Graphs	Y	Y	Y	Y
Find Values Using Function Graphs	Y		Y	Y
Complete a Table for a Function Graph	Y		Y	Y
Identify Linear and Nonlinear Functions: Tables and Graphs	Y	Y	Y	Y

IXL Online Homework Assignments	*CU*	*PF*	*AR*	*SC*
Rate of Change: Graphs	Y	Y		

Note: CU = Conceptual Understanding, PF = Procedural Fluency, AR = Adaptive Reasoning, and SC = Strategic Competence. Y = Yes, the strand is assessed by that assignment.

Conceptual Understanding. Posttest and IXL online homework questions that focus on students' conceptual understanding assess how they connect relationships, processes, and theories across genres (National Research Council, 2001). All posttest items and IXL online homework assignments assessed students' conceptual understanding. Analysis of the IXL online homework assignments showed a mean score (*M* = 84) out of 100 and a standard deviation (*SD* = 30). Posttest items had a mean score (*M* = 1.27) out of 4 and a standard deviation (*SD* = 1.32). Descriptive statistics for items and assignments assessing conceptual can be found in Table 4.19.

Table 4.19 *Descriptive Statistics for Conceptual Understanding (n = 13)*

	Posttest		**IXL**	
	M	***SD***	***M***	***SD***
Knowledge Assessment	1.27	1.32	84	30

Procedural Fluency. Posttest items and IXL online homework assignments concentrating on students' procedural fluency assessed how well they executed mathematical tasks (Andrews, 2013; Rasila, Malinen, & Tiitu, 2015). Posttest items 1, 3, 4, 5, and 7 evaluated procedural fluency and had a mean score (*M* = 1.14) out of 4 and a standard deviation (*SD* = 1.34). All but two IXL online homework assignments gauged procedural fluency (Table 4.18) and had a mean score (*M* = 84) out of 100 and a standard deviation (*SD* = 29). See Table 4.20 for procedural fluency descriptive statistics.

Table 4.20 *Descriptive Statistics for Procedural Fluency (n = 13)*

	Posttest		**IXL**	
	M	***SD***	***M***	***SD***
Knowledge Assessment	1.14	1.34	84	29

Adaptive Reasoning. Adaptive reasoning focuses on the students' process of analyzing and communicating their thinking for posttest items and IXL online homework assignments (National Research Council, 2001; Groth, 2017). Posttest items 3, 5, and 7 evaluated students' adaptative reasoning and had a mean score (M = 1.34) out of 4 and a standard deviation (SD = 1.41). Out of the 17 IXL online homework assignments, 11 of them (Table 4.18) assessed adaptive reasoning and had a mean score (M = 81) out of 100 and a standard deviation (SD = 33). See Table 4.21 for descriptive statistics on adaptive reasoning.

Table 4.21 *Descriptive Statistics for Adaptive Reasoning (n = 13)*

	Posttest		**IXL**	
	M	***SD***	***M***	***SD***
Knowledge Assessment	1.34	1.41	81	33

Strategic Competence. Strategic competence was assessed by checking students' ability to represent mathematical ideas in multiple ways on posttest items and IXL online homework assignments (National Research Council, 2001). Items 2, 5, 6, and 7 evaluated students' strategic competence on the posttest and had a mean score (M = 1.13) out of 4 and a standard deviation (SD = 1.17). Twelve of the 17 IXL online homework assignments measured students' strategic competence and had a mean score (M = 83) out of 100 and a standard deviation (SD = 31). Descriptive statistics for strategic competence can be found in Table 4.22.

Table 4.22 *Descriptive Statistics for Strategic Competence (n = 13)*

	Posttest		IXL	
	M	***SD***	***M***	***SD***
Knowledge Assessment	1.13	1.17	83	31

Qualitative Findings and Interpretations

Qualitative data were collected to describe 8th Grade Mathematics students' experience with the IXL application. In addition, semi-structured interviews were designed to assess students' perceptions regarding the impact of IXL on their mathematical proficiency. The qualitative results will be broken into the following sections: (a) description of qualitative data, (b) description of qualitative data analysis, (c) participant descriptions, and (d) themes and interpretations.

Description of Qualitative Data

The purpose of this section is to detail the methods of qualitative data collection and analysis. This study collected qualitative data from four semi-structured interviews via four Zoom calls. Individual interviews varied in length, with the longest being almost 12 minutes and the shortest seven minutes; the interviews totaled 36 minutes and 50 seconds. Table 4.22 presents information on the sources of qualitative data and the information obtained.

Table 4.23 *Summary of Qualitative Data Collected*

Qualitative Data Source	**Number**	**Total Number of Codes Applied**	**Total Length of Interviews**
Interviews	4	122	36:50

Interviews of the participants were included to reveal their perspectives of IXL and describe their experiences. Interviews were transcribed verbatim through Otter.ai., and fluctuations in tone and emotion were added to the transcripts. Unfortunately, none of the participants chose to show their faces during the zoom call, so no physical expressions or facial emotions could be recorded. Table 4.24 shows the individual interviewee, the number of codes applied to the interview, and the interview length.

Table 4.24 *Data Sources, Total Codes Applied, and Interview Length*

Qualitative Data Source	**Total Number of Codes Applied**	**Length of Interview**
Charles	32	7:28
Arthur	18	6:27
Melody	36	11:38
Louise	36	11:17

Description of Qualitative Data Analysis

The purpose of this section is to provide details on how the interviews were analyzed, coded, and categorized. In addition, the methods and types of coding processes will be explained, and screenshots will be provided to create a comprehensive portrayal.

Once all the interviews were conducted and recorded, they were uploaded into Otter.ai, an online program that listens to audio recordings and converts them into written words. Then, each interview was listened to multiple times to make corrections for words or phrases missed by the program. Three rounds of coding were completed in the initial phases using elemental methods such as in vivo, structural, concept, attribute, and emotion coding. In vivo and structural codes were the focus of round one, and 63 codes were applied across the four interviews. In the second round, concept and attribute codes were applied to the transcripts, and 35 codes were added. In the final round of coding,

any answer that elicited a strong emotion was coded, adding the final 24 codes to the total.

Table 4.25 *Rounds, Type of Code Applied, and Total Number of Codes*

Round	Code Type	Total Number of Codes Applied
1	In Vivo, Structural	63
2	Concept, Attribute	35
3	Emotion	24

In Vivo coding was the most often used to preserve the language used by the participants. Saldana (2016) describes in vivo coding as using "words or short phrases from the participant's language in the data record as codes." (p. 294). For example, see Figure 4.1 for an In Vivo code example showing how the student uses the phrases "great job" and "excellent."

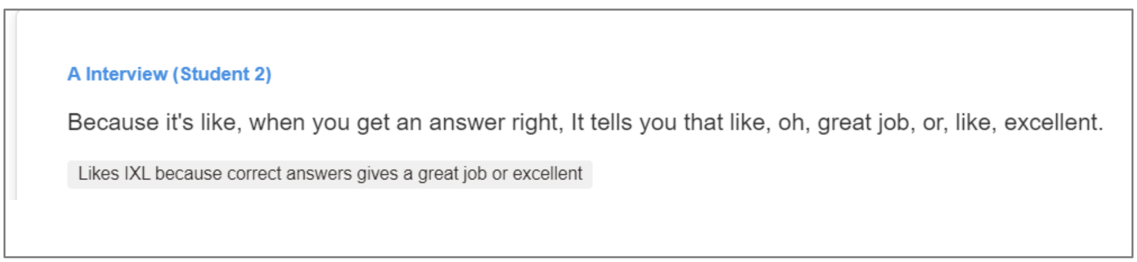


Figure 4.1 *In Vivo Code Example in Delve*

Structural coding made it easier to see how the answers from the students aligned with the research questions by applying a "content-based or conceptual phrase" to the participant's words (Saldana, 2016, p. 297). For example, Figure 4.2 shows how the questions and participants' answers align with the second research question about student perceptions of IXL. The interviewee speaks about both the positives and negatives of the program. She liked the learn by example but disliked losing points when trying to achieve a perfect 100 score.

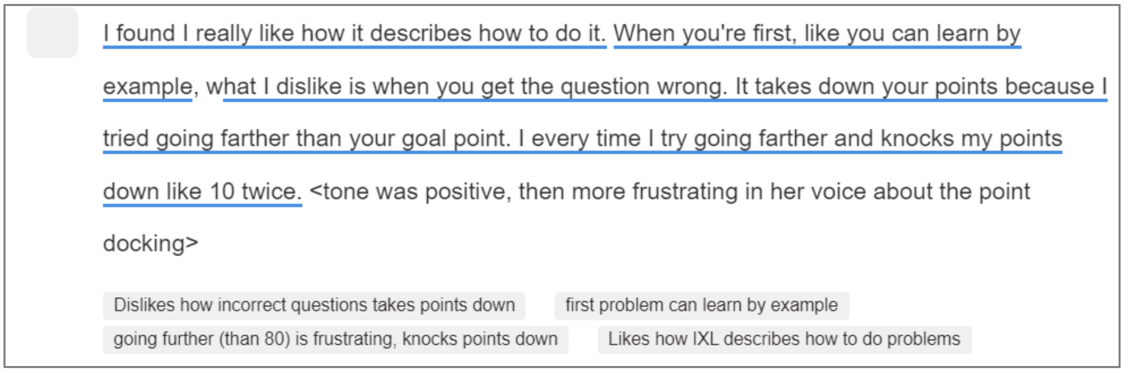


Figure 4.2 *Structural Coding Example in Delve*

Concept and descriptive coding were always intermingled with the other two techniques. Descriptive coding uses shorter phrases to describe what a participant has said in order to be able to build categories (Saldana, 2016). Concept coding is more interpretive and connects the statements made by the participant to the more significant meaning trying to be conveyed (Saldana, 2016). Evidence of concept and descriptive coding techniques are shown in Figure 3 in phrases such as feeling intimidated by the test and surprised by the posttest question.

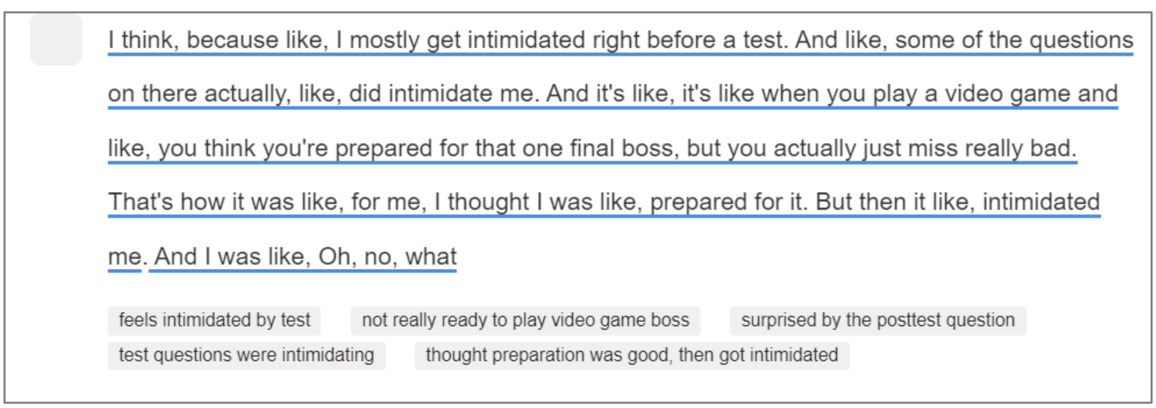


Figure 4.3 *Examples of Descriptive and Concept Coding*

There was also some attribute coding to get the participants' demographics (Saldana, 2016). Figure 4.4 shows how the participant's answers are coded to highlight

some of their demographics. For example, this interviewee stated his age, where he was born, and how long he lived in the Southeast region.

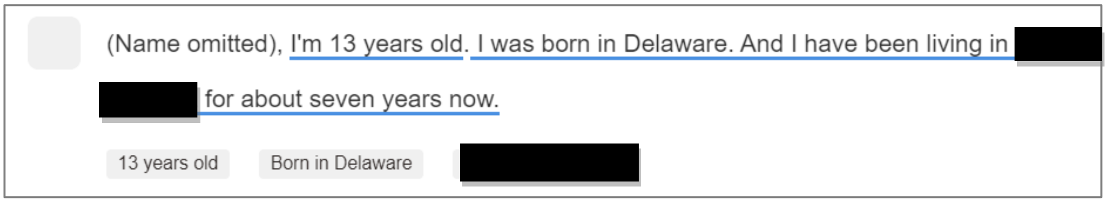


Figure 4.4 *Example of Attribute Coding*

The final technique used was emotion coding. This coding helped add another layer of detail to the participants' statements by attributing their feelings or inflections (Saldana, 2016). Figure 4.5 shows how the participant's tone and inflection were added to the stated words. The interviewee was upbeat when discussing the positives of IXL.

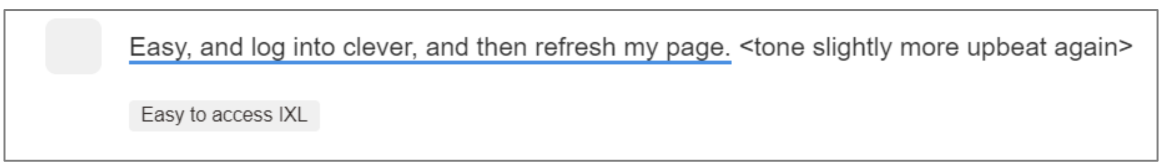


Figure 4.5 *Example of Emotion Coding*

Codes were assigned to an individual or multiple sentences if they were aligned in their concept or idea. Codes were made long enough so that a casual reader could understand the meaning or interpretation of the wording used by the participant. Also, each code was described so that further clarification of context and meaning could be easily identified when reading the code.

After the initial coding rounds, all the codes were transferred to a Google Jamboard onto sticky notes so they could be easily manipulated. Initially, all the codes were the standard yellow color (Figure 4.6). However, Jamboard has the option to use six different colors for the sticky notes, and the plan was to utilize those in the subsequent rounds of reorganization.

Figure 4.6 *Google Jamboard with All Codes on Sticky Notes*

Once all the codes were on sticky notes, axial coding was used. Axial coding is a process that divides the codes into categories, subcategories, and phenomena (Saldana, 2016). First, each sticky note was classified by topic into a large category and color-coded. Figure 4.7 shows the color-coding and large categories in which each group was classified. The six groups were defined as follows: *What students liked about the IXL app, what students disliked about the IXL app, useful features of the IXL app, teacher support, IXL posttest helpfulness*, and *posttest difficulties*. Each of the categories emerged after iterative rounds of rearranging and color-coding. Initially, the posttest section was one large group of green, but after further evaluation, it made more sense to divide the groups into two smaller categories. The only common theme between the codes was their reference to the posttest. One set of codes focused on connections between the posttest and IXL, and the other, disconnections between the posttest and IXL.

Figure 4.7 *Axial Coding using Different Color Sticky Notes for Categories*

Once the six categories were created, sticky notes were spread over multiple Google Jamboard slides to give room for subcategories. For example, posttest notes were grouped by similar content and color-coded to identify their subcategory quickly. Multiple iterations of this process fine-tuned where each code should belong.

Figure 4.8 shows how *teacher support*, *what students disliked about the IXL app*, and *IXL posttest helpfulness* are split into subcategories. First, the category of *what students disliked about the IXL app* was split into two subcategories: *Lowers score* and *cannot skip problems.* With only eight codes, *what students disliked about the IXL app* was one of the minor categories. *Next, teacher support* was split into three subcategories: *Videos*, *teacher help*, and *likes math.* Finally, the last category on this Jamboard slide, *IXL posttest helpfulness*, was split into three subcategories*: Reminder questions, remember questions*, and *uncertain*.

The category (Figure 4.9), *which students liked about the IXL app*, was split into five subcategories: *Positive affirmation is motivating, less time-consuming, and easy,*

feedback helps, progress bar and its features, and *likes it in general.* Each subcategory had at least three coded phrases, while the largest group of codes had seven. Finally, the *posttest difficulties* category was split into three subcategories: *fewer resources to help when stuck, not connecting IXL to posttest questions*, and *intimidating.*

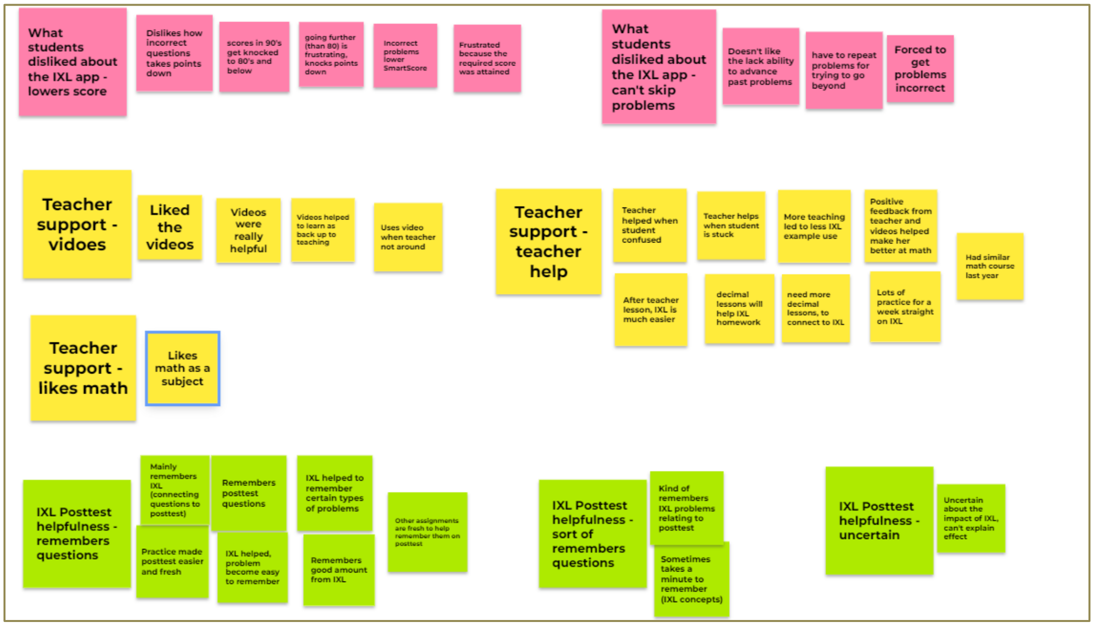


Figure 4.8 *Subcategory Jamboard 1*

Another category created was *the useful features of IXL such as correctness, examples, modeled work, and diagnostic exams*. Since the second research question is focused on participants' perspectives of IXL, it makes sense that this category would have the most codes. This category was split into five subcategories (Figure 4.10): *Incorrect problems will show how to solve correctly, diagnostic gives recommendations for assignments, example is helpful before starting assignments, progress bar shows correct versus incorrect*, and *learn by example not always used.* While most subcategories are positively framed codes, the *learn by example not used* is the only subset of more neutral codes.

