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A Multi-Case Examination of Training of Self-Explanation when Combined with Worked Examples

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A MULTI-CASE EXAMINATION OF TRAINING OF SELF-EXPLANATION WHEN COMBINED WITH WORKED EXAMPLES

by

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ABSTRACT

A MULTI-CASE EXAMINATION OF TRAINING OF SELF-EXPLANATION WHEN COMBINED WITH WORKED EXAMPLES

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As more students enter higher education unprepared for college level mathematics, amelioration of deficiencies may be a key barrier which, once faced, will increase overall college graduation rates (Attewell, Lavin, Domina, & Levey, 2006). Corequisite courses offer the opportunity for the underprepared learner to take the gateway mathematics course with support (Complete College America, 2012). Upon passing, mathematics and STEM courses will "unlock," thus allowing the learner to successfully complete their degree requirements. Faculty are challenged to retain the rigor of college-level coursework while supporting learners who possess a wide range of mathematics levels (Daugherty, Gomez, Carew, Mendoza-Graf, & Miller, 2018). Implementing a corequisite curriculum requires the creation or adaptation of materials and instructional strategies to align the basic skills instruction into the college-level content. A case study was conducted with the sample population of college undergraduates (N = 43) enrolled in two sections of College Algebra and participated within a 14-week semester course. A generative learning strategy, self-explanation when combined with worked examples, was introduced during Week 5, when multi-step problems were encountered. Training within the intervention was given to one section. The other section was informed that the strategy was useful to understanding mathematics. The quality of the self-explanation produced was evaluated at the beginning and end of the intervention. Attitudinal data was captured in a pre-

and post-Mathematical Attitudes and Perception Surveys (MAPS), in addition to participant semi-structured interviews and a reflection.

The sections were compared on measures of quality of the artifact produced, MAPS survey data, and through categories of ability as determined by incoming ACT score. The result indicated that those trained in self-explanation when combined with worked examples produced artifacts of higher quality. The participants who had the lowest incoming mathematical scores (ACT mathematics sub score < 17) produced higher quality self-explanations than any other mathematical score category from either case.

Attitudinal data showed that the trained section had marked increases in mathematical attitudes, with the highest increase in confidence. The untrained section's attitudes stayed relatively consistent throughout the study. Interviews and reflections indicated that, for both sections, the intervention assisted in mathematical understanding and metacognition. Trained participants used both components to understand and identify mathematical knowledge gaps. The majority of the untrained participants devoted more attention to the worked example portion of the intervention to create mathematical meaning and identify misunderstandings.

This study found that training the learner was an important aspect of the intervention and was necessary to produce results of a higher quality along with positive mathematical attitudes.

Keywords: generative learning, self-explanation, worked example, training, metacognition, mathematical attitudes

This dissertation is dedicated to my wonderful husband, John, who has loved and supported me on every step of this academic journey. I also dedicate this to my two children, Andrew and Hannah, who have given me love, support, and encouragement to know that anything is possible. I do this for you! I love you all more than anything.

I would also like to dedicate this to my parents, James and Hannah Ketzner Leveridge, who instilled within our family the love of learning. One of my fondest memories is my dad giving me math problems for fun when I begged him. My mom, a gifted art and music teacher not only showed what it was to be a kind and compassionate teacher but also the dedication necessary to complete an advanced degree. They provided a wonderful life for myself and my sister, Kathryn (Kathy) Leveridge DaSilva. We couldn't have asked for better parents and I miss them each day. I know that they and my son Alexander are proud of this accomplishment.

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CHAPTER I

INTRODUCTION

Mathematics can be a challenging subject, where learners can have years of struggle as they progress through the K-12 system, despite the best efforts of talented educators. As these learners enter college, the stakes become higher, in terms of time and financial impact. Entry level mathematics courses serve as prerequisites for many academic disciplines and degrees. Withdrawals or failures from these courses can add additional time and expense to a four-year degree plan. It can also force students to reevaluate their degree plans by switching from STEM (science, technology, engineering, and mathematics) to a different non-STEM major. For others, it can cause self-doubt as to whether they are "college-material" and should continue on with their college degree endeavor. These unsuccessful attempts have a financial effect as well as the students' lost years of higher income earning ability (Logue, Douglas, & Watanabe-Rose, 2019).

Crafting instruction includes the alignment of content and activities to learning objectives. A dynamic part of instruction is the selection of instructional strategies which assist the learner in making connections to content. Learning mathematics may be affected by many factors such as the cognitive ability, motivation, instructional strategies, methods used, and teacher competency (Saritas & Akdemir, 2009). To assist learners, particularly those who have struggled, educators must create mathematical instruction which informs the learner of the goal and relevance of teaching and learning strategies, and forms a learning environment conducive for mathematical development and success (Martin & Navarro-Zavala, 2006).

Creation of a classroom culture which maximizes student success is composed of several factors: introduction of a task, supporting learners as they engage within the task, strategy sharing, and assessment (Sullivan et al., 2013). While strategy training has been shown to increase student performance (Tuckman, 2003), it is often a frequently overlooked component of instruction, particularly when the learner is an adult within the higher education system. Educators must not confuse the age of the learner with the ability to "acquire mature mathematics learning strategies" (Martin & Navarro-Zavala, 2006, p. 351). When higher education teachers choose interventions, particularly for underprepared learners, they must provide a variety of instructional strategy supports and scaffoldings to assist learners as they use the strategies which will foster the much-needed connections.

Underprepared Learners

Many students enter college unprepared for the intellectual rigor of college-level mathematics. In 1998, the need to remediate students was described as "the most important educational problem in America today" (Astin, p. 12). In the twenty years that have passed since this observation, remediation remains a critical challenge to both the learner and the educational institution. Logue (2017) noted that unsuccessful remediation affects the learner but also the university system as a whole. Ameliorating mathematics deficiencies may a key barrier which, once faced, will increase overall college graduation rates (Attewell, Lavin, Domina, & Levey, 2006). Students who do not successfully complete the remediation course(s) tend to drop or transfer out of the university system. For the university, this can lead to lower enrollment in non-mathematics courses, lower operating budgets for departments, and lower total funds for the institution.

Research has shown that students have a better chance of graduating when their remediation gaps are not severe (Adelman, 1996; Bettinger & Long, 2005). Green and Winters (2005) indicated that approximately one-third of 2002 students had the requisite mathematics skills necessary to successfully complete college-level mathematics. The percentage of readiness was lower when comparing minorities (23% African-American and 20% Hispanic) to Caucasian students (40%). Approximately 70% of college freshmen require one or more remediation courses in English and/or mathematics (Logue, 2018). Yet, despite the development of remediation programs across the nation, students are struggling to complete the programs or to find success in later mathematics courses. Chen (2016) found that only 58% of students enrolled in remediation programs completed them. Limited data has been collected on longitudinal studies to document success of remedial mathematics learners, however, Bailey, Jeong, and Cho (2010) found that only 20% of students taking remedial math courses were able to successfully complete later college-level mathematics courses.

This lack of mathematical readiness can present significant disadvantages when compared to college-level learners (Hagedorn, Siadat, Fogel, Nora, & Pascarella, 1999; Logue, Douglas, & Watanabe-Rose, 2019; Vandal, 2014). Underprepared learners who wish to pursue a STEM degree struggle to quickly fill-in mathematical gaps necessary for successful completion of the degree. However, many learners are motivated due to plethora of STEM-based careers and increased compensation available upon graduation. Overcoming mathematical gaps can change the trajectory of a student's life. On a macro level, it follows that a significant increase (or decrease) in students' mastery of mathematical deficiencies can literally change the course of our society.