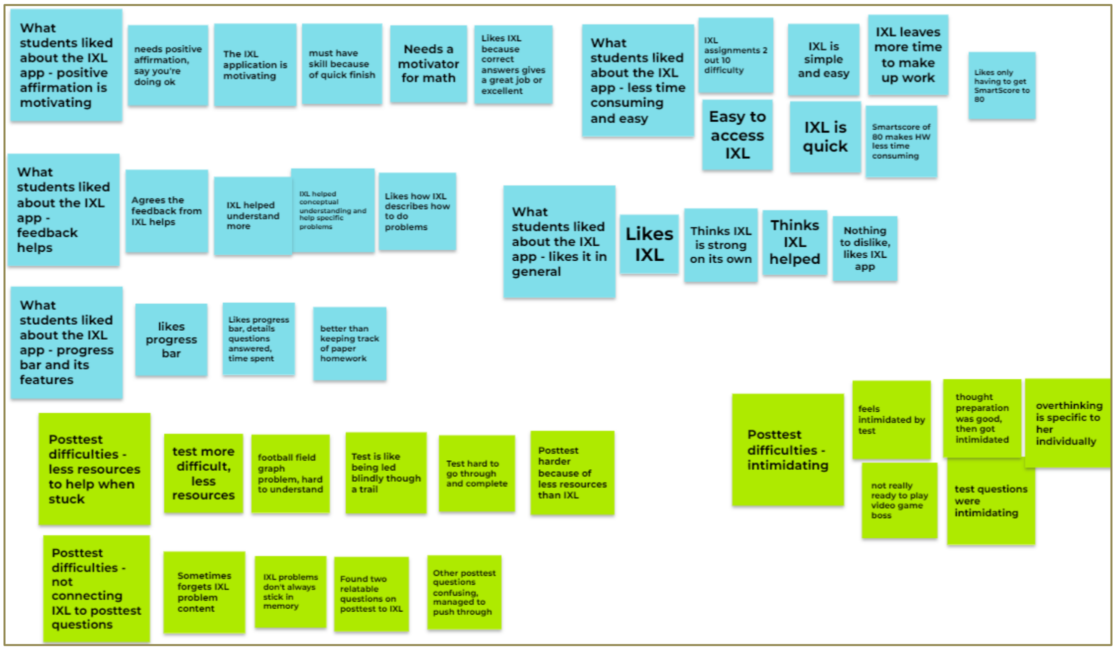


Figure 4.9 *Subcategory Jamboard 2*

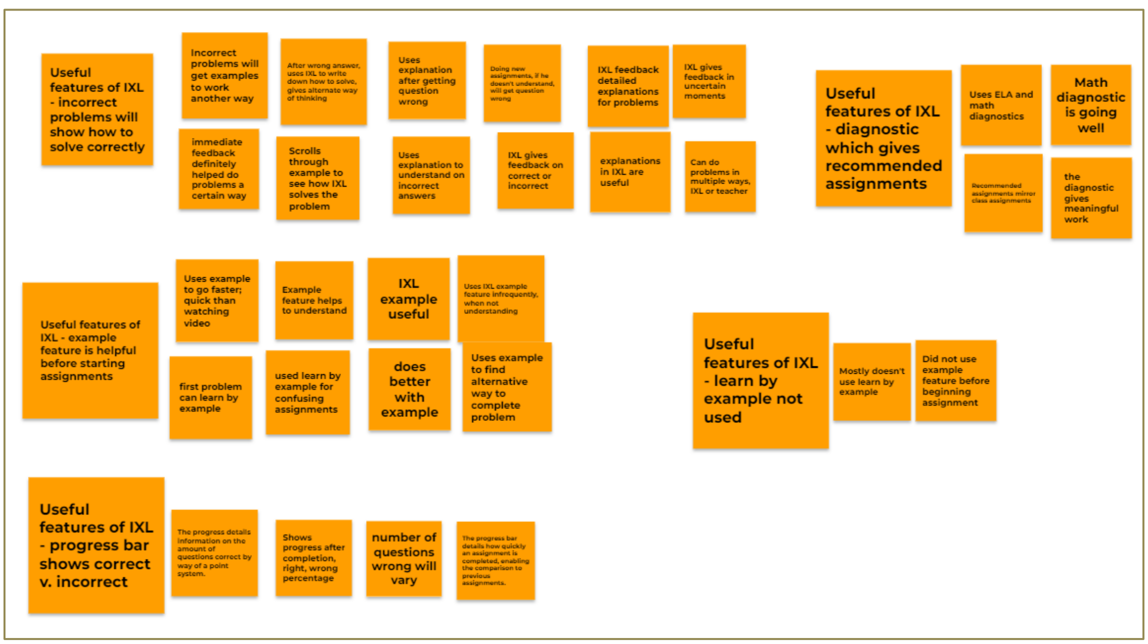


Figure 4.10 *Subcategory Jamboard 3*

After creating the subcategories, connections between subcategories and categories were analyzed to generate general themes that encompass the responses' main ideas. The themes were as follows: *IXL has many motivating and helpful features which*

aided participants' comprehension, remembering and connecting IXL content to the posttest varied¸ participants disliked the loss of points and inability to skip problems in IXL, and *videos, lessons, and liking math improved the participants' experience with IXL*. Table 4.18 shows how the subcategories and categories align with the overarching themes.

Participant Descriptions

Initially, 10 participants were asked to interview and provide insight into their experiences. The goal was to get perspectives from participants with varying amounts of success on the posttest. Of the 10 participants asked to interview, four agreed to speak with me via Zoom. In order to protect the identities of the participants, pseudonyms were used. The participants will be described as follows: (a) Charles, (b) Arthur, (c) Melody, and (d) Louise.

Charles

The first participant interviewed was a 13-year-old Caucasian male. He is a native of Delaware, where he lived for approximately six years before moving to South Carolina. Charles is also an avid gamer, playing Rocket League and Call of Duty in his free time. He enjoyed the complex math challenges presented in class and was very independent in his work completion. Many of his IXL topics were completed independently, and he often helped other students after completing his assignments.

Arthur

The second participant interviewed was a 13-year-old Latino male. He was born in Mexico, moved to Texas, then Florida, and finally found a home in South Carolina. He is fluent in English and Spanish but still mildly struggles with the complexities and

nuances of the written English language. Most of his activities outside of school include gaming, playing outside, and helping his dad. He is also a very independent student and often tried to complete the IXL activities before I even taught the lesson. He is another student who frequently helped others when his work was complete.

Melody

The third participant interviewed was a 13-year-old Caucasian female. She was born and raised in Pittsburgh, Pennsylvania, and moved to South Carolina to live with her aunt and uncle. Melody considers Math her favorite subject. She enjoys drawing and creating artistic pieces of work outside of school. Melody also enrolled in the Khan Academy Algebra I course to improve her math skills for high school. She significantly improved her Measure of Academic Progress (MAP) test during the year due to her hard work and diligence. She is quiet and reserved and would complete additional Khan Academy assignments when finished with her IXL assignments.

Louise

The fourth participant interviewed was a 13-year-old Caucasian female. She is a South Carolina native and has lived in North Charleston for most of her life. She is very introverted and enjoys completing complex drawings and art pieces. Assessments and high-stakes testing intimidate her and bring on much anxiety and stress, even when she feels prepared. Louise often did very well on her IXL activities but scored poorly on her assessments.

Themes and Interpretations

This section describes the themes and categories ascertained from participants' answers to the interview questions. Wherever possible, existing literature has made

connections to the themes and categories. An integral part of this review ascertains whether a theme or category disproves or confirms existing literature. The themes that will be discussed are as follows: *IXL has many motivating and helpful features which aided participants' comprehension, but some features were demotivating, remembering and connecting IXL content and classroom instruction to the posttest varied*, and *videos, lessons, and liking IXL helped the participants complete assignments and understood the content in IXL.* A breakdown of the themes, categories, and subcategories can be found in Table 4.26.

Table 4.26 *Themes, Categories, and Subcategories*

Themes	**Categories**	**Subcategories**
IXL has many motivating and helpful features which aided participants' comprehension, but some features were demotivating	What participants liked about the IXL application	Positive affirmation is motivating
		Feedback helps
		Features of the progress bar
		Less time consuming and easy
		Likes IXL in general
	The useful features of IXL such as correctness, examples, modeled work, and diagnostic exams	Incorrect problems will show how to solve correctly
		Example feature is helpful before starting assignments
		IXL program shows correct versus incorrect after answering
		Diagnostic gives recommended assignments
	Participants disliked their SmartScore lowering, they could not skip problems, and lessons did not seem to connect with IXL	Learn by example not always used
		IXL application lowers score
		Can't skip problems
		Better coordination of Illustrative Mathematics lessons with IXL content

Themes	Categories	Subcategories
Remembering and connecting IXL content and classroom instruction to the posttest varied	Participants remembered, sort of remembered, or were uncertain if IXL questions connected with the posttest items	Remembers questions Sort of remembers questions Uncertain
	Intimidation, lack of immediate help, and connection to IXL made the posttest difficult	Fewer resources to help when stuck Not connecting IXL to posttest questions Intimidating
Videos, lessons, and liking math helped the participants complete assignments and understood the content in IXL	Videos, lessons, and liking math helped the participants complete assignments and understood the content in IXL	Teacher created IXL content videos Teacher lessons and individual help Likes IXL online homework application

Theme 1: IXL Has Many Motivating and Helpful Features Which Aided Participants' Comprehension, But Some Features Were Demotivating

Theme 1 encompasses participants' descriptions of how they liked or disliked their experience with the IXL application and what they found helpful or a hindrance. According to existing research, online homework programs, such as IXL, have improved students' self-empowerment when completing assignments (Arasasingham et al., 2011; Archer & Olson, 2018; Arora et al., 2013). The participants discussed numerous features of IXL, mentioning what they liked and found helpful in their learning, enabling them to work more independently. Online homework programs that rewarded accuracy and

completion correlated with improvements in comprehension (Goehle & Wagaman, 2016). Three categories are discussed that further explain this theme: (a) what participants liked about the IXL application, (b) the valuable features of IXL, and (c) Participants disliked their SmartScore lowering, that they could not skip problems, and lessons did not seem to connect with IXL.

What Participants Liked about the IXL Application. This category arose after discovering commonalities among the participants mentioning the motivating factors of IXL and how their SmartScore went up every time they got a question correct. The statements from participants were framed positively and supported the use of IXL for online homework assignments. Strong and positive attitudes have been associated with higher grade point averages (Doorn et al., 2010; Hagger, Sultan, Hardcastle, & Chatzisarantis, 2015; Lin et al., 2008). Arthur, for example, found the IXL application motivating when it encouraged correct answers. Similarly, Louise needed feedback to ensure that she did the problems correctly. Students 2 and 4 are quoted below on how IXL shaped their attitudes:

Arthur: There is nothing really to dislike; I like the app. Because it is like, when you get an answer right, it tells you that like, oh, great job, or, like, excellent. And it's like, it's motivating, you know?

Louise: Yeah. So, I guess like, the real thing about is that like, I just need to like, I need like a motivator or something positive to be like, oh, yeah, you are doing okay.

Another positive commonality among the interviewees was using feedback from the IXL application. Differentiated feedback in online homework has improved students'

mathematical skills and autonomy (Schuetz, Biancarosa, & Goode, 2018). The speed of innovation must also be quick enough for students to process mistakes and correct mislearning (Alexander, 2013). All four interviewees discussed the importance of receiving feedback from IXL:

Charles: Every once in a while, when I do not understand it. I will scroll down and look at how they did it. And then usually I can understand it from there. So yeah, it helps.

Melody: Yes. (The example was useful)

Arthur: Oh, yeah, it did help me.

Louise: I think that it definitely helped me on a few things. It told me specifically like to do it like this, not this way. It shows you how. It really explains detail by detail on how to do it correctly.

Students 3 and 4 also liked the progress bar feature that provided additional information on an individual assignment. The progress bar shows students three pieces of information: how many questions they have answered, the elapsed time, and their current SmartScore, which tracks the difficulty a student achieved out of 100 (www.ixl.com). Students who see their progress know that their time is purposeful and meaningful and can aid their classroom performance (Maltese et al., 2012). For example, students 3 and 4 said:

Melody: I also really like how you can see our progress.

Louise: Yeah, sometimes I will use it, and it is like, oh, well, I finished this quicker than that. So, I must have this skill.

Of all the features IXL provides, the feedback on incorrect answers seemed the most helpful for the interviewees. All four students gave positive reviews. Two students found the encouragement from correct answers motivating, but for different underlying reasons. One student liked the encouragement, and the other needed positive affirmation. The last two of the interviewees liked the progress bar and its information.

The Useful Features of IXL, Such as Correctness, Examples, Modeled Work, and Diagnostic Exams. This category emerged as the participants described the valuable features mentioned when asked about IXL's features. Participants highlighted the many positive aspects of the program, such as feedback on correctness, modeled work, diagnostics, and correctly worked examples. One feature paramount in an online homework program is immediate and corrective feedback (Gönülateş & Kortemeyer, 2017; Leong & Alexander, 2013; Lunsford & Pendergrass, 2016). Rasila et al. (2015) showed improved grades when online homework tasks had immediate corrective feedback. Three interviewees commented on this portion of the IXL online homework application. Each student commented on different aspects of the feedback and how they perceived its helpfulness. For example, students 2 and 3 found the program gave them an additional way of solving the problem, and Melody would compare the teacher's method with the IXL method to see which way she better understood. Louise liked how IXL broke the problems down step-by-step on how to solve them correctly. The students said:

Arthur: That just gives you an example of what the problem is, and then you can work it out another way.

Melody: When I get an answer wrong, I read through each part, and write down how they solved it. So, I have another way of thinking about

it. So, I can do it better. Or I can do it the way I understand it if it is your way or the IXL way.

Louise: I think that it definitely helped me on a few things it told me specifically oh, I wish I was able to do it like this, not this way. It shows you how it really explains detail by detail on how to do it correctly.

Before beginning any IXL assignment, the student has an option to review a worked example. Online homework containing modeled work has enhanced comprehension (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006). Modeled work also increased students' self-regulation of their understanding (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006; Yerushalmy et al., 2017). Student responses differed on the use of the example. One student enjoyed and used IXL's example solution, another used it sparingly for clarification, and one had not used it. The students' responses were as follows:

Melody: I found I really like how it describes how to do it. When you are first, you can learn by example.

Louise: Sometimes, when an assignment is confusing, I will use the learn with an example, but most of the time, I do not really use it.

Charles: No, I have not used that.

While modeled work can enhance learners' understanding, the example problem at the beginning of IXL online homework assignments was used moderately.

While the students are completing their work, the progress bar is always visible on the side of the program. It was discussed prior as something students liked;

additionally, Louise used it to build more self-awareness of her learning. Progress tracking on online homework improved learners' self-regulation of their understanding and analyses (Alsulami, 2016; Glancy & Isenberg, 2013; Keengwe et al., 2014; Miller-First & Ballard, 2017). Also, it built self-consciousness by reflecting on their learning (Arora et al., 2013; Babaali & Gonzalez, 2015; McLoughlin, Lee, & Chan, 2006; Seo & Engelhard, 2014). Louise appreciated the feedback on questions answered, time spent, and the SmartScore. Louise stated, "Specifically on the progress bar, where it tells you how many questions you have answered, how much time you have spent on it. And your points are based on the amount of questions you have correct." Research shows that Louise could regulate her learning and remain actively aware of her abilities using the progress bar.

The final feature utilized by one student was the IXL diagnostic assessment. Teachers can assign it, or students can opt to take it independently. The diagnostic serves two purposes. First, it assesses students' current mathematical ability according to their grade level or course. Second, suggested assignments are provided based on the student's incorrect answers. Prior studies have shown that problems leveled appropriately have improved conceptual understanding (Kanive et al., 2015; Abramovich, 2015). Melody used the diagnostic to find additional work to improve her weaknesses. Melody stated in her interview, "And how it (IXL) does like diagnostics too, so it can show us and gives us work that we need to work on and stuff to do." This student intended to improve her math scores and was excited when talking about the diagnostic feature. She even used the diagnostic feature for her English class as well.

Participants Disliked their SmartScore Lowering, They could not Skip Problems, and Lessons did not Seem to Connect with IXL. This category emerged as participants detailed parts of the IXL application that they found unfavorable. Commonalities between answers showed that there were some negative aspects of the IXL online homework assignments that they would have liked to change. As discussed, IXL assigns a SmartScore that awards points for correct answers and removes points for incorrect answers. All students were required to achieve a SmartScore of 80 for an assignment to be complete. Two students found the loss of points when getting a question incorrect to be a negative aspect of the IXL application. Feedback from an online homework program should aid students' knowledge and enable them to form connections to solve the task (Laswadi, Darwis, & Afgani, 2016; VanDerHeyden & Codding, 2020). As the SmartScore is lowered, the number of attempts must increase to achieve 80. Prior research has shown that when similar problem attempts increase, the connection between learning and performance decreases (Bowman, 2014; Gönülateş & Kortemeyer, 2017; Kortemeyer, 2015; Yourstone et al., 2010). If Charles became stuck, he did not want his SmartScore to be lowered, so he would get a problem wrong only to see a worked solution. Melody disliked her lower score because she wanted to complete an assignment fully and try the upper-tier problems after an 80 was achieved. Students 1 and 3 said:

Charles: Okay, one thing I do not like about it is that you cannot go on to the next question if you do not understand it. You have to get it wrong. If you already have that score, it is going to lower your score.

Melody: It takes down your points because I tried going farther than your goal point. Every time I try going farther and knocks my points down like ten twice . . . And you know, like, how if you are in the 90s, it will knock you back down below an 80.

Both students became frustrated at lowered scores, which lessened their engagement with the IXL application.

Melody keenly observed disconnects between the content taught and the IXL online homework. She felt there was a disparity between the types of solutions that the Illustrative Mathematics curriculum showed versus the types of solutions that IXL expected. She wanted the teacher to connect the lesson more with the IXL homework. Research has shown that performance increases when data-driven decisions are made to alter classroom teachings (Arora et al., 2013; Babaali & Gonzalez, 2015; Bowman, 2014; Kong & Song, 2013; Roschelle et al., 2016; Tabor & Minch, 2013; Yerushalmy et al., 2017). Melody stated,

> You should do more of the decimal lessons than the IXLs. But, because of the decimals, when we do those, it is easier for us to comprehend. And you can teach us more about decimals. And then, when we go to IXL, we can use the decimal to help us on the IXL.

When Melody stated "decimals," she was referring to the fact that IXL used 3.14 (for Pi), and the Illustrative Mathematics text used the symbol for Pi (π). Therefore, IXL would multiply answers by 3.14, and Illustrative Mathematics would not multiply by Pi but attach it to the numerical answer. The mismatch between the lessons and IXL online homework assignments was frustrating for the student because it added another

unexpected layer of difficulty. She suggested that future iterations of this content should anticipate the mismatch and prepare students to provide answers in either form, decimal, or Pi.

Overall, the positive comments about IXL being motivating and helpful outweighed the negative ones. Students found the encouragement and rising SmartScores motivating but disliked when the SmartScore moved in the opposite direction. The feedback on incorrect answers was helpful, and the example feature was useful. Additionally, the progress bar contained valuable information that helped the students gauge their understanding of topics. Not all the features of the program were liked, unfortunately. The loss of points and being forced to get problems incorrect to see solutions frustrated participants.