A mathematics curriculum provides skills and understanding necessary to function in a world which features changing technologies (Ngussa & Mbuti, 2017). In 2017, the United States was ranked 11th in the world in the proportion of students who had college degrees (Logue, 2017). To maintain the level of dominance in science and technology fields, the 2012 U.S. President's Council of Advisors on Science and Technology (PCAST) Report indicated that one million STEM graduates would be needed within the next decade in the United States workplace (Olson & Gerardi-Riordan, 2012). However, a recent report (Khan, Robbins, & Okrent, 2020) issued by the National Science Board indicated that China, and other countries, have invested in science education to increase their dominance while the United States' global share has shrunk.

Post-secondary remediation programs provide assistance to students who do not enter the university system at a "college-level" in mathematics. Historically, these programs have been referred to as "remedial," "developmental," or "preparatory" education (Tomlinson, 1989) and focus on gaining skills and new knowledge prior to enrolling in the college level mathematics course. Students who qualify for remediation programs come from a diverse set of student factors. In 1988, Hardin identified six categories of learners who need remediation, 1) insufficient test takers, 2) adult learners who may have forgotten concepts over time, 3) international students, 4) disability students, 5) students without a clear academic direction, and 6) the forgotten student who was ignored or slipped through earlier educational settings without their academic insufficiencies identified or addressed.

Traditional remediation courses have been identified as "the largest single academic block to college student success" (Logue, 2018, para. 4). Placement, at most universities, occurs with the use a single academic test measure such as a standardized test or placement exam (Bailey, 2009; Kozeracki, 2005). While all students may have gaps in their mathematical knowledge, remedial students' gaps are significant enough to result in test scores which do not meet the prerequisite requirements for the entry-level mathematics courses. However, underprepared learner's needs are specific and are not represented well by an incoming standardized test score. Use of these measures to filter students may present more hurdles as placement exams are inaccurate measures and make a poor predictor of student success (Burdman, 2013).

Historically, underprepared learners at the collegiate level would take one or more remediation courses, depending on their incoming mathematics level. While the sequence of courses was required, they did not count towards the student's degree program. Failures, withdrawals, and multiple attempts caused financial hardship and delays in graduation as the college-level courses were restricted until learners successfully completed all prerequisite remedial courses. Underprepared learners, struggling to remediate, became trapped within the development courses which created a roadblock for entry into the degree bearing course. Complete College America called this method of "long sequences of fragmented reductive coursework … not an on-ramp to college for underprepared students, but a dead end" (Charles A. Dana Center, Complete College American, Inc., Education Commission for the States, & Jobs for the Future, 2012, p. 3).

It is estimated that 50% of underprepared mathematics learners who were placed into remedial programs had the potential to earn a passing grade, C or better, in a college-level course (Clayton, 2012). Individual needs of the learner must be met within a remedial program to fully support the learner at their present educational level and where they wish to be (Complete College America, 2011). As research refines and develops the sequences of courses to remediate the underprepared learner, a new model has emerged to assist this learner to be successful in a college-level course.

Corequisite Model

The corequisite model redesigns the entire remediation system by allowing underprepared learners to enroll in the required college-level gateway mathematics course, while simultaneously receiving academic support developed to scaffold their learning (Logue, 2018). The corequisite structure removes the stigma of remediation as the learner is placed within a college-level course and whose success counts towards their degree. Underprepared learners engage in the same academic experience as learners whose standardized test scores were deemed college-level (Vandal, 2014). Additionally, the need to enroll and pay tuition for non-credit remedial courses, which had previously acted as a roadblock to student's college completion, was eliminated. The potential for students to exit the remediation sequence was removed as students only take courses necessary for degree completion. Corequisite classes have shown positive results over time. Logue, Watanabe-Rose, and Douglas (2016) conducted a longitudinal study which indicated that students assigned to the corequisite group had higher course passing rates and overall graduation rates.

Success in college-level mathematics depends on an understanding of principles and topics, not just exposure to the ideas (Conley, 2017). Corequisite initiatives allow underprepared students to have success in college level mathematics courses while they make connections to principles and topics not previously mastered (Vandal, 2014). Typically, corequisite classes are paired with a support class. The goal of the support course is to provide knowledge and practice on the prerequisite material, which assists in the mastery of the college-level material (Boylan, 1999, Hagedorn & Kuznetsova, 2016). Prior research has shown that support courses encourage engagement and assist with the development of student-to-student and student-to faculty relationships (Kuh, 2008). Corequisite courses can feature mixed mathematical levels (college-level and underprepared learners) within the same class. Other corequisite structures use a cohort model in which the class is comprised entirely of underprepared learners, which provides an additional level of academic support for the learner (Edgecombe, 2011).

Academic support, designed for underprepared learners, can be presented in a variety of formats such as a separate support class or an extra credit hour added onto the college-level course (Vandal, 2017). The content of the support course can be used for additional mathematical instruction, recitation practice, or development of non-cognitive skills, such as study strategies, time management, notetaking, and metacognition. Use of the separate support course gives the underprepared learners extra time to make the connections and an opportunity to address skills from past mathematical classes which are critical for success with the college level material (Daugherty, Gomez, Carew, Mendoza-Graf, & Miller, 2018; Vandal, 2017).

As the corequisite course structure has gained adoption, attention is turning to fine-tuning instructional strategies and pedagogies which support the academically varied student base that may be present with the same classroom. To meet the needs of the diverse underprepared learner population, Kozeracki (2005) advises that educators must be experienced with a variety of pedagogical strategies to "diversify and fine-tune instructional methods" (Atuahene & Russell, 2016, p. 19). Instructional strategies which scaffold the learner and help to make connections to content must be tested, refined, and shared. Thus, research should explore methods which create a "bridge between theory and practice" (Kozeracki, 2005, p. 47).

Climates for Success

Providing support to underprepared learners is more than remediating mathematical deficiencies. Addressing a student's negative mathematical attitudes, anxiety, and/or study skills help to support the learner towards present academic success while improving the chance that they will have their prospects for success in future mathematical courses (Tobias, 1993). Pajares (2000) indicated, "Efficacious teachers create classroom climates in which academic rigor and intellectual challenge are accompanied by the emotional support and encouragement necessary to meet that challenge" (para. 11). Focusing on attitudes in addition to successful completion of remediation provide comprehensive interventions that will change mindsets and academic abilities. Educators can determine how their course structure and mathematical interventions can be strengthened or altered to encourage positive attitudes while ameliorating negative student attitudes (Hendy, Schorschinsky & Wade, 2014).

An important aspect of creating a successful mathematical environment is to treat the whole student, both in terms of their mathematical deficits and in their mathematical attitudes. Negative attitudes may exacerbate as they struggle to make connections between concepts that should have been mastered in K-12, to the required material which is a part of the college level course requirements (Kozeracki, 2005). Underprepared learners may struggle with a proven intervention. Albert Bandura (1997) stated:

> Educational practices should be gauged not only by the skills and knowledge they impart for present use but also by what they do to [students'] beliefs about their capabilities, which affects how they approach the future. Students who develop a strong belief in their efficacy are well-equipped to educate themselves when they have to rely on their own initiative. (p. 176)

Faculty needs. As the population of underprepared learners in higher education has increased, faculty with low or no prior experience with underprepared learners, may be required to teach developmental courses (Kozeracki, 2005). Faculty can be challenged to retain the rigor of college-level coursework while supporting learners who possess a wide range of mathematics levels (Daugherty et al., 2018). Implementing a corequisite curriculum requires the creation or adaptation of materials and instructional strategies which will align the basic skills instruction with the college-level content. Educators may find themselves without a networked system of support when looking for strategies that assist underprepared learners. Many teachers may develop these academic efforts in isolation (Grubb & Associates, 1999).

Choosing pedagogical strategies which assist learners with a myriad of knowledge gaps can be difficult. In 1992, Berenson, Carter, and Norwood indicated the diverse needs of the underprepared learner population have prohibited the application of educational strategies which address the needs of all learners. Since this time, classroom educators have used techniques such as differentiated instruction to address the varying academic needs that exist within the same classroom (Finley, 2017). Other strategies include the use of group-based activities and real-world situations to aid in the construction of knowledge as learners share mathematical viewpoints and experiences (National Research Council, 1989; National Research Council & Up 2001).