Theme 2: Remembering and Connecting IXL Content and Classroom Instruction to the Posttest Varied

Participants in this study were probed on how the IXL online homework influenced their posttest performance. This theme was shaped by participants' responses on their feelings about how the IXL online homework assignments and posttest were related. Interview answers showed that the participants had different perspectives on the interrelatedness of the classwork, homework, and the posttest. Research on the effects of online homework and performance is mixed. Multiple studies show no significant effects on learner performance from using an online homework system to deliver the content (Cole & Todd, 2003; Hauk, Powers, & Segalla, 2015; Mathai & Olsen, 2013). However, Brewer (2009) and Goehle and Wagman (2016) demonstrated that weaker mathematical students improved their mathematical performance when using online homework. Two

categories are discussed that further explain this theme: (a) participant variation in the degree of IXL helpfulness on the posttest, and (b) intimidation, lack of immediate help, and connection to IXL made the posttest difficult.

Participants Remembered, Sort of Remembered, or were Uncertain if IXL Questions Connected with the Posttest Items. This category was shaped by the varied responses on the relationship they found between the IXL online homework and the posttest. Interview answers revealed that remembering and connecting IXL online homework content to the posttest ranged from a "yes" answer to "I do not know." For example, Charles felt his test results positively correlated with his IXL assignments. Research has shown that comprehension increases when online homework rewards accuracy and completion (Goehle & Wagaman, 2016). Both reward features are embedded within the framework of the IXL program, giving students positive comments for correct answers and certificates for completed assignments.

Furthermore, multiple studies have shown positive statistical significance in student performance when using online homework innovations (Martorell, & McIntire, 2011; Archer & Olson, 2018; Arora, Yun Jin, & Masson, 2013; Babaali & Gonzalez, 2015; Bowman, 2014; Burch & Kuo, 2010; Dodson, 2014; Doorn, Janssen, & O'Brien, 2010; Jonsdottir, Bjornsdottir, & Stefansson, 2017; Roschelle, Feng, Murphy, & Mason, 2016a; Schubert, 2013). Charles felt the IXL application's consistent practice helped improve his posttest score. He responded in the interview, "I feel like since we have that practice, on the assignments, it just overall made the last posttest much easier and fresh. The other assignments are fresh in my head. We are doing that every single day for a

week straight." Connections were made from the posttest to Charles's IXL online homework assignments, which correlate well with several studies.

The other three participants had difficulty remembering and connecting the IXL online homework with the posttest questions. Research has shown that using an online delivery system such as IXL can yield no significant effects (Cole & Todd, 2003; Hauk, Powers, & Segalla, 2015; Mathai & Olsen, 2013). Demirci (2007) also showed minimal improvement in exam performance in the online homework group, but the effect was insignificant. Therefore, online homework can yield minimal to no effect. Students 1 and 3 felt similarly in their responses and used language like "kind of" and "sort of" when asked. Neither student could connect IXL online homework assignments to the posttest questions directly. Louise was the sole interviewee who felt she could connect two questions and went into further detail about a particular problem on the test. Her answer, however, was not definitive and used similar language to students 1 and 3. Here are the students' responses when asked about how they felt the IXL online homework impacted their posttest results:

Charles: Yeah, sort of, sort of, I do not know. I cannot really explain it.

Melody: Kind of.

Louise: Like, two questions, maybe I found a relatable question that I have done.

Louise: One of the questions was a graph where it showed somebody running on a football field, and I did not understand that one at first, and then we did an IXL on it. And I was like, oh, well, this is kind of easy to remember. And it sort of helped me.

While Charles seemed to think that the IXL made the posttest easier, most participants had difficulty making that connection. Louise recalled the particulars of a posttest question, but she felt there was little relatability between IXL assignments and the posttest assessment.

Intimidation, Lack of Immediate Help, and Connection to IXL Made the Posttest Difficult. A further exploration formed this category into the impact of IXL online homework on remembering and connecting posttest content. It was revealed that students faced additional challenges when attempting to connect the information they learned. Therefore, the posttest was found to be difficult for a variety of reasons. Two participants thought the posttest was tricky and intimidating, and they could not remember or connect the IXL online homework to the posttest. While IXL shows correct solutions and gives feedback on correctness, it does not give process-based responses. Instead, the program validates or invalidates solutions, followed by another question or a written solution. Research has shown, for example, that correctness-based feedback was not enough to positively affect performance (Mathai & Olsen, 2013; Stickles, 2017). However, significant performance improvements were shown when feedback was given on a step-based analysis and provided exemplary work (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006). Melody felt the test was difficult because of the lack of resources available during the test compared to the IXL online homework. When asked about why she thought the posttest was much more difficult, she stated:

> The test was a lot more hard, because you do not have the resources that you have on the computer. And so, it was kind of hard to go through and do it.

Louise thought she was prepared, but once the test was in front of her, she became intimidated and could not remember her practice. She said:

> I think because I mostly get intimidated right before a test. And, like, some of the questions on there actually, like, did intimidate me. And it is like when you play a video game, and you think you are prepared for that one final boss, but you actually just miss really bad. That is how it was for me. I thought I was, like, prepared for it. But then it intimidated me. And I was like, oh, no, what did I do?

The IXL online homework did not connect well with the posttest questions for both students. Perhaps they had grown accustomed to the available resources, or the skills needed to succeed had not yet been cemented by the number of practice problems.

The varied connections from the IXL online homework to the posttest showed that individual students conceptualize the mathematics content differently. Charles felt the IXL prepared him well, and he remembered the content quickly. The rest of the students were uncertain about the impact of the IXL online homework on their posttest scores. Students 3 and 4 thought the test was complex, and Louise even felt intimidated by the types of questions. Therefore, students' connection between the IXL online homework and the posttest had many answers, aligning with metadata from all the studies.

Theme 3: Videos, Lessons, and Liking IXL Helped the Participants to Complete Assignments and Understand the Content in IXL

For the last theme, participants described different aspects of the Illustrative Mathematics curriculum and classroom environment that shaped their opinion on the difficulty levels of the IXL online homework assignments. This theme means that

participants felt that teacher-created videos, lessons, and their outlook on IXL were positives that helped them to understand the material. In addition, research has shown that students who engage in learning and receive more personal feedback develop greater depths of understanding (Lai & Hwang, 2016; Morris, 2019) and increase class participation (Lai & Hwang, 2016). Therefore, the interplay between the course elements and the IXL online homework can influence perceptions and attitudes.

Three participants mentioned videos after probing about what aided their experience with the IXL online homework assignments. Explanatory videos were created and uploaded in Canvas, our learning management system, to aid students in their completion of the IXL online homework**.** Videos clarified IXL online homework content for confused or stuck students, and a teacher was not available for help. IXL contains written explanations, but not videos, that students can view before starting an assignment or after answering a question incorrectly. Mathematics performance on online homework improved when internet-based support was available (Ali Alshehri, 2017; Gönülateş & Kortemeyer, 2017; Mathai & Olsen, 2013) and differentiated feedback and support supported autonomous learning (Lai & Hwang, 2016; Morris, 2019). The students found the video support to be helpful in different ways:

Arthur: I use those (videos) whenever you are not here.

Melody: One thing I did find helpful is when we do not understand what you are teaching, you made the little videos that show a different style. That is what I felt was really helpful for me.

Louise: Then the videos you will put right underneath the assignment (made her better at math).

Confirming past research, the additional support in an online environment improved the participants' experience with the course and the IXL online homework assignments.

Interview participants were further questioned about other classroom modalities that may have impacted their assignment completion in IXL. For example, content related to IXL online homework assignments was presented during teacher lessons and supported in class with one-on-one and small group help sessions. The teacher could be an additional resource while students complete their IXL online homework assignments. Prior research had shown that the student-teacher relationship and instruction quality improved when performance feedback was given promptly (Arora, Yun Jin, & Masson, 2013; Babaali & Gonzalez, 2015; Bowman, 2014; Kong & Song, 2013; Roschelle et al., 2016; Tabor & Minch, 2013; Thiet, 2017; Yerushalmy, Nagari-Haddif, & Olsher, 2017). Mathematics proficiency, furthermore, has been dramatically improved through specific instruction about theories, processes, and process-based feedback on errors (Sheldon, Epstein, & Galindo, 2010). When the students were questioned about additional ways that helped them with the IXL online homework, they expressed that the lessons and support provided by the teacher were helpful. Often there was ample time to complete the assignments in class, so one-on-one help from the teacher was a staple of the classroom environment. Interview quotes from the students are as follows:

Charles: You help most of the time like that.

Arthur: Yes. Because after you go over it and then I do the IXL, I will be able to do it much easier.

Melody: Especially when you are teaching more, and the more I got to act as like I was being helped through it, so I was not really paying attention to it.

Louise: Definitely positive feedback from you (helped with understanding).

In line with prior research, all four participants had positive interactions within the classroom, which supported their understanding of the material through direct help or the lesson.

The final subcategory to emerge during questioning was how students' perception of the IXL online homework program positively shaped their attitudes. All participants expressed optimistic perceptions of the IXL online homework application. Demirci (2007) indicated that learners' attitude toward technology usage was influenced by online homework. Research has also shown that IXL gives learners control of their learning and success, which results in a positive perception of the program (Ali Alshehri, 2017; Sullivan, 2020; Wooten & Dillard-Eggers, 2013; Xu & Wu, 2013). Lower- and middle-achieving students' satisfaction increased in courses assigned online homework (Leong & Alexander, 2013). Students 1 and 2 both expressed that they generally liked the application. Melody liked the descriptions of how to complete the assignments, while Louise appreciated the quickness assignments can be completed and the ease of tracking homework assignments. When probed about what they thought of the IXL online homework application, the quotes were as follows:

Charles: I like it (IXL).

Arthur: Well, I mean, I like math, in general. There is nothing really to dislike; I like the app.

Melody: I found I really like how it describes how to do it.

Louise: I definitely like how it is quick. And it is a bit simple and easy. And it is a lot better than keeping track of like paper homework; you can hand it to you.

Each participant expressed appreciation for the application differently, but all found something positive about the program. In addition, students' academic achievement in the study correlates well with prior research, connecting greater course satisfaction with an online homework innovation.

Chapter Summary

The purpose of this chapter was to present and analyze the data collected regarding two overarching research questions: What were the students' perceptions of and what was the impact of the IXL online homework on students' mathematical proficiency? Using descriptive data from the student survey, the perceived impact of the IXL online homework was neutral in effect, with neither a positive nor negative significance. Inferential statistics on the pre- and posttest showed a significant increase in the mean scores, and Kuder-Richardson Formula 20 test for reliability score makes that conclusion reliable. Breaking down students' mathematical proficiency and analyzing it according to the four strands showed similar results. Student interviews revealed several insights into the perceived impact of the IXL online homework. Overall, IXL was very motivating and helpful, with a few features that could use some alterations. For example, connecting and remembering IXL content to the posttest varied by the student, and three

of the four interviewed had difficulty doing so. Furthermore, the structure of the class lessons, embedded videos in Canvas, and liking IXL were perceived to positively influence students' experiences with the IXL online homework assignments.

CHAPTER 5

DISCUSSIONS, IMPLICATIONS, AND LIMITATIONS

Chapter Five will ground the research findings with previously conducted studies on online homework. This research aimed to determine the effects of IXL online homework assignments on students' mathematical proficiency and perceptions in 8th Grade Mathematics at Cedar Hill Middle School. Quantitative (i.e., student surveys and pre- and posttests) and qualitative (i.e., student interviews) methods were employed for data collection and analysis. The impacts of the research on mathematical proficiency are discussed according to four of the five strands: strategic competence, conceptual understanding, adaptive reasoning, and procedural fluency (National Research Council on Mathematics, 2001). In addition, two significant categories emerged from an analysis of student interviews on their perceptions of the IXL online homework: impact on student learning and use of resources. Research discussions, implications, and limitations are analyzed in the following sections.

Discussion

Numerous studies have analyzed the use of online homework assignments instead of traditional pen and paper assignments. The effectiveness of online homework assignments on mathematical proficiency is a source of much deliberation and discussion as new modalities replace older models of homework delivery. Prior research has shown

that successful increases in mathematical proficiency focused on the strands for developing independent learning (Cozean, 2011; James, 2016) and improved competence (Allsopp, Lovin, & van Ingen, 2017). This research sought to expand the ideas of effective online homework on the mathematical proficiency strands and students' perceptions. Therefore, the discussion will be framed in the context of the two research questions and sub-questions.

Research Question One: How does IXL online homework affect the mathematical proficiency of 8th Grade Mathematics students at Cedar Hill Middle School?

The effectiveness of online homework has been tied to increases in a few key metrics. Online homework that increases time on task over traditional homework correlates positively with performance (Babaali & Gonzalez, 2015; Bowman, 2014). Additionally, online homework has also been shown to increase comprehension when feedback data was utilized for altering classroom instruction (Jonsdottir et al., 2017; Roschelle et al., 2016). IXL provides information about participants' time on task, provides process-based feedback, and gives examples of problems (Kolmos, 2010). The pre- and posttest results showed small positive gains (Pretest M = 21.92; Posttest M = 31.34).

These results are similar to the Dmirici (2007) study, which showed that an online homework delivery system had minimal effect on exam performance. Additionally, students with low mathematical proficiency can have a compounding effect as they progress in their education. They are far more likely to fall and stay behind grade-level standards if they have difficulty with mathematics relatively early (Nelson, Parker, & Zaslofsky, 2016). Most students who participated in the study were low-achieving

students before enrolling in 8th Grade Mathematics based on their MAP (Measure of Academic Progress) scores.

There was a disparity in the relationship between the IXL online homework and the related posttest mean (Posttest M = 31.34; IXL M = 84). Participants scored much higher on the online homework assignments than on the posttest. The structure of the IXL SmartScore may be misleading. A SmartScore is raised by getting questions correct and lowers when answers are incorrect. There is no limit to the number of questions a student can answer to achieve the recommended SmartScore of 80 points. Grades were given to each student as a percentage of 80 possible points. Prior research has shown that learning and performance decreased as skill attempts increased (Bowman, 2014; Gönülateş & Kortemeyer, 2017; Kortemeyer, 2015; Yourstone et al., 2010). Kortmeyer (2015) showed that five attempts were the maximum number of times a skill was attempted before random guessing and learning regression increased significantly (Kortemeyer, 2015). Therefore, a SmartScore is unreliable when a participant uses copious attempts to achieve a predetermined achievement metric.

Further discussion of students' mathematical proficiency on the posttest can be seen by looking closer at the relationships between the IXL online homework assignments and posttest questions on (a) strategic competence, (b) conceptual understanding, (c) procedural fluency, and (d) adaptive reasoning.

Strategic Competence

Items that assessed strategic competence checked students' ability to create, represent, and answer mathematical problems (Andrews, 2013; Groth, 2017; Rasila et al., 2015; Suh et al., 2012). Students received an average of approximately 28% correctness

for all questions on the posttest related to this strand (*M* = 1.13/4.0; *SD* = 1.17). There was a significant disparity when comparing the posttest to IXL online homework descriptive data. Students averaged over 83% on the 12 homework assignments that assessed strategic competence (*M* = 83.0; *SD* = 31.0). Similar to the previous comparison of SmartScores and the number of attempts, SmartScores have not correlated well with assessment performance.

Prior research has shown that strategic competence can be improved when students' problem-solving processes are grounded in their mathematical understandings (Suh, 2007; Ozdemir & Pape, 2012; Suh et al., 2012). Furthermore, to build strategic competence, it has been shown that students must go through a reciprocal construction and evaluation process necessary to reflect upon and grow their mathematical thinking (Ozdemir & Pape, 2012; Suh et al., 2012). IXL is a program that primarily uses multiple-choice or short-answer-type questions for mathematics. If a student works a problem on IXL incorrectly, they can review it or move on. However, there are no indications from the IXL data to tell if students were using the available worked solution to review their work and reflect upon their mathematical process and understandings. Overall, the impact of the IXL online homework was minimal in increasing posttest scores on items that assessed students' strategic competence.

Conceptual Understanding

Conceptual understanding items assess students' abilities to correspond, describe, and theorize mathematical arguments (Zahner et al., 2012). Students earned an average of approximately 32% correctness for all posttest questions related to this strand (*M* = 1.27/4.0; *SD* = 1.32). Similar to items that assessed strategic competence, items that

assessed conceptual understanding on IXL online homework slightly impacted posttest items. Students averaged 84% on all 17 homework assignments that assessed conceptual understanding (M = 84.0; SD = 30.0). Therefore, there seems to be a gap in knowledge that the IXL online homework assignments did not address.

Online homework that provides structured feedback has been shown to correlate with increased conceptual understanding (Archer & Olson, 2018; Cheng et al., 2004; Hegedus et al., 2015; James, 2016; Rasila et al., 2015). IXL provides answers to questions in a picture and text format, requiring students to scroll through and interpret multiple pieces of information. For students to absorb this information, it requires a strong background in reading comprehension. Students who struggle with reading comprehension have correlated with learning difficulties in mathematics (Nelson, Parker, & Zaslofsky, 2016). Therefore, it is unknown how much low-achieving mathematics students will absorb when given text-based solutions if their reading comprehension abilities are also limited.

Conceptual understanding also has been shown to correlate positively with online homework that allows individuals to express their knowledge in various forms (Kanive, Nelson, Burns, & Ysseldyke, 2014; Rasila, Malinen, & Tiitu, 2015; Riegel & Branker, 2019). IXL accepts open-ended answers; however, answers must often be specific and formatted for the application to process. Thus, the IXL program has limitations in accepting various knowledge expressions. As a result, students exclusively using IXL for online homework and mathematics practice would limit their ability to develop conceptual understanding fully.

Students' conceptual understanding improvements also came from appropriately leveled problems based on their abilities (Kanive et al., 2015; Abramovich, 2015). IXL structures assignments on curriculums and grade-level standards. The challenge is that many Cedar Hill Middle School students are below grade level, so the content being taught and assessed is too challenging. When content is appropriately leveled, students have increased conceptual understanding through self-regulated learning (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006; Yerushalmy et al., 2017). Often, many students received assistance from the teacher or another mathematically apt student when IXL was worked on in class. However, the benefits of self-regulation and information absorption are limited when too much assistance is provided to complete assignments.

Procedural Fluency

Procedural fluency is defined by students' ability to perform mathematical tasks with accuracy, dexterity, and proficiency (Andrews, 2013). Students earned a slightly lower average of approximately 29% correctness for all posttest questions related to this strand (M = 1.14/4.0; SD = 1.34). Students averaged 84% on 15 homework assignments that assessed procedural fluency (M = 84.0; SD = 29.0). This category had the highest IXL average while also the lowest standard deviation. However, there are still similar issues to the other strands with the transfer of knowledge from IXL to the posttest.

One of the critical factors in developing procedural fluency has been correlated to homework tasks that were less challenging (Foster, 2013; Rasila et al., 2015). Bautista (2013) concluded that mathematics abilities and skills primarily influenced students' procedural fluency. Therefore, appropriately leveling assignments to develop procedural

fluency should use more manageable tasks with a lower degree of mathematics abilities (Rasila, 2015). Students who are mathematically below grade level but are asked to complete grade-level tasks will have difficulties developing procedural fluency. They will not be able to take a complex problem and simplify it into manageable segments (VanDerHeyden & Codding, 2020). Therefore, whenever possible, the appropriateness of an online homework assignment should depend on students' mathematical abilities; otherwise, the task will not correlate to the development of procedural fluency.

Adaptive Reasoning

Adaptive reasoning is students' ability to analyze and communicate mathematical processes and thinking (Groth, 2017). Students earned a slightly higher average than other strands, with approximately 34% correctness for all posttest questions related to this strand (M = 1.34/4.0; SD = 1.41). Students also averaged 81% on 11 homework assignments that measured adaptive reasoning (M = 81.0; SD = 33.0). Results for adaptive reasoning items were mixed. On the posttest, 34% correctness was better than the other strands, yet the IXL online homework assignments had the lowest average score. Similar to previous conclusions, there is a discrepancy between the IXL online homework assignments and posttest results.

Prior research had shown that learners' adaptive reasoning could be significantly improved when teachers utilized a problem-based curriculum (Samuelsson, 2010). The Illustrative Mathematics curriculum uses a problem-based approach to learning, and students are often tasked with discovering patterns and formulas. Therefore, the IXL homework utilized throughout this unit was aligned with the lessons and standards taught during the unit. Problem-based curriculums deviate from more traditional classrooms,

which teach formulas and then apply them. Ideal problem-based curriculums have students establish their understanding of the problem and attempt to find a viable solution (Mahendra et al., 2017; Ostler, 2011). The teacher then goes over the problem and clarifies any misconceptions or misunderstandings. This type of curriculum assumes that the prior knowledge skillset has been fortified from previous mathematics learning. Unfortunately, many Cedar Hill Middle School students did not possess the prior knowledge skillset needed for many problems. As a result, CHMS students scored lower than state and national averages in mathematics. Therefore, many classroom activities and IXL online homework assignments had to be teacher-led because the content was too difficult to solve independently.

Learners have gained adaptive reasoning skills when various problem-solving approaches have been established and discussed (Ostler, 2011). In addition, adjustments to conjectures and problem-solving techniques further enhanced the development of adaptive reasoning (Hernández et al., 2020; Stahl, Çakir, Weimar, Weusijana, & Ou, 2009). As stated earlier, students were approximately 34% correct on all adaptive reasoning posttest items (M = 1.34/4.0; SD = 1.41). Connecting the design of IXL, which does not allow corrections or adjustments to answers, to the posttest assessment scores, we see that adaptive reasoning skills could have been further developed. Unfortunately, when students do not or cannot detail and adjust their thinking, their adaptive reasoning skills remain stagnant or decline.

Research Question Two: What are 8th-grade mathematics students' perceptions regarding the impact of online homework using IXL on their mathematical proficiency?

Research Question Two was formed to understand how IXL online homework assignments impacted students' perceptions of their mathematical abilities. In order to answer this question, all participants were given two surveys (mid and post-study), and four students participated in interviews. Survey items and interview questions were guided by existing research to be able to analyze IXL online homework assignments' effect on students' perceptions of learning and attitudes. Multiple themes emerged from the interview conversations and survey answers. One theme focused on IXL online homework assignments' impact on student learning and the other on students' use of resources.

Students' attitudes and perceptions of mathematics are shaped by their classroom experiences and educational technology. The *Student Perception of Online Homework Survey 2020-2021* and student interviews gathered data on attitudes and perceptions. Surveys were administered to students at the midpoint of the study and end to measure any changes in opinions. Perceptions and attitudes did not change statistically from the midpoint to the final survey. In addition, interviews were conducted after the study. Student attitudes and perceptions are described through (a) use of resources and (b) impact on student learning.

Use of Resources

Prior research has shown that higher grade point averages correlate with strong and positive attitudes (Doorn et al., 2010; Hagger, Sultan, Hardcastle, & Chatzisarantis,

2015; Lin et al., 2008). However, when students were surveyed following the posttest about using resources provided by IXL, the mean was very close to neutral (*M* = 2.92). There was also a considerable variation in the standard deviation, meaning that experiences with IXL were likely very distinct depending on the student (*SD* = 0.98). This section will explore the features and resources on IXL that may have influenced the variation in attitudes and their effects on learning.

Reward Systems. Research has shown a positive correlation between learning and online homework programs when there is a built-in reward system for accuracy and completion (Goehle & Wagaman, 2016). When a student gets a question right on IXL, the screen flashes a congratulatory message and increases students' SmartScores. Sullivan's (2020) study showed that learners using IXL had positive attitudes toward their success due to the small reward system that gave them more autonomy over their learning. Two students had similar sentiments to this study and confirmed in their interviews that features of IXL provided encouragement and aided their usage of the application. Arthur stated, "It (IXL) tells you . . . great job, or, excellent. And it is. . . motivating," and Louise said, "I need a motivator or something positive to be, oh, yeah, you are doing okay." Their responses align with other studies showing that online homework applications can improve students' self-empowerment when completing assignments (Arasasingham et al., 2011; Archer & Olson, 2018; Arora et al., 2013). The small rewards on IXL helped shape students' attitudes toward learning and completing assignments.

Feedback. Immediate and corrective feedback has been a prominent feature in many online homework applications (Gönülateş & Kortemeyer, 2017; Leong &

Alexander, 2013; Lunsford & Pendergrass, 2016). Further connecting feedback to learning, Rasila et al. (2015) showed that student grades increased when online homework programs gave immediate feedback. IXL provided immediate feedback on correctness and worked solutions for the students in this study to review.

Therefore, based on prior research, there is potential for a positive relationship between the feedback from the IXL online homework and learner comprehension. Student interviews indicated that they expressed that the feedback received on the IXL online homework assignments was helpful to their understanding of the material. For example, Arthur stated, "That (IXL) just gives you an example of what the problem is, and then you can work it out another way." Similarly, Melody said, "When I get an answer wrong, I read through each part and write down how they (IXL) solved it." Finally, Louise detailed a comparable experience, "It shows you how it really explains like detail by detail on how to do it correctly." Overall, the feedback and explanations after an incorrect answer enabled students to clarify their mistakes and correct them on subsequent homework items. The results of this study showed a slight positive effect on the mean scores from the pre- to posttest (Pretest $M = 21.92$, $SD = 9.23$; Posttest $M = 31.34$, $SD = 7.83$). While there was an increase in the mean scores, the overall grade is still well below what would be considered a passing average. Therefore, it is difficult to argue in favor of the effectiveness of the IXL feedback, given that the students still had large knowledge gaps.

Modeled Work. A key feature of online homework that has been correlated with increased learner comprehension was modeled work (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006). When online

homework contains modeled work, students have self-regulated their understanding of the material (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006; Yerushalmy et al., 2017). It was evident from the interviews that one student found it to be a valuable feature of the IXL online homework, while others were mixed on its utilization. Melody found the examples analogous to the research findings when she stated, "I found I really like how it describes how to do it." Louise also had a similar sentiment about the modeled work example when an assignment was unclear. She stated, "Sometimes when an assignment is confusing, I will use the learn with an example, but I do not really use it most of the time." In line with prior research, modeled work gave Students 2 and 4 autonomy over the assignment. Although, the results of the study showed that learner comprehension was not affected enough to yield passing results on the posttest (M = 31.34).

One student did not use the modeled work feature of the IXL online homework. Charles stated, "No, I have not used that." It could be several reasons, but this student often could complete most assignments without additional help. Therefore, the student's perception of modeled work feature aligned with the research and was mainly used to clarify misconceptions.

Progress Bar. Learners' self-regulation of their understandings has been positively correlated with progress tracking in online homework assignments (Alsulami, 2016; Glancy & Isenberg, 2013; Keengwe et al., 2014; Miller-First & Ballard, 2017). Additionally, a progress bar empowered students to reflect on their learning, increasing self-awareness of their metacognition (Arora et al., 2013; Babaali & Gonzalez, 2015; McLoughlin, Lee, & Chan, 2006; Seo & Engelhard, 2014). Only one student commented

on the progress bar feature, and his view aligned with the research. When asked about features, Louise stated, "Specifically on the progress bar, where it tells you how many questions you have answered and how much time you have spent on it. And your points are based on the amount of questions you have correct." As a result, he gained more profound insights into his efforts on specific assignments and used that information to understand his current development. While there is not an abundance of data to support the positive effect of a progress bar, Louise's insights aligned well with the prior research in that he gained a meta-awareness of his assignments and his progress towards mastering each skill.

Math Diagnostic. One feature of the IXL program is a mathematics diagnostic test. It can be used to assess students' current level of aptitude. Once the diagnostic test has been completed, IXL gives assignment recommendations based on students' scores. Research has shown that problems leveled appropriately can improve conceptual understanding (Kanive et al., 2015; Abramovich, 2015). While this was not a studied feature of IXL, Melody opted to complete this on her own. When asked about other features she may have liked in her interview, she stated, "And how it (IXL) does like diagnostics too, so it can show us and gives us work that we need to work on and stuff to do." Confirming findings from prior research, Arthur showed a remarkable improvement in her mathematics MAP scores for the year.

SmartScores. Previous research showed that student motivation to complete homework assignments increased when there was a positive correlation between attitude and understanding (Doorn et al., 2010; Hagger, Sultan, Hardcastle, & Chatzisarantis, 2015; Lin et al., 2008). As previously discussed, a SmartScore can be lowered when

questions are answered incorrectly, and this process affects students' attitudes. Charles stated, "You cannot go on to the next question if you do not understand it. You have to get it wrong. If you already have that (80) score, it is going to lower your score." Melody also had a similar sentiment on the SmartScore and said, "It takes down your points because I tried going farther than your goal point. Every time I try going farther and (IXL) knocks my points down like ten twice." Melody liked to work beyond the required score of 80 points to further her knowledge of the content but was often frustrated because any questions incorrect above 80 points would knock her score back below 80. Both students' statements showed decreased attitudes towards this IXL program feature because of the lowered SmartScore. Students 2 and 4 intertwined their understandings and attitudes toward their SmartScore, confirming research that understandings and attitudes are linked. Moreover, the program's design could further negatively affect students' attitudes with detrimental consequences for misunderstandings.

Impact on Student Learning

Previous research has shown online homework to be a motivator that increases students' homework completion rates (Hagger et al., 2015; Hodge et al., 2009; Kolmos, 2010; Richards-Babb et al., 2011). Additionally, Hoskins' (2012) research found that online homework increased the quality of student interactions and engagement. However, when surveyed about the impact of IXL online homework assignments on their learning, the posttest survey results showed that students remained relatively neutral on its impact (M = 2.96). Although, the standard deviation for the posttest survey was considerable (SD = 1.05). Consequently, students had a wide variety of opinions on the impact of the IXL program.

The overall completion rate and mean score for the IXL online homework assignments were high (*M* = 83). Unfortunately, the posttest results did not reflect the strength of the IXL homework data (*M* = 31.3). In order to understand how students' felt IXL impacted their performance, the following key areas are going to be discussed: (a) connecting IXL to the posttest, (b) lack of connection between IXL and the posttest, (c) IXL teacher-created content videos, and (d) teacher feedback

Connecting IXL to the Posttest. Online homework that rewards accuracy and completion has been shown to correlate with increased comprehension (Goehle & Wagaman, 2016). Multiple studies have also shown that student performance improves when using online homework (Martorell, & McIntire, 2011; Archer & Olson, 2018; Arora, Yun Jin, & Masson, 2013; Babaali & Gonzalez, 2015; Bowman, 2014; Burch & Kuo, 2010; Dodson, 2014; Doorn, Janssen, & O'Brien, 2010; Jonsdottir, Bjornsdottir, & Stefansson, 2017; Roschelle, Feng, Murphy, & Mason, 2016a; Schubert, 2013). In addition, IXL rewards correctness and accuracy by flashing sayings such as "Great Job!" on the screen after a correct answer. IXL has also improved mathematical proficiency for 7th-grade mathematics students (Arms, 2019). Charles felt that the IXL online homework prepared him well for the posttest. He stated, "It just made the last posttest much easier and fresh." This student earned one of the higher scores on the test, confirming prior research. He was also very independent and was often helping other students during class with their IXL online homework assignments.

Lack of Connection between IXL and the Posttest. Earlier research has demonstrated that online homework systems such as IXL yielded no significant effects on mathematical proficiency (Cole & Todd, 2003; Hauk, Powers, & Segalla, 2015; Mathai

& Olsen, 2013). Likewise, Demirci's (2007) study showed minimal but not statistically significant improvements in exam performance when using online homework. Students 1, 3, and 4 confirmed in their interviews that connecting IXL online homework to posttest items was challenging. When probed about how they felt about the impact of IXL on their posttest, Charles responded, "Yeah, sort of, sort of, I do not know," and Melody stated, "Kind of." Both failed to connect homework to the posttest, which was reflected in their scores. Louise added more detail with her answer and said, "Like, two questions, maybe I found a relatable question that I have done." Confirming the disparity in prior research conclusions, not all students connected IXL online homework items with posttest assessment items. Online homework can yield diverse student perceptions and outcomes, aligning with the survey results and previous studies.

IXL Teacher Created Content Videos. In prior research, online homework performance in mathematics improved when internet-based support was available (Ali Alshehri, 2017; Gönülateş & Kortemeyer, 2017; Mathai & Olsen, 2013). Likewise, in studies that examined differentiated feedback and support, students gained more autonomy over their learning and improved online homework performance (Lai & Hwang, 2016; Morris, 2019). Three students confirmed that the teacher created IXL videos helped to complete assignments when a teacher was not immediately available to assist in learning. Arthur stated, "I used those (videos) whenever you are not here." Melody felt that the videos differentiated instruction enough from the IXL explanation. She stated, "You made the little videos that show a different style. That is what I felt was really helpful for me." Louise also thought alike and noted that she used the videos in her

interview. All three students confirmed that the internet-based support and differentiated delivery methods were beneficial to completing their IXL online homework.

Teacher Feedback. Prompt performance feedback has been shown in previous research to improve student-teacher relationships and instructional quality (Arora, Yun Jin, & Masson, 2013; Babaali & Gonzalez, 2015; Bowman, 2014; Kong & Song, 2013; Roschelle et al., 2016; Tabor & Minch, 2013; Thiet, 2017; Yerushalmy, Nagari-Haddif, & Olsher, 2017). Additionally, mathematics performance was improved when instruction contained information about principles, methods, and process-based errors (Sheldon, Epstein, & Galindo, 2010). All students mentioned how the teacher's feedback and aid helped them complete their IXL online homework and aided their perception of the classwork. Louise had the most robust answer when asked what aided her understanding and perception of IXL content, and she stated, "Definitely positive feedback from you." Arthur also mentioned how performance feedback aided her perception of the class and content by saying, "Because you go over it and then I do the IXL, I will be able to do it much easier." Confirming prior research, students who received that performance feedback and teacher aid positively perceived the class and IXL online homework assignments.

Positive Perceptions of IXL. Research has shown that online homework influences learners' attitudes toward technology usage (Demirci, 2007). IXL has been shown in prior studies to give students autonomy over their learning and success, which resulted in positive experiences with the program (Ali Alshehri, 2017; Sullivan, 2020; Wooten & Dillard-Eggers, 2013; Xu & Wu, 2013). Each student interviewed had at least one positive statement regarding their impression of the IXL program. For example,

Louise described her experience by stating, "Definitely like how it is quick. And it is a bit simple and easy. And it is a lot better than keeping track of paper homework." Interviewees confirmed existing research on how online homework can positively influence student perceptions.

Another critical factor was that most study participants had average or below-average mathematics MAP scores. Online homework has been shown to increase the overall satisfaction in a course for lower- and middle-achieving students (Leong & Alexander, 2013). Arthur affirmed that prior research could influence his perspective of a course. He stated in his interview, "I like math, in general." IXL positively impacted all the interviewees' perceptions of the program and the course.

Implications

The research conducted in this study has implications for educators, academic researchers, and me. Three types of implications are considered: (a) personal implications, (b) implications for integrating online homework technology, and (c) implications for future research.

Personal Implications

I began this doctoral program as a mathematics teacher at a Catholic High School. I changed jobs twice during the four-year journey and ended the program as a middle school Algebra I teacher at Buist Academy of Advanced Studies. While the population of students I taught changed twice, the role of online homework in mathematics was always at the center of my research. The lessons learned throughout my coursework and research enhanced my knowledge of (a) research methodologies, (b) qualitative and quantitative analysis, (c) writing, and (d) sharing and communicating findings.

Enhancing My Knowledge of Research Methodologies

Before entering the doctoral program and conducting action research, I had limited knowledge of how to research educational technologies. The private school I taught at the time primarily utilized pen and paper assessments, notes, homework, and exams. While I knew that there were great applications in the educational space that could enhance daily activities, data collection, and analysis, I still needed to learn the requirements for best practices. For example, one of the math department's debate areas was about grading homework. Most departments did not have time to grade homework assignments and return them with process-based feedback, which has been shown to enhance comprehension (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006). We wanted to shift the current student narrative about homework from an emphasis on completion to understanding. We needed a methodical approach to address this problem, and action research was a viable solution (Mills, 2011). It was a more minor, localized problem at our school, and action research helped address and improve it (Bradbury-Huang, 2010). Action research gave me the formal data collection, inquiry, and implementation process to make a significant change.

In order to gain a deeper understanding of online homework technologies, a literature review was performed. Critical facets of online homework technologies were researched. I learned how to effectively search various platforms, such as *ERIC*, *Education Source*, *JSTOR*, *Google Scholar*, and *ProQuest*. While the student population changed when changing jobs, the research methodologies did not. The ability to search and find relevant academic literature will help me in my future endeavors as an educator and, more so, as a researcher.

Enhancing My Knowledge of Qualitative and Quantitative Analysis

This study utilized a parallel convergent mixed method design, which allowed me to gather and compare qualitative and quantitative data and enhance the analysis of the innovation's results (Edmonds & Kennedy, 2017). During this research, abilities were gained to triangulate qualitative and quantitative data to answer research questions (Mertler, 2014j; Creswell, 2014). As a mathematician, I enjoyed expanding my skill sets during quantitative analysis. Using JASP and running descriptive statistics, such as means and standard deviations, were familiar mathematical calculations, but inferential statistics were still foreign. I learned how to calculate a paired samples *t*-test, a Cronbach Alpha reliability test, Kuder-Richardson Formula 20 test, and a Bonferroni adjustment. These skills will be vital for analyzing and understanding data collected during studies.

Building my qualitative analysis skills was a more complicated process. Early attempts to code transcripts were not very successful before coding interviews in the study. However, after reading the Saldana (2016) text multiple times, I felt more confident in my ability to analyze interviews in multiple ways, such as in vivo, structural, concept, attribute, and emotion coding. The website Delve eased the process of tracking, making changes, and coding in multiple ways and iterations. Codes were then categorized over multiple sessions and weeks, and emergent themes were uncovered. My qualitative and quantitative skillsets will continue to expand as I attempt to answer more questions with future research.