Faculty may feel challenged to assist students who have vastly differing needs, language barriers, or mathematical disabilities (Vandal, 2014). However, by understanding the varied issues that surround the underprepared learner, the educator can create productive instructional strategies to provide a positive mathematical experience (Daugherty et al., 2018). The educator can also use this knowledge to direct learners to existing university support mechanisms. This multi-dimensional approach, encourages both academic growth and awareness of student attitudes to demonstrate to the student that prior negative mathematical experiences do not need to repeat themselves.

Supporting educators who teach underprepared learners is mandatory for success. The corequisite instructor must have support in learning how to recognize when learners struggle academically and which pedagogical strategies are most beneficial to underprepared learners. As a part of this support, information on how strategies were introduced, implemented, and assessed must be shared among educators who work with this population.

This case study examined the role training has on underprepared learners as they use self-explanation when combined with worked examples, a generative learning strategy. The intervention is incorporated into a corequisite College Algebra mathematics course for mathematically underprepared college students. Mathematical attitudes were examined during the intervention to determine attitudinal changes.

This research can assist educators who struggle to find interventions that can be applied to a variety of educational situations and academic levels. By understanding how underprepared learners are affected by the manner in which interventions are introduced, more support can be created for them. The use of self-explanation, when combined with worked examples, can create mathematical meaning in a personal way for the learner as they create connections between prior mathematical knowledge and the current academic content. The intervention, if adopted into their learning habits, can assist them within future classes which features mathematics at the core of the subject matter.

Generative Learning Theory

Wittrock (1974b) states, “although a student may not understand sentences spoken to him by his teacher, it is highly likely that a student understands sentences that he generates himself” (p. 182). Generative learning strategies give the learner the opportunity to become an active participant in the creation of their own learning. Within this active construction of knowledge, the learner makes associations from the current content to prior knowledge or experiences (Wittrock, 1974a). Learners will remember more if they co-construct some of the information themselves (McFarland, Frey & Rhodes, 1980).

Wittrock's (1990) model identified four components needed for meaningful learning: generation, motivation, attention, and memory. Generation refers to active construction of information among the parts of the content and between the content and prior experience. Motivation is the desire to be an active participant in the generation of representations and recognizing that this effort can lead to success. Attention guides the generative learning to specific and relevant parts of the text or remembering past events which may be useful. Memory relates to any historical experiences, prior knowledge, metacognitions, and preconceptions brought into the learning environment. Examples of generative strategies include paraphrasing, notetaking, graphic organizers, and self-explanation.

Self-Explanation

Self-explanation, or explaining the concept to themselves, produces a learner created elaboration as the student chooses words which make sense to them. A method which assists the learner to support schema development, the learner generates original sentences, relating prior knowledge or a past experience to the new situation. This strategy helps to organize the new information by providing a reference to something that is familiar and understood. The explanations are meaningful since they are created by the learner.

While there is consensus about the process of self-explanation, there is disagreement about the product of the generation. Some researchers consider the entire generation produced as a self-explanation (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Chi, De Leeuw, Chiu, & LaVancher, 1994; McNamara, 2004). Other researchers consider only the generations which provide reasons for the event as self-explanations (Wolfe & Goldman, 2005). While this debate is primarily due to the focus of the research, it is important to note the differences between categories of self-explanation.

Self-explanations are usually categorized as an elaboration which explains the content, practice, experiences, and methodology to themselves as they attempt to integrate the new knowledge as they create meaning (Rittle-Johnson, Loehr & Durkin, 2017). Paraphrasing or restatements of a strategy are not considered self-explanations as they do not add prior knowledge either from within the problem or external (McNamara & Magliano, 2009).

The quality of a self-explanation is an important aspect when examining the generation produced. Fiorella and Mayer (2016) indicated that the effectiveness of the strategy depended on the quality of the generation produced. The quality of the self-explanation is a predictor of the learner's ability to transfer the knowledge to similar or dissimilar problems (Jonassen, 2004). Chi et al. (1989) conducted a groundbreaking study known as the "Self-Explanation Effect" in which they showed learners who had more effective problem-solving abilities naturally generated a greater number of self-explanations. The learners were able to relate the solutions to further problems while they monitor their own learning. The self-explanations were produced as the learners integrated concepts from external resources and generalizing the example steps (Chi & VanLehn, 1991). A gap in the research was identified by Wong, Lawson, and Keeves (2002), as they indicated that future research should examine the quality of the explanatory activity generated by students.

Worked Example

A worked example is the presentation of a completed mathematical problem, consisting of the problem statement, solutions steps, and the final solution (Renkl, 2002). Worked examples are useful in building skill acquisition in mathematics and other structured domains (VanLehn, 1996) and can serve as models for similar problems (Renkl, Stark, Gruber, & Mandl, 1998). For learners who lack prior mathematical knowledge, the worked example becomes a vehicle in which the learner can view the solution to create a deeper understanding so that the concept, similarities, differences, and procedures are retained. The efficient nature of learning from worked examples can assist students in higher educational classrooms who must effectively remediate in reduced time.

Worked examples can be found in printed text, classroom lecture examples, and computerized learning materials. Familiarity of the presentation of worked examples may cause learners to overlook them when found within instructional materials. However, the simplicity of the worked example masks the power that it gives the underprepared learner. By gaining confidence in a strategy, which can be applied to a myriad of mediums, the learner may be more likely to consistently use the strategy to gain understanding of complex topics.

The use of worked examples is beneficial for novice learners as they may not recognize similarities that problems possess but rather notice superficial features (Mayer, 1992). The inspection can allow learners to determine relationships between concepts and terms.

Self-Explanation When Combined with Worked Examples

Use of effective instructional strategies is vital to helping the underprepared learner as they remediate within a semester course. An essential part of mathematics is the communication of mathematical thoughts through explanations, logical construction of arguments, reflections, and clarification of thinking (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Mathematical communication allows the learner to focus on *why* the mathematical step was performed, which helps to make connections as opposed to the memorization of steps.

By combining two effective strategies, self-explanation and worked examples, the power of mathematical communication supports learners who struggle to understand mathematical concepts. Self-explanation of a worked example allows the learner to write down the meaning, reason, or prior connection to the step being illustrated in the worked example. Worked examples can assist the learner as they describe an expert's problem-solving model. The model can be used to illustrate how similar problems could be solved. As students inspect a worked example, they can discern similarities and/or differences between the example and their target problem to determine what is applicable (Nokes-Malach, VanLehn, Belenky, Lichtenstein, & Cox, 2013).

Many researchers have examined worked examples and self-explanation. However, this researcher did not find the research to be grounded in Wittrock's Generative Learning Theory but rather, the research rested on the "Self-Explanation Effect" (Chi et al., 1989). Yet, if one examines the self-explanation of worked examples research using the lens of Wittrock's theory, learner created elaborations, such as self-explanation of steps in a worked example, can be classified as generative learning strategies. Within the worked example, the learner explains the mathematical procedures or concept using sentences which makes sense to them. The process allows the learner to identify information, inferences, discrepancies, processes, while mapping these to prior mental models (Wylie & Chi, 2014). Chi and VanLehn (1991) indicated that through explanation, the learner is able to add details that an example may have omitted and can emphasize the relationship between concepts to facilitate personal understanding.

Training

Effective instruction sets up the conditions for learning. However, instruction should not be evaluated merely by the speed at which the content can be learned (Jones, Wilson, & Bhojwani, 1997). Instruction must include problem solving skills but also generalizable skills which apply the learning to new situations. The learning environment should strive for a condition of self-sufficiency where the learner has been provided the tools necessary for increasing their own performance. Bruner (1966) indicated the goal of instruction was:

> Finally, it is necessary to reiterate one general point already made in passing. Instruction is a provisional state that has as its object to make the learner or problem solver self-sufficient… Otherwise the result of instruction is to create a form of mastery that is contingent upon the perpetual presence of a teacher. (p. 53)

Jones, Wilson, and Bhojwani (1997) found that effective instruction enhances learner performance; however, ineffective instruction can result in poor performance and negative student attitudes. Their research indicated that quality instruction is affected by organization and presentation of content. Within these areas, a variety of factors must be considered when creating instruction. The selection of materials, course structure, activities used, along with how the guidance and support from the instructor can provide a learner-centric environment. However, Bruner tell us that the environment should not focus on merely the coverage of the content to be mastered but also to the process in which the instruction is provided. Training the learner on how to learn, implement, and use a strategy is an important factor to maximize the student's success with the strategy.

Wittrock (1990) indicates that a role of the instructor within a generative classroom is to facilitate the connection of relationships. The environment helps the learner to generate the necessary bridges between the new information and prior stored knowledge (Wittrock, 1974a). Training the learner to successfully self-explain will enable him/her to learn more effectively (Bielaczye & Recker; 1991). Given the expediency with which remediation must occur at the college level, effective and efficient instructional strategies are needed.

As new pedagogies are tested, it is important to ensure that all parties, both faculty and students, have a clear understanding of the goal and desired outcome. Brown, Campione, and Day (1981) identified three classifications of training, based on the information provided to the learner regarding the significance of the instruction to learning: blind training studies, informed training, and self-control. Blind studies do not inform the learner of the importance or benefit of the intervention. Informed training is provided to the learner with information regarding the importance and benefit of the activities. Self-control provides information regarding the importance of the intervention but also includes training to provide regulation and monitoring of his or her own performance.

An educator may assume that the instructional intervention can be achieved without student training or without the learner understanding the relevancy the intervention will have to learning. However, this is often an incorrect assumption. As higher education instructors search for the most effective strategies to help the struggling student, understanding *how* an initiative should be implemented and *what* the learner should know regarding its importance to learning is vital to determining whether the intervention was successful.

Mathematical Attitudes

Affective factors have been demonstrated to be related to mathematics performance but in many cases are not included within the development of an intervention targeting remedial learners (Benken, Ramirez, Li, & Wetendorf, 2015). Given this, the underprepared learner may resist an intervention due to attitudes regarding prior unsuccessful mathematical experiences. Bonham and Boylan (2011) challenge educators who teach remediation to focus on mathematical attitudes when they emphasize that “this is a rich area of information for educators designing developmental mathematics courses and one that should definitely not be ignored by anyone attempting to improve student performance in developmental mathematics" (p. 4).

Conclusion

For the mathematics instructor, it is important to choose effective pedagogical methods to stimulate and support the learner. Self-explanation, a generative learning strategy, allows the learner to connect past knowledge to current information using words that the learner creates. By understanding the role that training has on a generative instructional strategy, the faculty member can incorporate scaffolding into the pedagogy to help the learner understand mathematics more effectively.

Student attitudes can create a barrier to success. By examining the learner's perspective on mathematics, which includes their view on mathematics and benefits of instructional strategies, the instructor can assist the underprepared learner to utilize new learning methods. The new methods can replace faulty or insufficient strategies that may have contributed to mathematical failure.

This study examined how the inclusion (or exclusion) of training affected underprepared mathematics learners in a corequisite College Algebra course. Quality of the self-explanation produced was examined at the beginning and end of the study by use of a coding structure which rated the quality of the explanation in terms of the knowledge added, either internally or externally to the problem, within the generation. Therefore, the results determine if the training in how to construct a self-explanation enabled the learners to create explanations which reference information and concepts that were found beyond the step being explained.

Student perceptions of the instructional strategy and mathematical attitudes were captured as the strategy was unfolding. These perceptions were used to document attitudinal changes as the intervention was in use and to give the learner a voice as “so many developmental students had compelling stories to tell” (Stewart, 2006, p. 64). These voices relate their experiences, both past and present, which shaped their attitudes brought into and present during the remediation focused setting.

These findings will inform faculty, particularly those who teach underprepared learners, that implementation of the strategy may affect a student’s experience. Training the learner at the onset of an initiative will allow them to have the greatest chance for success with that strategy. The research documents the experience of the underprepared learner as they use the generative learning strategy and face the many constraints of the course, which includes time management, study skills, and mathematical attitudes.

This study addressed the following research questions:

1. How did the training condition influence the instructional strategy of self-explanation when combined with worked examples?
2. What were the corequisite students’ perceptions of self-explanation when combined with worked examples as an instructional strategy?
3. How have students’ mathematical attitudes changed by learning a new instructional strategy?

CHAPTER II

LITERATURE REVIEW

Within this study, literature was reviewed within five areas to critically analyze the most recent and salient findings which would inform the current study. The first area examined Generative Learning Theory, the conceptual framework, from which learners actively construct meaning. Self-explanations and worked examples, the proposed generative strategy and the mathematical vehicle which help connect the explanations to the content, are examined next. Self-explanation training is examined to understand the role that it has within the intervention. Lastly, mathematical attitudes that can surround any intervention are examined.

Generative Learning Theory

Generative learning must feature the linking to prior knowledge and the generation of organized or integrated relationships to allow the learner to formulate a personal meaning (Grabowski, 2004; Wilhelm-Chapin & Koszalka, 2016). Learners can generate understanding of the content through note taking, adjunct questions, self-explanation, elaboration, and paraphrasing (Jonassen & Grabowski, 1993). Through this intimate construction of meaning that the learner individually makes, a bridge is created to what is meaningful and memorable to them.

Wittrock (1990) identified nine principles learned through his study and research:

- Learners generate relationships among text and with their experience which aids in comprehension.
- Critical components of generative instruction are the individual experiences, knowledge, and ideas that learners bring.
- Learners must generate associations that are relevant to comprehension that is being assessed. Inappropriate generations are a distraction.

- When learners write and construct their own representations, associations made to parts of the text and to prior experiences are increased.
- Generative teaching must encourage learners to construct relevant representations that learners would not create on their own.
- Generative learning is flexible for the teacher. The lessons can be direct, indirect, organized, or more loosely structured. The lessons should be customized to the learner's needs in terms of background and ability.
- Learners can be taught metacognitive strategies to assist them to organize, assess, and regulate their generative constructions.
- Generative activities can be adapted to differentiate the instruction to learners to assist in their comprehension.
- Learners must be instructed in how to generate elaborations. Learners go through a developmental progression as they begin to understand and learn from a teacher's elaborations to the mastery of creating their own generations.

Wittrock's model does not supplant the teacher. Rather, the teacher is vital to the generative learning process. The teacher has the flexibility to construct and introduce lessons, based on the learner's ability, which encourages the creation of an artifact. The artifact constructed is a meaningful, individual connection to their prior and current learning. Without the structure of the lesson and the guidance of the teacher, the learner may not be able to spontaneously compose the representation. By introducing, modeling, and supporting the learner's proficiency and metacognitive needs throughout the generative learning process, the learner can develop, monitor, and strengthen their ability to create meaningful representations.

This body of research lays the foundation for generative learning theory whose purposeful instruction makes the learner an active participant within their knowledge creation. Wittrock principles help educators craft instruction based on a variety of teaching styles. Whether the teaching style is structured or one that promotes learner self-discovery, the generative learning model allows an educator to create dynamic learner-center instruction.