Enhancing My Knowledge of Writing

Perhaps one of the skills most often overlooked in a research study and a doctoral program is the amount of research-based writing. As someone who formerly struggled to

compose a few sentences for an email to a parent, this process has been cathartic. I had such a negative view of my writing capabilities, and the last four years forced me to learn and grow.

As I progress in my instructional design or learning design career, I am thankful to have gone through this process. I had never thought that clearly expressing oneself on paper would profoundly affect other areas in my career and studies.

Enhancing My Knowledge of Sharing and Communicating Findings

A research study aims to answer a few questions but often leads to many more. While there were improvements in participants' mathematical abilities, the impact was not as substantial as I had hoped. The lessons learned during this process have made me a better educator, analyzer, and implementer of technology in the classroom. I must remember that action research is cyclical, and future iterations of technology innovations will be adjusted and improved.

As math department head and 8th-grade team leader, I have shared my findings and understanding of technology with my peers and administrators. Our school analyzes the effect of technologies purchased yearly, and we must decide which to renew or cancel. A critical aspect of this study is that I perhaps overestimated the potential effect of online homework technologies. Cedar Hill Middle School had many challenges that online technologies could not fix. According to their MAP scores, many 8th-grade Mathematics students tested on a 4th to 5th-grade level. Perhaps I was naïve to think that IXL could be the catalyst to overcome the gaps in mathematics knowledge, analysis, and social-emotional intelligence. As someone who has had tremendous past successes in the classroom, this experience was very humbling. Even the best intentions and research

designs can yield unfavorable results. The lack of support and sometimes unstable homelife of students overshadowed the benefits of any digital technologies.

Implications for Implementing Online Homework Technology

This study revealed several implications for including online homework technologies to enhance performance in all classrooms, not just mathematics classrooms. The lessons learned through this research related to the following topics: (a) online homework technology selection and (b) building thinking classrooms.

Online Homework Technology Selection

IXL was a viable option when selecting an online homework program with favorable attributes. Two critical factors considered for selection were the inclusion of process-based feedback and internet-based support. Process-based feedback in prior research enhanced comprehension (Anderson, 2019; Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006) and enabled self-regulation of learning (Bokhove & Drijvers, 2012; Chamala et al., 2006; Nicol & MacFarlane-Dick, 2006; Yerushalmy et al., 2017). Performance was also improved when students had access to internet-based support (Ali Alshehri, 2017; Gönülateş & Kortemeyer, 2017; Mathai & Olsen, 2013). The only drawback was that IXL allowed unlimited attempts to achieve the desired SmartScore. I knew from prior research that multiple attempts did allow for more chances for success, but as attempts increased, learning and performance decreased (Bowman, 2014; Gönülateş & Kortemeyer, 2017; Kortemeyer, 2015; Yourstone et al., 2010). This design mechanism in IXL had implications for the disconnect between the SmartScores and the posttest assessment scores. Future iterations of implementing IXL in the classroom, or any online technology, should pay close attention to the number of

attempts it takes to reach the desired outcome. Unfortunately, the data collected during this study did not include attempts for completion but would have given me more information on the relationship between the SmartScore and the posttest score.

Building Thinking Classrooms

Mathematical proficiency improvement is linked to five interwoven strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (Andrews, 2013; Bokhove & Drijvers, 2010; Groth, 2017; Rasila et al., 2015; Suh et al., 2012). This study focused on the first four because they related to the thought processes behind improving mathematical proficiency. Many of the items on online homework assignments and the assessments were classified under multiple strands, and all strands assessed had low-performance outcomes on the posttest. The study's results showed that most students had not gained autonomy over their learning and were not thinking on their own.

The IXL online homework assignments were tied to the Illustrative Mathematics curriculum, which is problem-based. Often during lessons and homework, the students struggled to complete items in the lesson and homework items without further assistance from me, my co-teacher, or a knowledgeable friend in class. A problem-based curriculum only works if the students are engaged in a reflective thought process about the questions being asked. Research has shown that new knowledge has been created by expanding existing knowledge through collaborations and practices (Alsulami, 2016; Keengwe, Onchwari, & Agamba, 2014; Koohang, Riley, Smith, & Schreurs, 2009; Miller-First & Ballard, 2017; Richardson, 2003; Vidmar, 2011). Unfortunately, I think the Illustrative Mathematics curriculum and assessments were above the knowledge level of most

students. Between the teacher support, IXL support, modeled work, classmate help, and video examples, most students could complete IXL assignments successfully by reaching the required SmartScore. However, the knowledge did not transfer to the assessments. Students could only think at their ability level, and more work needed to be done to shift the focus from completing assignments to thinking, engaging, reflecting, and growing. The technology selected should further develop students and their ability to structure their thinking processes.

Implications for Future Research

Future researchers conducting their studies regarding the effects of online homework technologies on proficiency may be interested in the findings of this study. Recommendations for future research should include a larger population of participants. This study collected data on 13 participants. An action researcher wants the desired outcome for a localized issue (Bradbury-Huang, 2010), and only implications are communicated because the data from this study cannot determine causality or generalities (Mertler, 2017). A larger population size of 30 students or more would strengthen the study's implications due to the broader representation of the student population being studied.

Additional iterations should also alter the study to include an analysis of the number of attempts and the time it takes to complete the IXL online homework assignments. Previous research revealed that performance and higher attempt numbers on homework items are inversely related (Bowman, 2014; Gönülateş & Kortemeyer, 2017; Kortemeyer, 2015; Yourstone et al., 2010). Data on the number of attempts for a relative SmartScore will provide additional information on areas of weakness and struggle.

Performance and increased time on task have been positively correlated in prior research (Babaali & Gonzalez, 2015; Bowman, 2014). Time on task data can reveal precisely how long students take to complete assignments and the effect on assessment performance.

It is also a recommendation that future studies use a focus group instead of individual interviews. Given the age of the students and lack of comfortability in a one-on-one setting, a group setting may entice more comprehensive answers and more interviewees. In addition, focus groups are helpful and valuable when exploring common trends and topics (Mertler, 2017). Great points were made in individual interviews that could have primed the others to think and comment, giving a broader perspective while also providing the comfortability of a group setting.

Finally, the last suggestion relates to implementing online homework technologies for all mathematics educators. Future studies should examine how data from online homework technologies alter classroom instruction. Technology should be a tool that connects homework and classroom activities but not be the primary mode of learning. Classroom instruction has increased comprehension when online homework data is used to tailor lessons to students' needs (Jonsdottir et al., 2017; Roschelle et al., 2016). As online homework technologies advance and become more sophisticated, educators must discern their selections and utilizations. The classroom teacher should always remain the driving force for learning and education.

Limitations

Per most research studies, limitations occurred that could be altered for future research. The limitations are categorized into those related to (a) Covid-19, (b) methodology, and (c) positionality of the researcher.

Covid-19

Unfortunately, much of the study was altered due to the prevalence of Covid-19. While the first two weeks of the study were off to a great start, the second half was drastically different. My wife contracted Covid-19 during my teaching and data collection. As a result, I was forced to leave work midday and quarantine for 20 days with my two young children at home. Instead of being a full-time teacher and researcher, I was a full-time parent and juggled my responsibilities as a researcher and educator.

Of the two class periods involved in the study, I could only continue to teach one section virtually. My co-teacher and special education instructor taught the other in-person section in my absence. She had limited experience teaching mathematics and acted primarily as a support role co-teaching. Furthermore, given the drastic change in dynamics for that section, most students opted out of the study after I was no longer the primary mathematics teacher. Consequently, data from this section was not only limited but altered due to the difference in presentation and delivery. Considering all those factors, data from that section were excluded from the study.

The remaining students in my study were taught remotely through Zoom, with an in-person substitute monitoring their classroom activities. The students remained at school and would connect virtually through their Chromebooks. Most students during this time opted to keep their cameras off during lessons, removing my ability to read body language and engagement. District policy at the time had eliminated teachers' ability to require that cameras remain turned on. Therefore, during the final preparations for the posttest, it was challenging to assess the preparation levels of the students. The only data for analysis was the IXL online homework assignments, which showed promising

progress. The final results were surprising and might have been much different without unforeseen circumstances and challenges.

Methodology

One of the first limitations was the study size since only one class (n = 13) of 8th Grade Mathematics participated fully. Due to the nature of action research, data from the study cannot determine causality or generalizations for larger populations; only implications can be utilized (Mertler, 2017). The findings apply to the participants of this study, and any takeaways from its findings must utilize discretion. Teachers of 8th Grade Mathematics have the potential to use the results of this study to benefit their integrations of online technologies for homework.

Another limitation was found in the use of interviews. This study initially hoped to interview eight to 10 participants with varying levels of posttest performances, but only four students opted to participate. A more significant number of interviews would provide more variation and an in-depth understanding of the how and why to explain further quantitative data (Creswell & Creswell, 2018; Collins, Onwuegbuzie, & Sutton, 2006). Also, given their age and language abilities, interview participants' communication quality may have been limited by their ability to formulate their thoughts (Creswell & Creswell, 2018).

Some limitations came from the reliability of the data collected. The *Student Perception of Online Homework Survey 2020-2021* was created by modifying a version of the survey created by Gutierrez (2017), which compared online homework to pen and paper. The reworking of the survey instrument to fit the subject matter of this research study can be considered a limitation (Mertler, 2017). In addition, since the surveys were

administered via Google Forms remotely, the opportunity to clarify any statements to the participants was not an option. Therefore, there is some uncertainty regarding the accuracy of the results and if the students would have needed clarification.

Positionality of the Researcher

The positionality of the researcher was also a limitation. Given my role as a researcher and person in authority, the study's results should be understood and contemplated (Giampapa, 2011). A researcher needs to understand any biases or prejudices from the active involvement in the study (Morgan, 2013). Students knew participation was optional, but feelings of obligation and subordination could have led to reluctant participation. Furthermore, while only a few students participated in the interview process, the overall review of the IXL program was primarily positive. While I reminded the participants that their positive or negative opinions are invaluable to the study, participants may have been reluctant to give more negative feedback, given my role as a teacher and researcher.

REFERENCES

Abramovich, S. (2015). Mathematical problem posing as a link between algorithmic thinking and conceptual knowledge. *Teaching of Mathematics*, *18*(2), 45–60.

Alexander, N. (2013). Exploring attitudes and achievement of web-based homework. *The Turkish Online Journal of Educational Technology*, *12*(4), 75–80.

Ali Alshehri, A. (2017). The perception created of online homework by high school student, their teacher and parents in Saudi Arabia. *Journal of Education and Practice*, *8*(13), 85–100. https://files.eric.ed.gov/fulltext/EJ1143921.pdf

Allsopp, D., Lovin, L. H., & van Ingen, S. (2017). Supporting mathematical proficiency. Teaching Exceptional Children, 49(4), 273–283. https://doi.org/10.1177/0040059917692112

Ally, N., & Christiansen, I. M. (2013). Opportunities to develop mathematical proficiency in Grade 6 mathematics classrooms in KwaZulu-Natal. *Perspectives in Education*, *31*(3), 106–121.

Alsulami, S. (2016). Toward a constructivist approach in Saudi education. *English Language Teaching*, *9*(12), 104. https://doi.org/10.5539/elt.v9n12p104

Andrews, P. (2013). Finnish mathematics teaching from a reform perspective: A video-based case-study analysis. *Comparative Education Review*, *57*(2), 189–211. https://doi.org/10.1086/669124

Arasasingham, R. D., Martorell, I., & McIntire, T. M. (2011). Online homework and student achievement in a large enrollment introductory science course. *Journal of*

College Science Teaching, *40*(6), 70–79. http://www.eric.ed.gov/ERICWebPortal/recordDetail?accno=EJ963647%5Cnhttp://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Online+Homework+and+Student+Achievement+in+a+Large+Enrollment+Introductory+Science+Course.#0

Archer, K. K., & Olson, M. (2018). Practice. Practice. Practice. Do homework management systems work? *International Journal for the Scholarship of Teaching and Learning, 12*(2), 0–6. https://doi.org/10.20429/ijsotl.2018.120212

Arms, D. R. (2019). *Middle school mathematics, student growth, and the role of technology-assisted, independent practice* (Order No. 13815068). Available from ProQuest Dissertations & Theses Global. (2228141390). Retrieved from https://login.pallas2.tcl.sc.edu/login?url=https://www-proquest-com.pallas2.tcl.sc.edu/dissertations-theses/middle-school-mathematics-student-growth-role/docview/2228141390/se-2?accountid=13965

Arora, M. L., Yun Jin, R., & Masson, C. (2013). Longitudinal study of online statics homework as a method to improve learning. *Journal of STEM Education: Innovations & Research*, *14*(1), 36–44. http://www.library.umaine.edu/auth/EZProxy/test/authej.asp?url=http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=89173557&site=ehost-live

Azevedo, R., & Bernard, R. M. (1995). A meta-analysis of the effects of feedback in computer-based instruction. *Journal of Educational Computing Research*, *13*, 111–127.

Babaali, P., & Gonzalez, L. (2015). A quantitative analysis of the relationship between an online homework system and student achievement in pre-calculus. *International*

Journal of Mathematical Education in Science and Technology, *46*(5), 687–699. https://doi.org/10.1080/0020739X.2014.997318

Bas, G., Senturk, C., & Mehmet Ciherci, F. (2017). Homework and academic achievement: A meta-analytic review of research. *Issues in Educational Research*, *27*(1), 31–51.

Bautista, R. G. (2013). The students' procedural fluency and written-mathematical explanation on constructed response tasks in physics. *Journal of Technology and Science Education*, *3*(1), 49–56.

Blair, E. (2015). A reflexive exploration of two qualitative data coding techniques. *Journal of Methods and Measurement in the Social Sciences*, *6*(1), 14-29. https://doi.org/10.2458/v6i1.18772

Bokhove, C., & Drijvers, P. (2010). Digital tools for algebra education: Criteria and evaluation. *International Journal of Computers for Mathematical Learning*, *15*(1), 45–62. https://doi.org/10.1007/s10758-010-9162-x

Bokhove, C., & Drijvers, P. (2012). Effects of a digital intervention on the development of algebraic expertise. *Computers and Education*, *58*(1), 197–208. https://doi.org/10.1016/j.compedu.2011.08.010

Bottino, R. M., & Robotti, E. (2007). Transforming classroom teaching & learning through technology: Analysis of a case study. *Educational Technology and Society*, *10*(4), 174–186.

Bowden, A., Fox-Rushby, J. A., Nyandieka, L., & Wanjau, J. (2002). Methods for pre-testing and piloting survey questions: Illustrations from the KENQOL survey of health-related quality of life. *Health Policy and Planning*, *17*(3), 322–330.

https://doi.org/10.1093/heapol/17.3.322

Bowman, C. R. (2014). Predicting student success via online homework usage. *Journal of Learning Design*, *7*(2), 48–61.

Boyce, C., & Neale, P. (2002). Conducting in-depth interviews: A guide for designing and conducting in-depth interviews for evaluation input. *Attachment and Human Development*, *4*(2), 207–215. https://doi.org/10.1080/14616730210154225

Bradbury-Huang, H. (2010). What is good action research? *Action Research*, *8*(1), 93–109. https://doi.org/10.1177/1476750310362435

Brewer, D. S. (2009). *The effects of online homework on achievement and self-efficacy of college algebra students* (Doctoral dissertation). ProQuest Dissertations & Theses Global. (Order No. 3366157)

Brisson, B. M., Dicke, A. L., Gaspard, H., Häfner, I., Flunger, B., Nagengast, B., & Trautwein, U. (2017). Short intervention, sustained effects: Promoting students' math competence beliefs, effort, and achievement. *American Educational Research Journal*, *54*(6), 1048–1078. https://doi.org/10.3102/0002831217716084

Burch, K. J., & Kuo, Y. (2010). Traditional vs. online homework in college algebra. *Mathematics and Computer Education*, *44*(1), 53–63. http://library.capella.edu/login?url=http://search.proquest.com/docview/235939210?accountid=27965%5Cnhttp://wv9lq5ld3p.search.serialssolutions.com.library.capella.edu/?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rfr_id=info:sid/ProQ&rft_val_fmt=info:of

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research*, *65*, 245–281.

Capraro, M. M., Capraro, R. M., Carter, T., & Harbaugh, A. (2010). Understanding, questioning, and representing mathematics: What makes a difference in middle school classrooms? *RMLE Online*, *34*(4), 1–19. https://doi.org/10.1080/19404476.2010.11462077

Cartwright, K., & Mathematics Education Research Group of Australasia. (2018). Exploring mathematical fluency: Teachers' conceptions and descriptions of students. *Mathematics Education Research Group of Australasia*.

Chamala, R. R., Ciochina, R., Grossman, R. B., Finkel, R. A., Kannan, S., & Ramachandran, P. (2006). EPOCH: An organic chemistry homework program that offers response-specific feedback to students. *Journal of Chemical Education*, *83*(1), 164–169. https://doi.org/10.1021/ed083p164

Cheema, J. R., & Sheridan, K. (2015). Time spent on homework, mathematics anxiety and mathematics achievement: Evidence from a US sample. *Issues in Educational Research*, *25*(3), 246–259.

Cheng, K. K., Thacker, B. A., Cardenas, R. L., & Crouch, C. (2004). Using an online homework system enhances students' learning of physics concepts in an introductory physics course. *American Journal of Physics*, *72*(11), 1447–1453. https://doi.org/10.1119/1.1768555

Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *American Association for Higher Education Bulletin*, *39*(7), 2–6.

Chubbuck, S. M. (2010). Individual and structural orientations in socially just teaching: Conceptualization, implementation, and collaborative effort. *Journal of Teacher Education, 61*, 197–210.

Cole, R. S., & Todd, J. B. (2003). Effects of web-based multimedia homework with immediate rich feedback on student learning in general chemistry. *Journal of Chemical Education*, *80*(11), 1338–1343. https://doi.org/10.1021/ed080p1338

Collins, K. M. T., Onwuegbuzie, A. J., & Sutton, I. L. (2006). A model incorporating the rationale and purpose for conducting mixed-method research in special education and beyond. *Learning Disabilities: A Contemporary Journal*, *4*(1), 67–100.

Cooper, H. (1989). Synthesis of research on homework. *Educational Leadership*, *47*(3), 85–91.

Cooper, H., Robinson, J., & Patall, E. (2006). Does homework improve academic achievement? A synthesis of research, 1987-2003. *Review of Educational Research, 76*(1), 1–62.

Cooper, H., & Valentine, J. C. (2001). Using research to answer practical questions about homework. *Educational Psychologist*, *36*(3), 143–153. https://doi.org/10.1207/S15326985EP3603_1

Corno, L. (2005). Looking at homework differently. *The Elementary School Journal*, *100*(5), 529–548. https://doi.org/10.1086/499654

Cosio, M. N., & Williamson, V. M. (2019). Timing of homework completion vs. performance in general chemistry. *Journal of Science Education and Technology, 28*(5), 523–531. https://doi.org/10.1007/s10956-019-09783-x

Cozean, K. R. (2011). *Enhancing performance in high school algebra: Using guided*

*homework as an instruction strategy (*Doctoral dissertation). Retrieved from ProQuest Dissertations & Theses Global. (Order No. 3426511)

Cunningham, A. W., Dias, O., & Angulo, N. (2011). Math is not a spectator sport: The effect of online homework-completion tutoring on community college remedial mathematics performance. *Journal of Mathematics Education at Teachers College*, *2*(2), 59–65.

Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: SAGE Publications, Inc.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: SAGE Publications, Inc.

Demirci, N. (2007). University students' perceptions of web-based vs. paper-based homework in a general physics course. *Eurasia Journal of Mathematics, Science and Technology Education*, *3*(1), 29–34. https://doi.org/10.12973/ejmste/75371

Dillard-Eggers, J., Wooten, T., Childs, B., & Coker, J. (2008). Evidence on the effectiveness of online homework. *College Teaching Methods and Styles Journal*, *4*(5), 9–16. https://doi.org/10.1002/9780470774960.ch8

Dimitrov, D. M., & Rumrill, P. D. (2003). Pretest-posttest designs and measurement of change. *Work*, *20*(2), 159–165.

Dodson, R. J. (2014). The impact of online homework on class productivity. *Science Education International*, *25*(4), 354–371. Retrieved from https://library.iau.edu.sa/docview/1697490948?accountid=136546

Donawerth, A. S. (2013). Bridging the gap: Fourth grade before-school computer math lab and its impact on California standardized test scores (Doctoral dissertation).

Retrieved from ProQuest Dissertations & Theses Global. (UMI Number: 1586255).

Doorn, D. J., Janssen, S., & O'Brien, M. (2010). Student attitudes and approaches to online homework. *International Journal for the Scholarship of Teaching and Learning*, *4*(1). https://doi.org/10.20429/ijsotl.2010.040105

Edmonds, W. & Kennedy, T. (2017). Convergent-parallel approach. In *An applied guide to research designs* (pp. 181-188). SAGE Publications, Inc, https://www.doi.org/10.4135/9781071802779

Empire Education Inc. (2013, April 15). A study of student achievement, teacher perceptions, and IXL math. https://www.ixl.com/research/Beaverton-Study-of-Student-Achievement.pdf

Fan, H., Xu, J., Cai, Z., He, J., & Fan, X. (2017). Homework and students' achievement in math and science: A 30-year meta-analysis, 1986–2015. *Educational Research Review*, *20*, 35–54. https://doi.org/10.1016/j.edurev.2016.11.003

Fernández-Alonso, R., Suárez-Álvarez, J., & Muñiz, J. (2015). Adolescents' homework performance in mathematics and science: Personal factors and teaching practices. *Journal of Educational Psychology*, *107*(4), 1075–1085. https://doi.org/10.1037/edu0000032

Field, A. (2013). *Discovering statistics using IBM SPSS statistics: And sex and drugs and rock "n" roll*. (4th) Sage.

Foster, C. (2013). Mathematical études: Embedding opportunities for developing procedural fluency within rich mathematical contexts. *International Journal of Mathematical Education in Science and Technology*, *44*(5), 765–774. https://doi.org/10.1080/0020739X.2013.770089

Frels, R. K., & Onwuegbuzie, A. J. (2013). Administering quantitative instruments with qualitative interviews: A mixed research approach. *Journal of Counseling and Development*, *91*(2), 184–194. https://doi.org/10.1002/j.1556-6676.2013.00085.x

Galloway, M., Conner, J., & Pope, D. (2013). Nonacademic effects of homework in privileged, high-performing high schools. *Journal of Experimental Education*, *81*(4), 490–510. https://doi.org/10.1080/00220973.2012.745469

Garrison, J. (1995). Deweyan pragmatism and the epistemology of contemporary social constructivism. *American Educational Research Journal*, *32*(4), 716–740. https://doi.org/10.3102/00028312032004716

Giampapa, F. (2011). The politics of "being and becoming" a researcher: Identity, power, and negotiating the field. *Journal of Language, Identity, and Education*, *10*(3), 132–144. https://doi.org/10.1080/15348458.2011.585304

Gill, B. P., & Schlossman, S. L. (2005). Villain or savior? The American discourse on homework, 1850-2003. *Theory into Practice, 43*(3), 174–181. https://doi.org/10.1353/tip.2004.0035

Glancy, F., & Isenberg, S. (2013). A conceptual learner-centered e-learning framework. *Journal of Higher Education Theory and Practice*, *13*(3/4), 22–35.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Piscataway, NJ: Transaction Publishers. Retrieved from http://www.sxf.uevora.pt/wp-content/uploads/2013/03/Glaser_1967.pdf

Goehle, G., & Wagaman, J. (2016). The impact of gamification in web-based homework. *Primus*, *26*(6), 557–569. https://doi.org/10.1080/10511970.2015.1122690

Gönülateş, E., & Kortemeyer, G. (2017). Modeling unproductive behavior in online

homework in terms of latent student traits: An approach based on item response theory. *Journal of Science Education and Technology*, *26*(2), 139–150. https://doi.org/10.1007/s10956-016-9659-8

Gonzalez, G., & DeJarnette, A. F. (2013). Geometric reasoning about a circle problem. *Mathematics Teacher*, *106*(8), 586–591.

Greene, J. C., Carcelli, V. J., & Graham, W. F. (1989). Toward a conceptual framework for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis*, *11*(3), 255–274.

Groth, R. E. (2017). Classroom data analysis with the five strands of mathematical proficiency. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *90*(3), 103–109. https://doi.org/10.1080/00098655.2017.1301155

Guglielmi, R. S., & Brekke, N. (2018). A latent growth moderated mediation model of math achievement and postsecondary attainment: Focusing on context-invariant predictors. *Journal of Educational Psychology*, *110*(5), 683–708. https://doi.org/10.1037/edu0000238

Gutierrez, G. (2017). *Technology, textbooks, and mathematics: Perceptions of online math homework from traditional high school students enrolled at private schools* (Order No. 10680454). Available from ProQuest Dissertations & Theses Global. (2020854534). Retrieved from https://login.pallas2.tcl.sc.edu/login?url=https://www-proquest-com.pallas2.tcl.sc.edu/dissertations-theses/technology-textbooks-mathematics-perceptions/docview/2020854534/se-2?accountid=13965

Hagger, M. S., Sultan, S., Hardcastle, S. J., & Chatzisarantis, N. L. D. (2015). Perceived

autonomy support and autonomous motivation toward mathematics activities in educational and out-of-school contexts is related to mathematics homework behavior and attainment. *Contemporary Educational Psychology*, *41*, 111–123. https://doi.org/10.1016/j.cedpsych.2014.12.002

Hair, J., Black, W., Babin, B., & Anderson, R. (2010). Multivariate data analysis (7th ed.). Upper Saddle River, NJ: Prentice Hall.

Halcrow, C., & Dunnigan, G. (2012). Online homework in Calculus I: Friend or foe? *Primus*, *22*(8), 664–682. https://doi.org/10.1080/10511970.2012.694015

Hammond, M. (2013). The contribution of pragmatism to understanding educational action research: Value and consequences. *Educational Action Research*, *21*(4), 603–618. https://doi.org/10.1080/09650792.2013.832632

Hauk, S., Powers, R. A., & Segalla, A. (2015). A comparison of web-based and paper-and-pencil homework on student performance in college algebra. *Primus*, *25*(1), 61–79. https://doi.org/10.1080/10511970.2014.906006

Hays, D. G., Wood, C., Dahl, H., & Kirk-Jenkins, A. (2016). Methodological rigor in Journal of Counseling & Development qualitative research articles: A 15-year review. *Journal of Counseling and Development*, *94*(2), 172–183. https://doi.org/10.1002/jcad.12074

Hegedus, S. J., Dalton, S., & Tapper, J. R. (2015). The impact of technology-enhanced curriculum on learning advanced algebra in US high school classrooms. *Educational Technology Research and Development*, *63*(2), 203–228. https://doi.org/10.1007/s11423-015-9371-z

Heikkinen, H. L. T., Huttunen, R., & Syrjälä, L. (2007). Action research as narrative:

Five principles for validation. *Educational Action Research*, *15*(1), 5–19. https://doi.org/10.1080/09650790601150709

Hernández, A., Perdomo-Díaz, J., & Camacho-Machín, M. (2020). Mathematical understanding in problem-solving with GeoGebra: A case study in initial teacher education. *International Journal of Mathematical Education in Science and Technology*, *51*(2), 208–223. https://doi.org/10.1080/0020739X.2019.1587022

Higham, R. (2018). 'To be is to respond': Realising a dialogic ontology for Deweyan pragmatism. *Journal of Philosophy of Education*, *52*(2), 345–358. https://doi.org/10.1111/1467-9752.12290

Hodge, A., Richardson, J. C., & York, C. S. (2009). The impact of a web-based homework tool in university algebra courses on student learning and strategies. *Journal of Online Learning and Teaching*, *5*(4), 618–629. https://doi.org/10.1007/978-3-319-50237-3_2

Hollands, F.M. & Pan, Y. (2018). Evaluating digital math tools in the field. *Middle Grades Review*, *4*(1), 1-15.

Hoskins, B. J. (2012). Connections, engagement, and presence. *Journal of Continuing Higher Education*, *60*(1), 51–53. https://doi.org/10.1080/07377363.2012.650573

Hudson, S., Kadan, S., Lavin, K., & Vasquez, T. (2010). I*mproving basic math skills using technology* (Unpublished master's thesis). Saint Xavier University, Chicago, Il.

Husain, M., & Khan, S. (2016). Students' feedback: An effective tool in teachers' evaluation system. *International Journal of Applied and Basic Medical Research*, *6*(3), 178–181. http://doi.org/10.4103/2229-516X.186969

Ichinose, C. L., & Martinez-Cruz, A. M. (2018). Problem solving + problem posing = mathematical practices. *The Mathematics Teacher*, *111*(7), 504–511. www.jstor.org/stable/10.5951/mathteacher.111.7.0504

Illustrative Mathematics. (2018). *8th Grade Illustrative Mathematics.* Math Nation.

Jacob, S. A., & Furgerson, S. P. (2012). Writing interview protocols and conducting interviews: Tips for students new to the field of qualitative research. *The Qualitative Report*, *17*(42), 1-10. https://nsuworks.nova.edu/tqr/vol17/iss42/3

James, L. (2016). Mathematics awareness through technology, teamwork, engagement, and rigor. *Journal of Curriculum and Teaching*, *5*(2), 55–62. https://doi.org/10.5430/jct.v5n2p55

Jonsdottir, A. H., Bjornsdottir, A., & Stefansson, G. (2017). Difference in learning among students doing pen-and-paper homework compared to web-based homework in an introductory statistics course. *Journal of Statistics Education*, *25*(1), 12–20. https://doi.org/10.1080/10691898.2017.1291289

Kanive, R., Nelson, P., Burns, M., & Ysseldyke, J. (2014). Comparison of the effects of computer-based practice and conceptual understanding interventions on mathematics fact retention and generalization. *Journal of Educational Research*, *107*(2), 83–89.

Kapur, M. (2012). Productive failure in learning the concept of variance. *Instructional Science*, *40*(4), 651–672. https://doi.org/10.1007/s11251-012-9209-6

Kastberg, S. E., & Frye, R. S. (2013). Norms and mathematical proficiency. *Teaching Children Mathematics*, *20*(1), 28–35.

Keengwe, J., Onchwari, G., & Agamba, J. (2014). Promoting effective e-learning

practices through the constructivist pedagogy. *Education and Information Technologies*, *19*(4), 887–898. https://doi.org/10.1007/s10639-013-9260-1

Keith, T. Z. (1982). Time spent on homework and high school grades: A large-sample path analysis. *Journal of Educational Psychology*, *74*(2), 248–253. https://doi.org/10.1037/0022-0663.74.2.248

Kim, D., & Lim, C. (2018). Promoting socially shared metacognitive regulation in collaborative project-based learning: A framework for the design of structured guidance. *Teaching in Higher Education*, *23*(2), 194–211. https://doi.org/10.1080/13562517.2017.1379484

Kodippili, A., & Senaratne, D. (2008). Is computer-generated interactive mathematics homework more effective than traditional instructor-graded homework? *British Journal of Educational Technology*, *39*(5), 928–932. https://doi.org/10.1111/j.1467-8535.2007.00794.x

Kong, S. C., & Song, Y. (2013). A principle-based pedagogical design framework for developing constructivist learning in a seamless learning environment: A teacher development model for learning and teaching in digital classrooms. *British Journal of Educational Technology*, *44*(6), 209–213. https://doi.org/10.1111/bjet.12073

Koohang, A., Riley, L., Smith, T., & Schreurs, J. (2009). E-Learning and constructivism: From theory to application. *Interdisciplinary Journal of E-Skills and Lifelong Learning*, *5*, 91–109. https://doi.org/10.28945/66

Kulik, C. L. C., Kulik, J. A., & Bangert-Drowns, R. L. (1990). Effectiveness of mastery learning programs: A meta-analysis. *Review of Educational Research*, *60*(2), 265–299. https://doi.org/10.3102/00346543060002265

LaBelle, J. T., & Belknap, G. (2016). Reflective journaling: Fostering dispositional development in preservice teachers. *Reflective Practice*, *17*(2), 125–142. https://doi.org/10.1080/14623943.2015.1134473

Ladson, F. (2012). *The effect of homework completion on standardized math scores of fifth-grade African American students* (Doctoral dissertation). Retrieved from ProQuest Dissertations & Theses Global. (Order No. 3499745)

Lai, C. L., & Hwang, G. J. (2016). A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course. *Computers and Education*, *100,* 126–140. https://doi.org/10.1016/j.compedu.2016.05.006

Laswadi, Kusumah, Y. S., Darwis, S., & Afgani, J. D. (2016). Developing conceptual understanding and procedural fluency for junior high school students through model-facilitated learning (MFL). *European Journal of Science and Mathematics Education, 4*(1), 67–74. http://libproxy.library.wmich.edu/login?url=https://search.proquest.com/docview/1826544232?accountid=15099

Lazarus, J., & Roulet, G. (2013). Creating a YouTube-like collaborative environment in mathematics: Integrating animated GeoGebra constructions and student-generated screencast videos. *European Journal of Contemporary Education, 4(2),* 117-128. https://doi.org/10.13187/ejced.2013.4.117

Leedy, P.D., & Ormrod, J.E. (2005). *Practical research: Planning and design* (8th Ed.). Upper Saddle River, NJ: Merrill/Prentice Hall.

Leong, K. E., & Alexander, N. (2013). Exploring attitudes and achievement of web-based homework in developmental algebra. *Turkish Online Journal of Educational*

Technology, *12*(4), 75–79.

Li, Q., & Ma, X. (2010). A meta-analysis of the effects of computer technology on school students' mathematics learning. *Educational Psychology Review*, *22*(3), 215–243. https://doi.org/10.1007/s10648-010-9125-8

Liao, H., & Hitchcock, J. (2018). Reported credibility techniques in higher education evaluation studies that use qualitative methods: A research synthesis. *Evaluation and Program Planning*, *68*(March), 157–165. https://doi.org/10.1016/j.evalprogplan.2018.03.005

Lin, H.-T., Zhi-Feng Liu, E., & Yuan, S.-M. (2008). An implementation of web-based mastery learning system. *International Journal of Instructional Media*, *35*(2), 209–221.

Linnenbrink, E. A. (2005). The dilemma of performance-approach goals: The use of multiple goal contexts to promote students' motivation and learning. *Journal of Educational Psychology*, *97*(2), 197–213. https://doi.org/10.1037/0022-0663.97.2.197

Lunsford, M. L., & Pendergrass, M. (2016). Making online homework work. *Primus*, *26*(6), 531–544. https://doi.org/10.1080/10511970.2015.1110219

Mahendra, R., Slamet, I., & Budiyono. (2017). *The effect of problem posing and problem solving with realistic mathematics education approach to the conceptual understanding and adaptive reasoning*. Paper presented at the AIP Conference Proceedings. https://doi.org/10.1063/1.5016659

Mahmood, A. (2018). *The effects of teacher feedback versus computer feedback on mathematics homework on student mathematics achievement* (Doctoral dissertation).

Retrieved from ProQuest Dissertations & Theses Global. (Order No. 10744077)

Maksimović, J., Osmanović, J., & Đekić, S. (2018). Self-assessment of methodological competence of teachers for successful reflexive practice. *Research in Pedagogy*, *8*(1), 36–51. https://doi.org/10.17810/2015.69

Maltese, A. V., Tai, R. H., & Fan, X. (2012). When is homework worth the time? Evaluating the association between homework and achievement in high school science and math. *The High School Journal*, *96*(1), 52–72. https://doi.org/10.1353/hsj.2012.0015

Marsh, J. A., Pane, J. f., & Hamilton, L. S. (2006). *Making sense of data driven decision making in education: Evidence from recent RAND research* (Report No. OP-170). Santa Monica, CA: RAND.

Mathai, E., & Olsen, D. (2013). Studying the effectiveness of online homework for different skill levels in a college algebra course. *Primus*, *23*(8), 671–682. https://doi.org/10.1080/10511970.2013.782479

McLoughlin, C., Lee, M. J. W., & Chan, A. (2006). Using student generated podcasts to foster reflection and metacognition. *Australian Educational Computing*, *21*(2), 34–40.

Means, B., Chen, E., DeBarger, A., & Padilla, C. (2010). *Teachers' ability to use data to inform instruction: Challenges and supports*. Washington, DC: U.S. Department of Education.

Merriam, S., Ntseane, G., Lee, M.-Y., Kee, Y., Johnson-Bailey, J., Merriam, S., … Muhamad, M. (. (2000). Power and positionality: Negotiating insider/outsider status in multicultural and cross-cultural research. *Adult Education Research Conference*

Proceedings, Vancouver, BC, Canada, 1–9. http://newprairiepress.org/aerc/2000/symposia/3

Mertler, C. A. (2017). *Action research: Improving schools and empowering educators*. Thousand Oaks, CA: SAGE Publications, Inc.

Miller-First, M., & Ballard, K. (2017). Constructivist teaching patterns and student interaction. *Internet Learning*, *6*(1). https://doi.org/10.18278/il.6.1.3

Mills, G.E. (2011). *Action research: A guide for the teacher researcher* (4th ed.). Boston: Pearson.

Morgan, D. L. (2013). Pragmatism as a paradigm for social research. *Qualitative Inquiry*, *20*(10), 1–9. https://doi.org/10.1177/1077800413513733

Morris, T. H. (2019). Self-directed learning: A fundamental competence in a rapidly changing world. *International Review of Education*, *65*(4), 633–653. https://doi.org/10.1007/s11159-019-09793-2

Morse, J. M. (2015). Critical analysis of strategies for determining rigor in qualitative inquiry. *Qualitative Health Research*, *25*(9), 1212–1222. https://doi.org/10.1177/1049732315588501

Muin, A., Hanifah, S. H., & Diwidian, F. (2018). *The effect of creative problem solving on students' mathematical adaptive reasoning.* Paper presented at the meeting of Journal of Physics: Conference Series. https://doi.org/10.1088/1742-6596/948/1/012001

National Council of Teachers of Mathematics. (2014). Effective mathematics teaching practices. In *Principles to Actions: Ensuring mathematical success for all* (p. 1). Reston, VA.