Self-explanations. Self-explanation, a generative learning strategy, is defined as the generation of explanations to oneself in order to understand new information within the context of existing knowledge (Chi, 2000). The practice of self-explanation allows the learner to reference material that is beyond the scope of the given problem (Rittle-Johnson et al., 2017). By referencing properties, personal strategies, or strategies derived from a worked example, learners can make connections to content. Learners can address inconsistencies, points yet to be clarified, strategies used, answering specific questions which focus on "why" an action occurred, and emphasizing inferences (Chi et al., 1994; Fiorella & Mayer, 2016). The "Self-Explanation Effect" originated with the seminal study by Chi et al. (1989) and showed that learners, with more effective problem-solving abilities, generated a greater number of self-explanations. In Chi et al.'s (1989) study, learners used different strategies when interacting with insufficiently elaborated examples. When this occurred, learners would generate their own explanation for the worked example's step. The learners who self-explained while examining worked examples demonstrated more learning by subsequently problem solving as opposed to those who did not self-explain.

Self-explanation is an accessible instructional strategy which can assist learners to strengthen knowledge gaps within a variety of disciplines (Nathan, Mertz, & Ryan, 1994). Studies also found that learners who self-explained were able to self-monitor their knowledge state more effectively than an ineffectual problem solver (Atkinson, Derry, Renkl, & Wortham, 2000; Pirolli & Recker, 1994; Renkl, 1999). Learners can detect areas where a lack of understanding may exist which helps to monitor their own comprehension (Otero & Graesser, 2001). This understanding can help to avoid a flawed mental model.

Self-explanation can be used within a variety of contexts. Wylie and Chi (2014), described a continuum which ranged from open-ended (reflection), scaffolded (fill-in-the-blank) solved problems, and worked examples. Self-explanation prompts have been shown to improve transfer on mathematical problems and can improve learning through procedures (Rittle-Johnson, 2006). Self-explanation with peer feedback produced significant learning gains over the no-feedback group (Hall & Vance, 2010).

Self-explanation has been used with many age groups of mathematical learners, including kindergarten/elementary students (Calin-Jageman & Ratner, 2005; Foreman-Murray & Fuchs, 2019; Fuchs et al., 2016) to learners in higher education (Nokes-Malach et al., 2013; Renkl et al., 1998).

Most studies have examined the performance benefits of self-explanation when used with a variety of disciplines. However, one study by Chebbini, Varpio, St-Onge, and Chamberland (2019) examined the perceptions of 11 medical students regarding the effect that self-explanation had on their learning. The students were seven months into an 18-month clerkship at a Canadian medical school. Using a two-phase approach, the participants were introduced to self-explanation through oral and written instructions, which included the instruction of how to self-explain and the incorporation of their own individual knowledge within their construction. The students also had access to an audio self-explanation on a similar type of case. The audio illustrated how biomedical and clinical concepts can be linked within a self-explanation. The participants were also shown how knowledge monitoring could be achieved through the identification of knowledge gaps or misunderstandings. The clerks orally self-explained four clinical cases by providing a diagnosis and supporting reasoning for each. The participants then listened to an 8-minute audio of a junior resident who explained the case. The participants were asked to compare their clinical understanding to the audio, with opportunities for the participant to change their clinical diagnosis.

The second phase of the study the participant met individually with the researcher to solve seven clinical cases and participate within a semi-structured interview. The results indicated that participants perceived the self-explanation intervention as beneficial to knowledge reactivation, knowledge elaboration and organization, understanding of where gaps existed within their clinical knowledge, recall of clinical mechanisms, and extensive analysis of each case presented.

Self-explanation has been examined within the performance of STEM disciplines. Nokes-Malach et al. (2013) examined the results of 54 college-level participants who were randomly assigned to three instructional strategies: self-explaining, analogous comparison indicating similarities and differences, and reading/explanation of physics worked examples. All participants reviewed the same worked examples and completed the same near transfer problems within their experimental conditions. The reading group reviewed worked example and instructional explanations and then filled in a portion of the solution which was left blank. The self-explanation condition reviewed the worked example and explained each step. The analogy group compared and contrasted worked examples then answered questions which would prompt the participant to focus on specific conceptual aspects of the example. After the 68-minute training time, which included introduction of materials, procedures and review of materials, the participants were given 24 minutes for the far transfer test. The results indicated that for near transfer performance, the students within the self-explanation and reading groups outperformed the analogy group. However, the reading group was outperformed on the far transfer test, by the self-explanation and analogy group.

Some studies on learner created elaborations showed mixed results on learning. Berthold, Röder, Knörzer, Kessler, and Renkl (2011) conducted an experiment in which forty undergraduate tax law students were randomly assigned to one of two conditions. While both groups utilized e-learning modules, the experimental group used concept-oriented explanation prompts and the control group did not use prompts. Participants who used explanation prompts produced a significant higher number of more detailed elaborations, which were positively related to conceptual knowledge. However, the use of explanations decreased the number of calculations generated which negatively affected procedural knowledge acquisition. The researchers called the mixed results as “double-edged prompt effect” (p. 74).

Self-explanation within an elementary school mathematics program found that the method successfully provided remediation with children (Fuchs et al., 2016). This study examined participants who qualify as “at risk” but who may not have been diagnosed with a learning disability. Within this study, the researchers used the generative strategy of supported self-explanations as their sample contained learners with low mathematical achievement and may not have been able to create their own explanation. Supported self-explanations allow the learner to engage with previously created high-quality self-explanations. Three conditions were investigated: self-explanation of fraction magnitude comparison problems; word problems using the same fraction magnitude comparison problems; and a control group which examined part-whole comprehension. Instruction was identical between the two interventions conditions with the exception of the last seven minutes. During the differing seven minutes, the self-explanation group received instruction on how to produce a high-quality explanation within the fraction comparison problem while participants within the word problem group were instructed how to solve fraction-based word problems. After researchers modeled explanations, the participants analyzed and used the explanations to apply the mathematical concepts. Participants were encouraged to elaborate and explain any feature that they found important with the explanation.

Results of the study found that students who used and created their own self-explanations had more accuracy with the fraction comparison problems than the word-problems condition and with the control group. When analyzing word problems, the word problem group outperformed the self-explanation group. However, the results also indicated that self-explanation was beneficial for learners who had weaker working memory, whereas the word problem intervention assisted learners who had stronger analytical ability.

This body of research demonstrates the wide-ranging versatility that self-explanation has within educational contexts. Self-explanation has been shown to be effective for learners of all academic level and across disciplines. Within mathematics, self-explanation has been used in a variety of grade levels. The results from the majority of the studies document increases in mathematical performance and understanding of their own knowledge. These characteristics make this an attractive option for educators who teacher a wide range of academic abilities within the same classroom.

Self-explanation quality. Variations of quality exist within self-explanations. Typically, a “lower quality” self-explanation uses paraphrasing or restatements while a “higher quality” link information to specific areas of the text or problem. These higher quality statements can include information which help to fill in missing pieces of information by using concepts previously learned (Chi, 2000).

Researchers have shown that higher quality explanations are related to learning gains within a variety of disciplines. These include physics (Chi et al., 1989) and computer programming (Pirolli & Recker, 1994). Several studies have examined the quality of self-explanations in mathematics.

Using participants from the Fuchs et al. (2016) parent study, Foreman-Murray and Fuchs (2019) examined the quality of student's explanations as compared to their language and reasoning ability while using fraction magnitude comprehension problems. Seventy-one 4th grade participants, previously randomized into the parent study's control group, were selected. The results indicated that language ability is not directly responsible for the participant's creation of high-quality explanations but rather it was a predictor of comparison accuracy. The research suggests that students who struggle with language skill may not be disadvantaged when using self-explanation interventions. The language evaluated was domain specific and not mathematical vocabulary based.