National Research Council. (2001). A*dding it up: Helping children learn mathematics,* edited by Kilpatrick, J., Swafford, J., & Findell, B. Washington, D.C.: National Academy Press.

Nelson, P. M., Parker, D. C., & Zaslofsky, A. F. (2016). The relative value of growth in math fact skills across late elementary and middle school. *Assessment for Effective Intervention*, *41*(3), 184–192. https://doi.org/10.1177/1534508416634613

Nicholls, J. G. (1984). Achievement motivation: Conceptions of ability, subjective experience, task choice, and performance. *Psychological Review*, *91*(3), 328–346. https://doi.org/10.1037/0033-295X.91.3.328

Nicol, D., & MacFarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, *31*(2), 199–218. https://doi.org/10.1080/03075070600572090

Özdemir, İ., & Pape, S. (2012). Supporting students' strategic competence: A case of a sixth-grade mathematics classroom. *Mathematics Education Research Journal*, *24*(2), 153–168. https://doi-org.pallas2.tcl.sc.edu/10.1007/s13394-012-0033-8

Olson, J. F., Martin, M. O., & Mullis, I. V. S. (2008). *TIMSS 2007 Technical Report.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College. http://timss.bc.edu/timss2007/PDF/TIMSS2007_TechnicalReport.pdf

Ostler, E. (2011). Teaching adaptive and strategic reasoning through formula derivation: Beyond formal semiotics. *International Journal of Mathematics Science Education*, *4*(2), 16–26.

Paschal, R. A., Weinstein, T., Walberg, H. J., & Paschal, R. A. (1984). The effects of homework on learning: A quantitative synthesis. *Journal of Educational Research,*

78(2), 97–104. https://doi.org/10.1080/00220671.1984.10885581

Ramdass, D., & Zimmerman, B. J. (2011). Developing self-regulation skills: The important role of homework. *Journal of Advanced Academics*, *22*(2), 194–218. https://doi.org/10.1177/1932202X1102200202

Rasila, A., Malinen, J., & Tiitu, H. (2015). On automatic assessment and conceptual understanding. *Teaching Mathematics and Its Applications*, *34*(3), 149–159. https://doi.org/10.1093/teamat/hrv013

Raskind, I. G., Shelton, R. C., Comeau, D. L., Cooper, H. L. F., Griffith, D. M., & Kegler, M. C. (2019). A review of qualitative data analysis practices in health education and health behavior research. *Health Education and Behavior, 46*(1), 32–39. https://doi.org/10.1177/1090198118795019

Richards-Babb, M., Drelick, J., Henry, Z., & Robertson-Honecker, J. (2011). Online homework, help or hindrance? What students think and how they perform. *Journal of College Science Teaching*, *40*(4), 81–93. https://doi.org/10.3102/00346543076001001\r10.1021/ed081p441

Richards, K. A. R., & Hemphill, M. A. (2018). A practical guide to collaborative qualitative data analysis collaborative qualitative analysis. *Journal of Teaching in Physical Education*, *2*(37), 225–231.

Richardson, V. (2003). Constructivist pedagogy. *Teachers College Record*, *105*(9), 1623–1640. https://doi.org/10.1046/j.1467-9620.2003.00303.x

Riegel, C., & Branker, M. M. (2019). Reaching deep conceptual understanding through technology. *Mathematics Teacher, 112*(4), 307–311.

Roschelle, J., Feng, M., Murphy, R. F., & Mason, C. A. (2016). Online mathematics

homework increases student achievement. *AERA Open*, *2*(4), 1-12. https://doi.org/10.1177/2332858416673968

Samuelsson, J. (2010). The impact of teaching approaches on students' mathematical proficiency in Sweden. *International Electronic Journal of Mathematics Education*, *5*(2), 61–78.

Schmuck, R. A. (1997). *Practical action research for change.* Arlington Heights, IL: Skylight Professional Development.

Schoonenboom, J., & Johnson, R. B. (2017). How to construct a mixed methods research design. *Kolner Zeitschrift Fur Soziologie Und Sozialpsychologie*, *69*(2), 107–131. https://doi.org/10.1007/s11577-017-0454-1

Schubert, D. J. (2013). *The effects of online homework on high school algebra students* (Doctoral dissertation). Retrieved from ProQuest Dissertations Publishing. (Order No. 3545651)

Schuetz, R.L., Biancarosa, G., & Goode, J. (2018). Is technology the answer? Investigating students' engagement in math. *Journal of Research on Technology in Education*, (50)4, 318-332. https://doi.org/10.1080/15391523.2018.1490937

Seo, K. K. J., & Engelhard, C. (2014). Using the constructivist tridimensional design model for online continuing education for health care clinical faculty. *American Journal of Distance Education*, *28*(1), 39–50. https://doi.org/10.1080/08923647.2014.868754

Sheldon, S. B., Epstein, J. L., & Galindo, C. L. (2010). Not just numbers: Creating a partnership climate to improve math proficiency in Schools. *Leadership and Policy in Schools*, *9*(1), 27–48. https://doi.org/10.1080/15700760802702548

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*, *22*(2), 63–75. https://doi.org/10.3233/EFI-2004-22201

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research, 78*, 153–189.

Stahl, G., Çakir, M. P., Weimar, S., Weusijana, B. K., & Ou, J. X. (2009). Enhancing mathematical communication for virtual math teams. *Acta Didactica Napocensia*, *3*(2), 101–114. Retrieved from https://eric.ed.gov/?q=virtual+teach+for+math&pr=on&ft=on&id=EJ1056129

Stefan, M. A., & Popsecu, A. M. (2014, April). *Forming future-teacher students using constructivist theory in e-learning effectively*. Paper presented at The 10th International Scientific Conference eLearning and software for Education, Bucarest, Romania. Abstract retrieved from 10.12753/2066-026X-14-196%5Cnhttp://search.ebscohost.com/login.aspx?direct=true&db=eue&AN=96263303&site=ehost-live&scope=site

Steif, P. S., Lobue, J. M., Kara, L. B., & Fay, A. L. (2010). Improving problem solving performance by inducing talk about salient problem features. *Journal of Engineering Education*, *99*(2), 135–142. https://doi.org/10.1002/j.2168-9830.2010.tb01050.x

Stickles, P. R. (2017). The implementation of online homework in college algebra and its results. *Illinois Mathematics Teacher,* 1–10.

Stuckey, H. (2015). The second step in data analysis: Coding qualitative research data. *Journal of Social Health and Diabetes*, *03*(01), 007–010. https://doi.org/10.4103/2321-0656.140875

Suh, J. M. (2007). Tying it all together: Classroom practices that promote mathematical proficiency for all students. *Teaching Children Mathematics*, *14*(3), 163–169.

Suh, J., Leong, K. M., Freeman, P., Meints, K., Mimi, C., & Wills, T. (2012). Fostering strategic competence for teachers through modeling rational numbers problem tasks. *North American Chapter of the International Group for the Psychology of Mathematics Education.*, 474–481.

Sullivan, M. M. (2020). *How do middle grade teachers at a rural school utilize IXL in the classroom?* (Order No. 27830807). Available from ProQuest Dissertations & Theses Global. (2392038295). Retrieved from https://login.pallas2.tcl.sc.edu/login?url=https://www-proquest-com.pallas2.tcl.sc.edu/dissertations-theses/how-do-middle-grade-teachers-at-rural-school/docview/2392038295/se-2?accountid=13965

Tabor, S., & Minch, R. (2013). Student adoption & development of digital learning media: Action research and recommended practices. *Journal of Information Technology Education: Research*, *12*, 203–223. https://doi.org/10.28945/1882

Taylor, T. M. (2019). *The impact of completing homework online versus traditional homework on the attitude, motivation, and academic growth and achievement of 7th grade students in an urban public school* (Doctoral dissertation). Retrieved from ProQuest Dissertations Publishing. (Order No. 22621847)

Thiet, R. K. (2017). An interactive, instant polling exercise to allay student anxiety in science courses. *The American Biology Teacher*, *79*(6), 496–498.

Trautwein, U., Köller, O., Schmitz, B., & Baumert, J. (2002). Do homework assignments enhance achievement? A multilevel analysis in 7th-grade mathematics.

Contemporary Educational Psychology, *27*(1), 26–50. https://doi.org/10.1006/ceps.2001.1084

United States Department of Education, National Center for Education Statistics. (2011, November). *The Nation's Report Card: Mathematics 2011*. http://nces.ed.gov/nationsreportcard/pdf/main2011/2012458.pdf

VanDerHeyden, A. M., & Codding, R. S. (2020). Belief-based versus evidence-based math assessment and instruction. *Communique*, *48*(5), 1–25.

van Es, E. A., & Conroy, J. (2009). Using the performance assessment for California teachers to examine pre-service teachers' conceptions of teaching mathematics for understanding. *Issues in Teacher Education*, *18*(1), 83–102.

Vidmar, T. (2011). School and the understanding of knowledge between pragmatism and constructivism. *Journal of Contemporary Educational Studies/Sodobna Pedagogika*, *62*(1), 42–55.

Williams, C. (2019). [Powerschool online gradebook]. Unpublished raw data.

Wisniewska, D. (2011). Mixed methods and action research: Similar or different? *Adam Mickiewicz University Press Poznan*, *37*, 61–72. https://doi.org/oai:repozytorium.amu.edu.pl:10593/1693

Wooten, T., & Dillard-Eggers, J. (2013). An investigation of online homework: Required or not required? *Contemporary Issues in Education Research (CIER)*, *6*(2), 189. https://doi.org/10.19030/cier.v6i2.7728

Xu, J., & Wu, H. (2013). Self-regulation of homework behavior: Homework management at the secondary school level. *Journal of Educational Research*, *106*(1), 1–13. https://doi.org/10.1080/00220671.2012.658457

Yerushalmy, M., Nagari-Haddif, G., & Olsher, S. (2017). Design of tasks for online assessment that supports understanding of students' conceptions. *ZDM - Mathematics Education*, *49*(5), 701–716. https://doi.org/10.1007/s11858-017-0871-7

Zahner, W., Velazquez, G., Moschkovich, J., Vahey, P., & Lara-Meloy, T. (2012). Mathematics teaching practices with technology that support conceptual understanding for Latino/a students. *Journal of Mathematical Behavior*, *31*(4), 431–446. https://doi.org/10.1016/j.jmathb.2012.06.002

Zulnaidi, H., Oktavika, E., & Hidayat, R. (2020). Effect of use of GeoGebra on achievement of high school mathematics students. *Education and Information Technologies*, 25, 51–72. https://doi.org/10.1007/s10639-019-09899-y

APPENDIX A

INTERVIEW PROTOCOL AND SCRIPT

Hi, and thank you for agreeing to participate in this study voluntarily. Before we begin, I wanted to remind you of the purpose of this qualitative research. We aim to understand your perception of online homework's impact on using IXL on your mathematical proficiency. Your participation in this interview will not affect your grade in any way, positively or negatively. However, it does provide me with tremendous insight into your thinking, which is invaluable for me to grow and improve my abilities as an educator.

This interview should last approximately 10 minutes, and I will be taking notes throughout. This interview will also be audio recorded to ensure accuracy. All information and data from this interview will be protected and anonymized to ensure your privacy. I hope to describe the impact of online homework on students' mathematical proficiency in 8th Grade Mathematics. Some of your answers may be probed further to understand your response better.

Before we begin, I want to confirm that you have signed and dated the assent form?

Have your parents also completed, signed, and dated the consent form?

Are there any questions before we begin this process?

Ok, let us begin.

Tell me about yourself.

Probes (race, age, family, where they grew up, likes, dislikes, etc.)

What are your thoughts about completing the homework using IXL?

Probes (likes, dislikes, features, feedback, submissions, aspects, usefulness, motivation, attitude, and feelings)

What did you like/dislike about the online homework in IXL?

Tell me about some of the features of online homework.

What did you think of the feedback given?

Tell me about the online homework submission process.

How do you think doing the homework online with immediate feedback on what you got wrong impacted your learning and score on the posttest?

Probes (definitions, concepts, formulas, similarities in questioning, scores, and language)

Did it affect your understanding of the definitions?

Did you find any similarities in the homework questions and the questions asked on the pre and posttest?

Is there anything about online homework that you haven't mentioned but want to discuss?

Those are all the questions I have for today. Thank you for your time. Feel free to connect with me if you have any questions going further. I will present your interview data to you at a later date once transcribed to ensure transcription accuracy. Have a great day.

APPENDIX B

PRE- AND POSTTEST

Unit 5 Pre- and Posttest

1. Select **all** the functions whose graphs include the point $(16,4)$.

A. $y = 2x$

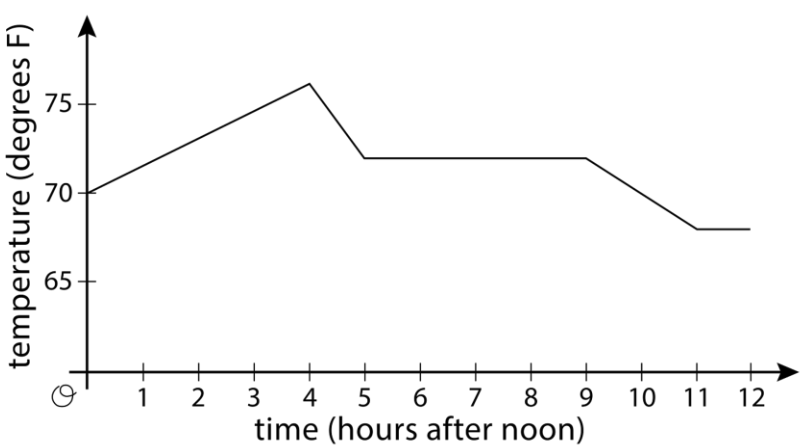
B. $y = x^2$

C. $y = x + 12$

D. $y = x - 12$

E. $y = \frac{1}{4}x$

2. This graph shows the temperature in Diego's house between noon and midnight one day.



Select **all** the true statements.

A. Time is a function of temperature.

B. The lowest temperature occurred between 4:00 and 5:00

C. The temperature was increasing between 9:00 and 10:00.

D. The temperature was 74 degrees twice during the 12-hour period.

E. There was a four-hour period during which the temperature did not change.

3. This table shows a linear relationship between the amount of water in a tank and time.

time (minutes)	water (gallons)
0	30
5	20
10	10

Which of these statements is true?

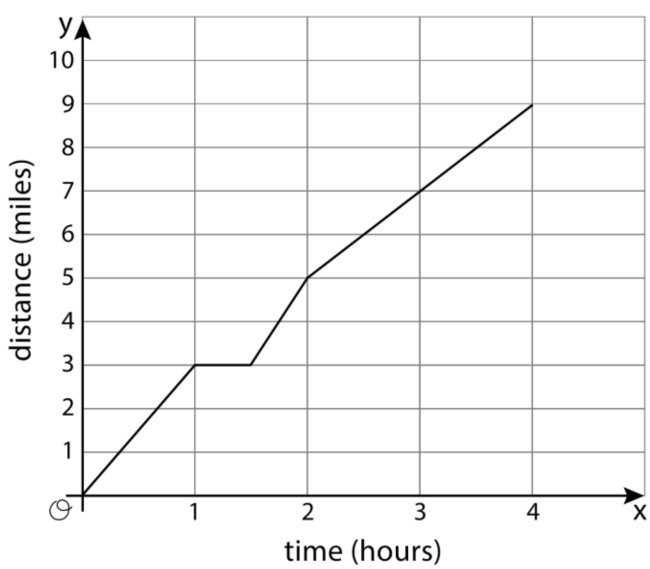
A. The water in the tank is increasing at a rate of 2 gallons per minute.

B. The water in the tank is increasing at a rate of 10 gallons per minute.

C. The water in the tank is decreasing at a rate of 2 gallons per minute.

D. The water in the tank is decreasing at a rate of 10 gallons per minute.

4. Elena goes for a long walk. This graph shows her time and distance traveled throughout the walk.



What was her fastest speed, in miles per hour?

5. Lin counts 5 bacteria under a microscope. She counts them again each day for four days, and finds that the number of bacteria doubled each day—from 5 to 10, then from 10 to 20, and so on.

Is the population of bacteria a function of the number of days? If so, is it linear? Explain your reasoning.

6. Draw a graph of Andre’s distance as a function of time for this situation:

When the football play started, Andre ran forward 20 yards, then turned around and ran 5 yards back. He stood in that spot for 3 seconds, then walked back to where he began.

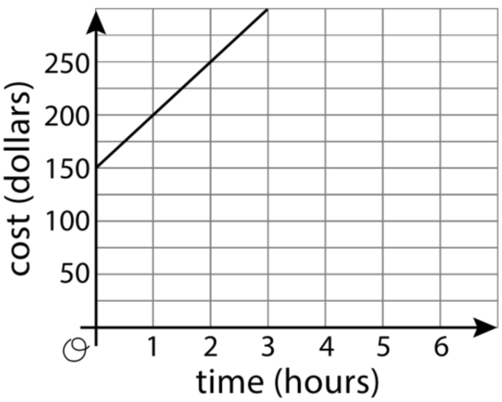
Label the axes appropriately. You do *not* have to include numbers on the axes or the coordinates of points on your graph.

7. Two plumbing companies charge money for each hour of work, plus a one-time fee.

A Plus Plumbing charges according to this table:

time (hours)	**cost (dollars)**
1	140
4	320
6	440

Quality Plumbing charges according to this graph:



a. How much does A Plus Plumbing cost for each hour of work, and what is the one-time fee? Explain or show your reasoning.

b. How much does Quality Plumbing charge for each hour of work, and what is the one-time fee? Explain or show your reasoning.

c. Can A Plus Plumbing and Quality Plumbing ever charge the same total for the same amount of time? Explain or show your reasoning.

APPENDIX C

PRE- AND POSTTEST ITEM STRAND CLASSIFICATION AND POINT BREAKDOWN

Items	Strands			
	Conceptual Understanding	Strategic Competence	Adaptive Reasoning	Procedural Fluency
Problem 1	2			2
Problem 2	2	2		
Problem 3	1		1	1
Problem 4	1			1
Problem 5	3	3	3	3
Problem 6	3	3		
Problem 7	4	4	4	4
Totals	16	12	8	11

Note: A number in the column indicates that the question was determined to assess that strand, while the number represents the number of points allocated for grading. The total represents the total amount of points possible for each strand on the pre- and posttest.

APPENDIX D

GRADING BREAKDOWN OF QUESTIONS FIVE THROUGH SEVEN

ON THE PRE- AND POSTTEST

Problem 5

Minimal Tier 1 response:

- Work is complete and correct.
- Sample: Yes, because there is one output for every input. (Or: Yes, because each day has only one number of bacteria.) No, because the number of bacteria do not go up by the same amount each day.

Tier 2 response:

- Work shows general conceptual understanding and mastery, with some errors.
- Sample errors: explanation appeals to the fact that the day is the independent variable but does not get at the "one output for each input" definition of function; one well-explained correct answer along with another answer that is poorly explained but correct, or along with an incorrect answer that shows some understanding.