Self-explanation comprehension and quality, using the Self-Explanation Reading Training (SERT), was examined by McNamara (2004). Forty-two participants were split between the control group which read text aloud and the experimental SERT training over the course of five experimental one-on-one sessions. The experimental group participated in a training which consisted of a brief introduction to self-explanation and its benefits, which included definitions and examples. Following the training, the participants read aloud and self-explained science related text-based material. Comprehension was measured with questions about the text. The participants also identified strategies used by another student when watching a video as they self-explained. The control group did not receive any training in self-explanation nor reading strategies. They were given the same science-based material to read and comprehension questions. The group was asked to self-explain the same text as the experimental group. The results indicated that the SERT training improved the comprehension and quality of the self-explanations produced by learners with lower-level knowledge. The comprehension was increased for text-based questions but not for bridging questions which assist the learner to link separate ideas presented within the text together.

Quality and text cohesion were examined in the study by Ozuru, Briner, Best, and McNamara (2010) as they examined how comprehension of 78 college-level students examined science related texts. The participants were randomly assigned to either a low cohesion group who read the text in its original form, whereas the high cohesion group, used a revised text in which the participants made inference. The participants then read the text for their group and self-explained seven target sentences which were generally found at the beginning or ending of a paragraph as they connected the topic back to the prior paragraph or forward to the next topic. Participants were presented within the self-explanation instructions an example of what constitutes a “good” self-explanation in that it integrates prior knowledge to content presented within other sentences of the text. Following the self-explanation, participants completed nine open-ended comprehension questions, eight open-ended prior-knowledge questions, and eight multiple-choice prior knowledge questions.

Quality of the self-explanations was measured in terms whether it contained paraphrasing, prior knowledge, or text-based information. A guide was created for the reviewers to consistently determine if the explanation contained the important information of the target sentence. Paraphrases were coded as being accurate or not accurate, to the original meaning of the sentence. Inferences were used for self-explanations that could not be tied back to the target sentence. Inferences were categorized as 1) *near-bridging*, which suggested the proximity of the sentence from which the inference was based, such as the previous sentence, or 2) *far-bridging*, which indicates the inference was based on a sentence that did not immediately precede or follow the target sentence, 3) *general knowledge*, which suggested prior, common, or personal knowledge to the participant, and 4) *domain knowledge*, or knowledge from a prior classroom exposure.

The results indicated that higher local cohesion produced higher quality self-explanations, which included statements that contained bridging language. Yet, while the explanations were of a higher quality, they did not assist in comprehension questions as those in the local cohesion condition. Therefore, when text scaffolds the reader to making inferences, the quality of the self-explanation was higher. Performance on the comprehension questions was related to the quality of the self-explanation produced by the participants and was not affected by prior knowledge.

Self-explanation prompts and quality was investigated within a study conducted by Kwon, Kumalasari, and Howland (2011). Forty-seven students within a web development course used self-explanation within two experimental groups. Participants in one group were given partial explanations within drop-down lists to finalize the explanation. The other group received prompts for which they provided open-ended explanations that they generated. Both groups monitored their competency with a metacognitive prompt inquiring about their confidence within their generation. Participants selected their confidence by using a five-point Likert scale. The participants completed a pre-test to determine entry-level knowledge, and a post-test.

The results showed that the individual generation was more effective than finalizing an explanation provided by the computer and did not require the participant to expend additional cognitive efforts. Additionally, confidence was higher for the participants who constructed their own elaboration. The quality of the self-explanations was an indicator of student's understanding of the problem as the results as comprehension results showed that students who generated correct explanations, from either group, they were more accurate within their solutions.

In most instances, quality of self-explanations has been shown to be an indicator of mathematical comprehension, even when the learner has lower-academic ability. The exception to this was when considering cohesion. Yet, the research makes quality an interesting factor to examine to learn more about the learner's comprehension.

Prompts. Self-explanation prompts, do not require training, and are supports which direct the learner to examine, and therefore explain, a particular context (Renkl, 2005). The use of prompts to encourage self-explanation does promote transfer within the domain even without the learner receiving feedback as to the quality and construction of the elaboration (Atkinson, Renkl, & Merrill, 2003; Renkl et al., 1998). Prompts can engage the learner to explain correctness or error within a step, which is effective in comprehension (Barbieri & Booth, 2016). Prompts act as a scaffolding which can help the learner to generate new knowledge connections.

Berthold, Eysink, and Renkl's (2009) study examined self-explanations, self-explanation prompts, or no prompts. While the results indicated that both self-explanation treatments encouraged procedural knowledge, conceptual knowledge was predominantly fostered by the use of prompts. They concluded that high-quality self-explanations can be fostered by prompts which help in both procedural and conceptual knowledge.

King (1994) found that the connections were strongest when learners were able to combine prior knowledge with new information. Chi et al.'s (1994) research showed that learner's self-explanations from prompts were more effective than self-explanations which were spontaneously generated. Atkinson et al. (2003) recommend prompts within mathematics as they produce medium to high transfer performance, no interference with fading, easy to implement as they do not take up instructional time and requires no training.

Examining problems or worked examples is a common manner of learning. However, many learners passively self-explain (Renkl, 1997). To focus the learner's attention, which in turn facilitates self-explanation, the use of prompts can be explored. This body of research indicates the power that this easily implemented method can provide in terms of comprehension and increase of conceptual knowledge, even in underprepared learners.

Worked Examples

A worked example is a step-by-step solution to a problem that begins with a problem statement and ends with the final solution. The use of worked examples is instrumental during initial stages of skill acquisition (Atkinson et. al., 2000). In VanLehn's (1996) stages of skill acquisition, the *intermediate* phase finds the learner attempting to apply the instructional principles to an actual problem. The goal of this active learning phase is to identify and correct any misunderstandings that the learner has regarding the instructional principle. When using worked examples, the learner understands how the principle applies within the problem and generates an explanation for the step (Chi et al., 1989; Renkl, 1999). By the end of the phase, a learner has corrected any misunderstandings and becomes proficient with the principle, even though unintended mistakes can be occasionally made. As learners are introduced to a concept, they may be in different phases when looking at the components needed for mastery of the skill.

Worked examples provide an efficient learning environment for mathematical material (Glogger-Frey, Fleischer, Gruny, Kappich, & Renkl, 2015; Renkl, 2014; Schwonke et al., 2009; Zhu and Simon, 1987) and support transfer more so than an open-ended problem (Glogger-Frey et al., 2015). Worked examples can appear within a textbook, computer software, or within an assignment to provide relevant knowledge as the learner tries to understand the concept(s) being shown. As a learner reviews the examples, he gains knowledge of how the principle or example can be applied to other situations (VanLehn, 1996). A learner can be successful in understanding a worked example without having to generate the solution (Renkl, 1999). The learner can focus on the strategy to understand each step of the process to determine properties. Examination of worked examples can add to the learner's basic knowledge while providing the model of a good solution, which can assist to enhance the learner's self-efficacy (Renkl, 2014).

Worked examples are effective to avert extraneous cognitive load (Kalyuga, 2011; Renkl, 1999; Sweller & Cooper, 1985). Sweller and Cooper's research showed that learners, with no prior knowledge, benefitted more from worked examples followed by problem solving than problem solving alone. Research has also shown that participants who use worked examples created fewer errors than the control group and outperformed, while completing fewer problems (Carroll, 1994).

Novice learners can overburden their limited amount of working memory when problem solving. When working memory's capacity is exceeded, the burden forces the existing information out of working memory before it can be rehearsed and stored as new information (Richey, Klein, & Tracey, 2011). Therefore, learners' benefit when working memory is kept within limits so that the learner has a chance to process and store the information.

This research reminds us of the power that worked examples have in terms of scaffolding underprepared learners who may struggle with completing a problem on their own. By reducing the learner's extraneous cognitive load, worked examples provide a superior mechanism for learning.

Incorrect worked examples. Learning from errors is a powerful instructional strategy. However, some teachers may be reticent to analyze errors as they feel that this will promote future mistakes (Santagata, 2005) or affect motivation (Ames & Archer, 1988). Learners benefit from analyzing their mistakes by explaining their reasoning (Santagata, 2005) or within the analysis and explanation of a fictitious student's errors (Booth, Lange, Koedinger, & Newton, 2013).

An effective use of incorrect worked examples can be when they are paired with correct worked examples (Booth et al., 2013; Durkin & Rittle-Johnson, 2012). While incorrect examples can be used for all student levels, the use of error reflections was more effective than reviewing correct examples for underprepared learners (Barbieri & Booth, 2016). Learners can explain incorrect examples which aids in their integration of knowledge (Booth et al., 2013).

This body of research indicates the power that incorrect worked examples have within the classroom as they can be utilized with all learner levels while they assist in knowledge integration. While it may seem counterintuitive, incorrect worked examples provide learners with experience in dealing with faulty strategies. This is very important for lower-level learners as their attention can be focused on these areas which can lead them mathematically astray.

Fading. To provide a smooth transition so that learners increase their level of processing required as they gain skill, fading can be introduced. Fading transitions learners to completing more steps on their own with each example. The generation of missing steps requires a deeper level of processing than fully completed worked examples and can aid the learner to be aware of their level of understanding (Baars, Visser, van Gog, de Bruin, & Paas, 2013). Fading within worked examples leads to higher transfer performance (Moreno, Reisslein, & Delgoda, 2006; Salden, Aleven, Renkl, & Schwonke, 2009) and is an efficient method of instruction (Schwonke et al., 2009). The use of fading increases motivation as a learner progresses from a novice to a more experienced learner (Atkinson et al., 2003; Renkl, Atkinson, Maier, & Stanley, 2002; Renkl & Atkinson, 2003). Self-explanation prompts can be initially provided to the learner and then gradually faded out so that the learner generates the missing explanation or as they find the solution steps (Atkinson et al., 2003; Salden et al., 2009).

Hesser and Gregory (2015) examined underprepared mathematics learners' uses of fading and showed that they outperformed their college level peers. Qualitative results showed that 74% of the underprepared learners preferred faded examples to open-ended problems and 79% felt that learning by fading worked examples allowed them to learn the material.

From these studies we infer that fading is an effective method when working with underprepared learners as it scaffolds their learning by showing them a partial solution. Its ability to promote higher transfer performance makes it a powerful tool. The combination of fading and self-explanation has provided an interesting mechanism to assist underprepared learners as they go through the various stages of learning.

Explaining within worked examples. The examination of worked examples alone does not ensure that learning will occur (Crippen & Earl, 2007). However, the effectiveness of worked examples is dependent upon the learner's self-explanation endeavors (Bielaczye, Pirolli, & Brown, 1995; Renkl, 1997). Use of spontaneous or prompted self-explanations have led to increased transfer to novel problems (Atkinson et al., 2003; Renkl et al., 1998). Learners can differ with respect to how they learn and explain worked examples (Chi et al., 1989). Intelligent tutoring systems have combined self-explanations and worked examples to provide metacognitive support (Schwonke et al., 2013).

In Chi et al.'s research, learners studied physics worked examples and provided a comment on each step within the example. The researchers classified the comments as one of three types: self-explanations in which the comment related to the content of the worked example; monitoring statement which was an evaluation of their own comprehension or misunderstanding of the example; or miscellaneous, which was an elaboration or paraphrase. Within their study, they found that good and poor students had the similar number of comments, yet "good students" generated more explanations per worked example than "poor students." The quality of the explanation differed by student ability. Good student's self-explanations referred to additional tacit knowledge within their generations as compared to poor student's generations which were composed of a greater number of paraphrasing with no prior or new knowledge being referenced. Learners who generated higher quality self-explanations also demonstrated more problem-solving success.

Research has shown that when STEM learners generate an explanation of why the steps are occurring, their comprehension increases (Chi et al., 1989; Crippen & Earl, 2007; Pirolli & Recker, 1994; Pirolli & Bielaczye, 1989). Nathan et al. (1994) examined self-explanation within a college algebra higher education setting in which worked examples were compared to the use of a problem-solving approach. Their results indicate that learners who used self-explanation with worked examples benefitted most. However, the benefit was greater for conceptual reasoning problems than procedural manipulation problems. They surmised that the self-explanation process cues learners to identifying knowledge gaps. These gaps can then lead to opportunities for discussion of gaps and instruction. Self-explanation of examples can enhance the learner's ability to effectively apply the new knowledge gained to new problems. Studying worked examples can effectively apply the knowledge gained to a practice problem (Sandoval, Trafton, & Reiser, 1995). When learning environments offer feedback and direct support of the self-explanation of the worked example, the learning can be as effective as problem solving practice.

Learners with low level prior knowledge also benefit from explaining worked examples (Renkl et al., 1998). Renkl (1997) researched fading, or removing steps of worked examples, as a method to transitioning learners to problem solving. The research, which used freshmen education majors in the examination of probability, found that even though participants had differences in their level of prior probability knowledge, their ability to self-explain did not depend on that knowledge. His research led him to classify participants within four groups. Successful learners, who used fruitful problem-solving strategies, were categorized into two groups, *principle-based reasoners* and *anticipative reasoners*. Principle-based reasoners focused on the mathematical meaning through the use of principles in addition to the identification of subgoals accomplished by the operators, yet they did not anticipate solutions. Anticipative reasoners, anticipated solutions steps, yet did not use frequently use principle based self-explanations or the identification of sub-goals.

Unsuccessful learners, were categorized as *passive* or *superficial explainers*. Both categories were often metacognitively unaware of their own learning struggles and had challenges in comprehending problems. The unsuccessful group, passive learners, produced poor quality of self-explanations with very few principle-based explanations. Superficial learners, which Renkl characterized as "merely medium successful learners" (p. 22), did not engage with the worked examples, both in terms of time and detail and were not aware of their comprehension problems.

While the anticipative reasoner group began with a higher level of prior knowledge, they were not the most successful group when examining the adjusted means. The anticipative reasoners did not produce many principle-based explanations as their prior knowledge led them to solutions without the benefit of the worked example. Principle-based learners, who began with a low level of prior knowledge, were the most successful. Their active examination of worked examples, both in terms of the quality of self-explanations and the time spent in review of worked examples produced active rich learning. Their assignment of mathematical reasons to the steps of the worked example, helped to construct meaning.

Renkl’s conclusion of poor performance due to less time examining a worked example is in direct contrast to Renkl et al.’s, (1998) study which indicated that time spent working with the problem was not related to performance. They concluded that time spent working on a problem can either encourage learning or, for learners with low prior knowledge, can lead to a negative relationship between time spent and learning achievement. In their study, 56 bank apprentices were instructed in the calculation of compound interest and real interest. A 2 X 2 factorial design measured variation of examples (uniform vs. multiple) and elicitation of self-explanations (spontaneous vs. elicited). The results indicated that eliciting self-explanations increased transferable knowledge. Participants who had low level of prior knowledge benefitted from the elicitation of self-explanations.

Renkl emphasizes that a learner’s self-explanation may be incomplete or prone to error. “Good” students in Chi et al.’s (1989) study, recognized, from their self-explanations, when their skill level was inadequate. However, Renkl (1998) emphasized that strategies must be put in place for learners who may not be able to self-recognize their learning needs. These supports can include ways to verify the learner's analysis and self-explanations, so errors or inadequacies are determined.

Research on self-explaining within worked examples is important as it provides a foundation for underprepared learners to use the scaffolding provided by the worked example with the generative benefits of self-explanation. The benefits include increased conceptual reasoning and performance. It was also important that prior research has examined the use of feedback on learner's explanations. This method was found to be as effective as problem solving. This is a central instructional benefit as the learner gets the scaffolding of the worked example while receiving the same benefits as problem solving.