Tier 3 response:

- Significant errors in work demonstrate a lack of conceptual understanding or mastery.
- Sample errors: an incorrect answer to one or both questions that does not show significant understanding; both responses are flawed in some way.

Problem 6

Minimal Tier 1 response:

- Work is complete and correct.
- Sample: See diagram, as well as notes in narrative.
- Acceptable errors: axes are labeled only as "distance/time" or "yards/seconds

Tier 2 response:

- Work shows general conceptual understanding and mastery, with some errors.
- Sample errors: axes unlabeled or labeled incorrectly; graph does not meet one of the criteria mentioned in the narrative.

Tier 3 response:

- Significant errors in work demonstrate a lack of conceptual understanding or mastery.
- Sample errors: graph does not meet two or more criteria mentioned in the narrative; graph fails to meet one of the criteria mentioned in the narrative, and the axes are unlabeled/incorrect.

Problem 7

Minimal Tier 1 response:

- Work is complete and correct, with a complete explanation or justification.
- Acceptable errors: omitting units ($).
- Sample:

a. The cost is $60, because The fee is $80 because .
b. The cost is $50, because the graph goes up by 50 every hour. The fee is $150 because for 0 hours, they charge $150.
c. A Plus starts with a lower price but costs more each hour. This means the graphs must intersect.

Tier 2 response:

- Work shows good conceptual understanding and mastery, with either minor errors or correct work with insufficient explanation or justification.
- Sample errors: correct work/explanation for part c based on mistakes in parts a and b; approach to part c involves a correct system of equations with arithmetic mistakes in the solution method; work calculating slope/rate of change involves arithmetic mistakes.

Tier 3 response:

- Work shows a developing but incomplete conceptual understanding, with significant errors.
- Sample errors: approach to parts a and b shows some understanding that the goal is to find a constant number to add each hour that will result in the numbers in the table, but the work is not systematic and involves errors; badly misinterpreting the table/graph, such as reversing the columns/coordinates, with reasonable work following that; approach to part c involves a correct system of equations but no reasonable approach to solving the system; work for parts a and b is correct but work for part c is conceptually flawed.

Tier 4 response:

- Work includes major errors or omissions that demonstrate a lack of conceptual understanding and mastery.
- Sample errors: no evidence of understanding the connection between charge per hour and the information in the table and graph; error types from tier 3 response on parts a, b, and c.

APPENDIX E

ONLINE HOMEWORK ASSIGNMENTS

IXL Online Homework Assignments	***Lesson***	***Standards***
Complete an Input/Output Table	1	8.F.A.1
Input/Output Tables: Find the rule	1	8.F.A.1
Identify Functions: Tables	2	8.F.A.1
Complete an Input/Output Table using an Equation	3	8.F.A.1
Find the Rule: Word Problems	3	8.F.A.1
Identify Independent and Dependent Variables	3	8.F.A.1
Interpret Points on a Graph of a Linear Function	4	8.F.A.1
Identify Functions: Graphs	4	8.F.A.1
Identify Functions	5	8.F.A.1, 8.F.A.3, 8.F.B
Complete a Table and Graph of a Linear Function	5	8.F.A.1, 8.F.A.3, 8.F.B
Compare Linear Functions: Tables, Graphs, and Equations	7	8.F.A.3, 8.F.B, 8.F.B.4
Compare Linear Functions: Graphs and Equations	8	8.F.B.4
Identify Independent and Dependent Variables in Tables and Graphs	4	8.F.A.2
Find Values Using Function Graphs	6	8.F.B.5
Complete a Table for a Function Graph	6	8.F.B.5
Identify Linear and Nonlinear Functions: Tables and Graphs	9	8.F.B.4
Rate of Change: Graphs	10	8.F.B.4

APPENDIX F

INVITATION TO PARTICIPATE LETTER

Dear 8th Grade Mathematics Students and Parents,

My name is Chad Williams. I am a doctoral candidate in the Curriculum and Instruction Department at the University of South Carolina. I am conducting a research study as part of my degree in Education Technology requirements, and I would like to invite you to participate.

I am studying the impact of online homework on 8th Grade Mathematics students at [redacted] If you decide to participate, you will be asked to complete some online homework surveys and your math grades and possibly meet with me for an interview about online homework and your math grades.

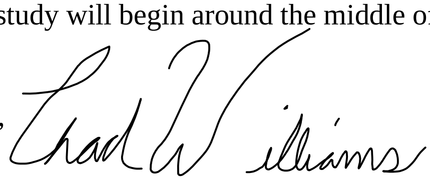
In particular, you will be asked questions about your perceptions of online homework, or we will discuss how you felt the online influenced your grades. You may feel uncomfortable answering some of the questions. However, you do not have to answer any questions that you do not wish to reply to. The meeting will take place at a mutually agreed upon time and place and last about 10-15 minutes. The interview will be audiotaped so that I can accurately transcribe what is discussed. The tapes will only be reviewed by the research team members and destroyed upon completion of the study.

Participation is confidential. Study information will be kept in a secure location at the University of South Carolina. The study results may be published or presented at professional meetings, but your identity will not be revealed. Each student will be given a pseudonym with the code for the names stored in a safe location, only obtainable by me.

You will receive a **dress-down pass** for participating in the study at its completion. If you decide to participate but withdraw in the middle, you will not get the dress-down pass. Only those that begin and end the study will be given the reward. You may withdraw from the study at any time.

We will be happy to answer any questions you have about the study. You may contact me [redacted] or [redacted] or my faculty advisor, [redacted]

Thank you for your consideration. If you would like to participate, please complete the assent form and have your parents complete the consent form. When you are done, please return both forms to me. The study will begin around the middle of February and run until the middle of March.

With kind regards,  [redacted]

Chad Williams
[redacted]

Faculty Advisor [redacted]

APPENDIX G

ASSENT FORM

UNIVERSITY OF SOUTH CAROLINA
ASSENT TO BE A RESEARCH SUBJECT

ASSESSING THE IMPACT OF ONLINE HOMEWORK ON 8TH GRADE STUDENTS' MATHEMATICAL PROFICIENCY AND PERCEPTIONS: AN ACTION RESEARCH STUDY

I am a researcher at the University of South Carolina. I am working on a study of online homework, and I would like your help. I am interested in learning more about students' mathematical proficiency and perceptions. Your parent/guardian has already said it is okay for you to be in the study, but it is up to you if you want to be in the study.

If you want to be in the study, you will be asked to do the following:

- Take a Pre- and Posttest
- Complete homework using IXL for Lessons 1-10 in Unit 5
- Possibly be interviewed for 10-15 minutes
- Take two surveys on your perceptions of the online homework

Any information you share with me (or study staff) will be private. Therefore, no one except me will know your answers to the questions. However, you will be allowed to review the interview tape to verify the questions being asked and the answers transcribed.

You do not have to help with this study. Being in the study is not related to your regular classwork and will not assist or hurt your grades. You can also drop out of the study at any time, for any reason, and you will not be in any trouble, and no one will be mad at you. Withdrawal from the student will not exempt you from the Pre- and Posttest or IXL homework for Unit 5. I will not use your data. I will not ask you for an interview. Also, I will not ask you to take the two surveys.

Please ask any questions you would like to about the study.

Please check the appropriate box. If you select "Yes, " please write your name and sign below. If you select "No, " please write your name and return the form.

☐ Yes, I would like to participate in the study.

☐ No, I do NOT wish to participate in the study

*For Minors 13-17 years of age:

My participation has been explained to me, and all my questions have been answered. Therefore, I am willing to participate.

____ _____________

Print Name of Minor Age of Minor

____ _____________

Signature of Minor Date

APPENDIX H

CONSENT FORM

PARENTAL CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY

INVESTIGATOR'S NAME: CHAD WILLIAMS

STUDY TITLE: ASSESSING THE IMPACT OF ONLINE HOMEWORK ON 8TH GRADE STUDENTS' MATHEMATICAL PROFICIENCY AND PERCEPTIONS: AN ACTION RESEARCH STUDY

INTRODUCTION

We ask for permission for your child to be allowed to participate in a research study. This research is being conducted to see how online homework using IXL impacts your child's mathematical proficiency. You have the right to be informed about the study procedures to decide whether you want to consent for your child to participate in this research study. This form may contain words that you do not know. Please ask the researcher to explain any terms or information you do not understand.

You have the right to know what your child will be asked to do so that you can decide whether or not to include your child in the study. Your child's participation is voluntary. They do not have to be in the study if they do not want to. You may refuse your child to be in the research, and nothing will happen. If your child does not want to continue to be in the study, they may stop at any time without penalty or loss of benefits to which they are otherwise entitled

We ask that you read this form and ask any questions that you may have before allowing your child to participate in this study.

DESCRIPTION OF THE RESEARCH

Your child has been invited to be in this study because I am researching the impact of online homework, and I would like your help. I am interested in learning more about students' mathematical proficiency and perceptions when doing homework with feedback via IXL.

The study will take place during the first ten lessons of Unit 5 in the Illustrative Mathematics textbook. It is estimated that the study will start in the middle of February and run approximately 3-4 weeks into March.

PROCEDURES OF THE STUDY

If you agree to have your child be a part of the study, they will be asked to do the following things:

- Take a Pre- and Posttest
- Complete homework using IXL for Lessons 1-10 in Unit 5
- Possibly be interviewed for 10-15 minutes
- Take two surveys on your perceptions of the online homework

HOW LONG WILL MY CHILD BE IN THE STUDY?

This study will take approximately four weeks or ten lessons to complete. Your child can stop participating at any time without penalty. The only difference between participating and not is that I will use and analyze the data of those participating. Those that choose not to participate will not have their data analyzed and will not be asked to complete any surveys or interviews.

HOW MANY PEOPLE WILL BE IN THIS STUDY?

Two classes will be invited into the study from my 8th Grade Mathematics courses.

WHAT ARE THE BENEFITS OF THE RESEARCH?

- Your child's participation will benefit by receiving more robust feedback from the IXL homework when completing homework independently.
- I will gain insights into the students' thinking and how they perceive the homework to benefit their mathematical abilities.

WHAT ARE THE RISKS OF THE RESEARCH?

There are no risks to the research.

PARTICIPATION IS VOLUNTARY

Participation in this research study is voluntary. You may refuse to allow your child to participate or withdraw from the study at any time. Likewise, your child may refuse to participate or withdraw at any time. Your child will not be penalized if you decide not to allow your child to participate or withdraw your child from this study. A withdrawal only means I will not ask for your child to take the additional surveys or interviews.

WILL MY CHILD BE PAID?

Your child will be compensated with *a dress-down pass* for participating in the study.

WHAT ABOUT CONFIDENTIALITY?

We will do our best to ensure that your child's answers to these questions are kept private. Information produced by this study will be stored in the investigator's file and identified by a code number only. The code key connecting your child's name to specific information about you will be kept in a separate, secure location. Information in your child's records may not be given to anyone unaffiliated with the study in a form that could identify your child without your written consent, except as required by law.

Your child may be interviewed and audio recorded during this study. You will be allowed to view or listen to audiotapes before giving your permission for their use if you request.

WHOM CAN I TALK TO ABOUT THE STUDY?

If you have any questions about the study or if you would like additional information, please call [redacted] or email [redacted]. In addition, my faculty advisor, [redacted], may obtain further questions or information at [redacted]

CONSENT

I have read this parental consent form and have been allowed to ask questions. I give my permission for my child to participate in this study. I understand that, for my child to participate, they will need to be able to give their assent also. I understand that participation is voluntary, and I can withdraw my child at any time without penalty or loss of benefits. You will be informed of any significant new findings discovered during this study that might influence your child's health, welfare, or willingness to continue participating in this study.

Please check the appropriate box. If you select "Yes," then please sign below. If you select "No, " please write your child's name and return the form.

☐ Yes, I grant permission for my child to participate in the study.

☐ No, I do NOT wish for my child to participate in the study.

Parent/Guardian signature_____________________________ Date: _________________

Child's Name:______________________________ _____________________________

You will be given a copy of this consent form for your records.

APPENDIX I

STUDENT SURVEY QUESTIONS

1. Online math homework provides me with resources that help me solve my math problems.

2. I earn higher test grades after I have online math homework.

3. I think that online math homework helps me to do math.

4. When completing online math homework, I use the online resources provided.

5. Online math homework does **NOT** provide me with resources that help me solve my problems.

6. I do **NOT** think that online math homework helps me learn how to do math.

7. I do **NOT** use the online resources provided when I am completing online math homework.

8. Online math homework is more good than bad.

9. Online math homework is more bad than good.

APPENDIX J

ORIGINAL GUTIERREZ SURVEY

Online and Paper Math Homework

Select the option that best describes how you feel.

1. Online math homework provides me with resources that help me solve my homework problems.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

2. Paper math homework provides me with resources to help solve my homework problems.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

3. I would rather have online math homework than paper math homework.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

4. I earn higher test grades after I have online math homework.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

5. I think that online math homework helps me learn how to do math.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

6. When completing online math homework, I use the online resources provided.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

7. Online math homework does **<u>not</u>** provide me with resources that help me solve my homework problems.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.

8. Paper math homework does **<u>not</u>** provide me with resources that help me solve my homework problems.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.

9. I would rather have paper math homework than online math homework.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.

10. I earn higher test grades after I have paper math homework.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.

11. I do **<u>not</u>** think that online math homework helps me learn how to do math.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.

12. I do **<u>not</u>** use the online resources provided when I am completing online math homework.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.

13. I think that paper math homework is useful for my learning.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.

14. There are things about paper math homework that prevent me from learning how to do math.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.

15. There are things about paper math homework that help me learn how to do math.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

16. There are things about online math homework that prevent me from learning how to do math.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

17. There are things about online math homework that help me learn how to do math.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

18. Online math homework is more good than bad.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

19. Online math homework is more bad than good.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

20. Paper math homework is more good than bad.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

21. Paper math homework is more bad than good.

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree	I prefer not to answer.
○	○	○	○	○	○	○

APPENDIX K

PERMISSION REQUEST FOR ONSITE RESEARCH

11/8/2020
[redacted]
Principal of [redacted] [redacted]
[redacted]

Permission to Conduct Research Study

Dear [redacted]:

I am writing to request permission to conduct a research study at [redacted] Middle School. I am currently enrolled in the doctoral curriculum and instruction program at the University of South Carolina in Columbia, SC. I am in the process of writing my doctoral dissertation. The study is entitled “Assessing the impact of online homework on 8th-grade students’ mathematical proficiency and perceptions: An action research study.”

I hope the school administration will allow me to recruit approximately 52 in-person scholars from the school to participate in my research. Most of the research will be integrated into the students’ daily routines. Due to the qualitative nature of the study, I hope to recruit 8-10 students from the selected pool for individual interviews to understand their perceptions of online homework innovation. Interested students, who volunteer to participate in the online homework innovation, will be given an assent form and consent form to be signed and completed with their parents.

If approval is granted, student participants will be asked to complete the following: a pre- and posttest, 11 online homework assignments, two in-class anonymous surveys, and 8-10 student interviews. The study will take place during Unit 5 on function at the end of January. The innovation will run approximately four weeks, or the length it takes to teach 11 lessons. The data collected will be pooled for my dissertation, and the individual results of this study will remain confidential and anonymous. Should this study be published, only pooled results will be documented. No costs will be incurred by your school/center or the individual participants.

Your approval to conduct this study will be much appreciated. Next week, I can follow up with an in-person meeting and would be happy to answer any questions or concerns you may have at that time. You may contact me at my email address:
[redacted]

If you agree, kindly sign below and return the signed form in the enclosed self-addressed envelope. Alternatively, kindly submit a signed letter of permission to your institution's

Letterhead, acknowledging your consent and permission for me to conduct this survey/study at your institution.

Sincerely,

Chad Williams, USC Ed.D. candidate

Enclosures

cc: Dr. Moore, Research Advisor, USC

Approved by:

______________________ ______________________ __________

Print your name and title here Signature Date

APPENDIX L

USC IRB DECLARATION OF NOT RESEARCH

UNIVERSITY OF SOUTH CAROLINA

OFFICE OF RESEARCH COMPLIANCE

INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH

DECLARATION of NOT RESEARCH

Chad Williams
[redacted]

Re: **Pro00105828**

Dear Mr. Chad Williams:

This is to certify that research study entitled ***ASSESSING THE IMPACT OF ONLINE HOMEWORK ON 8TH GRADE STUDENTS' MATHEMATICAL PROFICIENCY AND PERCEPTIONS: AN ACTION RESEARCH STUDY*** was reviewed on **11/19/2020** by the Office of Research Compliance, which is an administrative office that supports the University of South Carolina Institutional Review Board (USC IRB). The Office of Research Compliance, on behalf of the Institutional Review Board, has determined that the referenced research study is not subject to the Protection of Human Subject Regulations in accordance with the Code of Federal Regulations 45 CFR 46 et. seq.

No further oversight by the USC IRB is required. However, the investigator should inform the Office of Research Compliance prior to making any substantive changes in the research methods, as this may alter the status of the project and require another review.

If you have questions, contact [redacted]

Sincerely,

[redacted]
ORC Assistant Director and IRB Manager

APPENDIX M

[redacted] IRB APPROVAL FOR RESEARCH

[redacted]

December 15, 2020

Dear Chad Williams,

This is to inform you that your request for your research study, "Assessing the impact of online homework on 8th grade students' mathematical proficiency and perceptions: An action research study" has been reviewed and approved with one condition – the use of PBIS points and gift cards cannot be used as an incentive.

Please note that this district-level approval obligates no school or employee to participate. Final approval, consent to participate, and cooperation must come from the school principal or administrator of the unit involved. Please show this letter to the school principal or administrator.

[redacted]

Please adhere to the following guidelines:

- Except in the case of emancipated minors, researchers must obtain signatures of parents or legally authorized representatives on a consent form prior to a student's participation in the research study. All consent forms must contain the following sentences:
  - "I do not wish (my child) to participate." (This must be an option on the form.)
  - The school district is neither sponsoring nor conducting this research.
  - There is no penalty for not participating.
  - Participants may withdraw from the study at any time without penalty.
- Assent of children who are of sufficient age and maturity should be obtained prior to their participation in research. In all cases, students should be told that they have the right to decline participation.
- Parents or guardians of students participating in your research must be notified of their right to inspect all instructional materials, surveys, and non-secured assessment tools used in conjunction with your research. This notification should include details of how parents can access these materials.
- Student social security numbers should never be used.
- Data directly identifying participants (students, teachers, administrators), such as name, address, telephone number, etc., may not be distributed in any form to outside persons or agencies.
- All personally identifiable information, such as name, social security number, student ID number, address, telephone number, email address must be suppressed in surveys and reports. Reports and publications intended for audiences outside of the district should not identify names of individual schools or the district.
- Any further analyses and use of the collected data beyond the scope of the approved research project, and any extensions and variations of the research project, must be requested throug[redacted] Office of Assessment and Evaluation.
- Researchers should forward a copy of the results of the research to [redacted]ffice of Assessment and Evaluation.

Respectfully,

[redacted]