Recent research examined the use of prompted self-explanation to determine performance and viability for students with low knowledge. Booth et al., (2015) showed that prompting, when used with correct and incorrect worked examples within Algebra homework and classroom assignments, has been effective for learners who have low prior knowledge. Two experiments were conducted. In the first experiment, 56 participants, from three Algebra I classrooms used, were distributed between the treatment group, which used assignments featuring worked example and self-explanation prompts, and the control group, which performed the same types of problems without the use of worked examples or self-explanation prompts. Using a pretest and posttest, the results showed that participants in the treatment group, regardless of prior knowledge, outscored the control group. However, the low prior knowledge students' scores showed an increase among the treatment condition while high prior knowledge students decreased in the control.

In Experiment 2, 395 Algebra I students from five school districts participated in the study and the methodology was identical to Experiment 1. The results indicated that low prior knowledge students who used worked examples featuring self-explanation prompts had higher scores than participants with high prior knowledge. Additional results showed that worked examples were not helpful for improving student performance but that they may be helpful depending on the mathematical topic in review.

Özcan (2017) examined the effects of self-explanation prompts and four different types of worked examples on the mathematical performance of 67 novice sixth grade students while studying fractions. Novice students were selected from a fraction pretest with the score of 40% or lower. The four conditions examined were worked examples with self-explanation prompts, faded worked examples with self-explanation prompts, faded worked examples without self-explanation prompt, and worked examples. Performance was measured during the learning process, transfer test, and follow-up test. Results from the study showed that participants on the transfer test scored higher in both the worked example with self-explanation prompts and the faded example with self-explanation prompt than participants in the worked example groups without self-explanation prompts. Results on the follow-up exam showed similar results, however, only participants in the faded worked example with self-explanation prompts group were more successful than the worked example groups. This indicated that faded worked examples, when combined with prompts was effective for both short- and long-term knowledge transfer and confirmed findings by Atkinson et al., 2003.

Self-Explanation Training

Wittrock (1990) emphasized that training the learner is vital to their success when using generative learning strategies. Learners must be instructed on how to use this method, successful strategies, and how to discern when to use a different strategy when confronted with different types of text. Wittrock also recommended that training focus on metacognitive strategies, by instructing students *why* the method is important to their comprehension. Through this self-monitoring, learners will be motivated to continue and can gauge their comprehension and make adaptions or seek help if needed.

Renkl (1997) showed that learners, when viewing worked examples, may not always self-explain each step. Yet, with training, their self-explanations can be more effective as compared to others who spontaneously self-explain without training (Renkl et al., 1998). Renkl et al.'s research examined four conditions relating to the variability of examples (uniform and multiple), and the elicitation of self-explanations (spontaneous and elicited self-explanations).

While both uniform and multiple conditions contained compound interest problems within the same order, uniform dealt with only securities problems while multiple presented securities, loans, and shares. Spontaneous explainers received think aloud training and were asked to verbalize their thoughts while examining the worked examples. The elicited self-explainers received a brief training on self-explanation and were informed on the importance of self-explanation. The training consisted of a live model, who reviewed the rationale of self-explanation of each step of the worked example, concentrating on the subgoal of each step. The participants were then given a second worked example, which included blank spaces for the learner to self-explain and assign subgoals for each step. Students were mentored during this independent practice in two ways: 1) if participants omitted self-explanation on steps, the mentor would point these areas out and ask the participant to provide the explanations, and 2) the mentor answered any questions about self-explanation construction. Learning was measured by a post-test which used near- and far-transfer problems. The results indicated that the elicitation self-explanation group, produced more self-explanations and enhanced near (problems of the same structure) and far transfer (problems of differing structure) performance than the control. Learners with low-level prior knowledge benefitted most from the elicitation training.

Qualitative results of the study indicated three results. First, the elicitation training helped to increase the number of self-explanations produced but for many within the study, the quality and correctness were low. Second, some participants observed the examples superficially, even when supported by the elicitation training. Lastly, some participants, in both the spontaneous and elicited self-explanation groups, had considerable comprehension problems. Therefore, for weak learners, the elicitation training supported but did not remove their academic challenges.

Training does not need to be cumbersome within the educational process. Renkl et al. (1998) showed that effective training can consist of modeling how to self-explain using one worked example and coaching learners as they self-explain a second worked example. The feedback provided during the coaching can consist of pointing out omission and answering questions on how to self-explain. The time-saving method of training is cost effective, which is of particular importance as budgets for equipment and educational resources are tight, for both universities and students.

Hodds, Alcock, and Inglis (2014) examined self-explanation within a college-level proofs-based mathematics course via three experiments. The first experiment studied the effects that self-explanation training had on the quality of the explanations and the understanding of the proof. Seventy-six participants were randomly assigned to an experimental group and a control group. Students in the trained groups viewed at their own pace computer slides which instructed learners in how to examine each line of the proof and explain in terms of prior knowledge or given information within the proof. The control group read about the history of right triangles for an equivalent amount of time. The experimental group self-explained using the information learned within the training. The control group expressed comments regarding each proof's highlighted line. The participants were shown the proof while they completed a paper-based comprehension test. The results showed the trained group were able to produce both a greater number of and a higher quality of explanations than the control group. The self-explanation training group performed almost one standard deviation higher than the control group on the comprehension test.

The second experiment examined whether self-explanation training improved comprehension and the cognitive engagement of a proof. The study also sought to determine the level of attention participants gave to logical relationships in proofs. Eye tracking was used to examine the area of attention and amount of time the participants examined a proof after self-explanation training. Twenty-eight participant's data, from four experimental groups, were utilized in the study. Study two was conducted in three phases. In phase one, the participants examined one of two proofs and then took a 10-item comprehension exam while the proof was still visible. The training was conducted in phase 2 using the same methodology as in phase 1. The experimental group received training via slides and the control group read a passage on the history of the mathematical topic. During phase 3, all participants responded to questions on the proof that they had not previously viewed during phase 1. Similar to Experiment 1, the study showed that self-explanation training improved performance on the comprehension proof exam. Results also indicated that self-explanation training led to increased and deep engagement with mathematical proofs while also encouraging students to examine the proof for logical connections.

Experiment 3 integrated the self-explanation training into a classroom setting to examine whether self-explanation training improved comprehension and had lasting effects over time. Working with 107 freshman undergraduate calculus students in a university setting that had not participated within the first two experiments. The experiment took place within two lectures twenty days apart. Fifty-three participants in the experimental group examined the self-explanation training booklet. Fifty-four participants were in the control group and examined time-management materials presented within a booklet form. Both groups answered questions regarding Proof B with comprehension test from Experiment 2. Twenty days later, both groups read Proof A, from Experiment 1. Those in the experimental group reviewed the time management booklet while the control group examined the self-explanation materials. A new comprehension test was created which was a modification of the exam from the first experiment. Results indicated that the self-explanation training conducted in a classroom environment increased understanding of proofs over the short term and was effective over time.

Training in self-explanation has been investigated within mathematics and other STEM disciplines. Wong et al. (2002) examined the training of high school students using geometry theorems and found that even though both the experimental and control groups received similar pretest scores on prior knowledge, the learners in the experimental group who received training received statistically significant higher scores on the post-test. Students who used self-explanation scored higher on transfer problems and demonstrated more procedural accuracy over those who were not trained (Rittle-Johnson, 2006). Hodds et al. (2014) conducted two experiments in which college Calculus students were trained in self-explanation. In the first study, trained learners created a greater number of explanations and principle-based explanations. The experimental group also demonstrated greater comprehension when compared to the non-trained group. The researchers next embedded the strategy within a classroom setting and found that the treatment group demonstrated long lasting effects of the training intervention.

Self-explanation training has been used in other STEM disciplines. Chi et al., (1994) compared the performance of students within an eighth-grade biology class and found that learners who were trained on self-explanation performed higher, from pre- to post-test than the control group who read the text material twice. Bielaczye et al.'s (1995) study examined the performance of 24 participants within a computer programming class. Participants included 11 within the experimental instructional group and 13 forming the control. The study involved several phases. The Pre-Intervention Phase consisted of an encoding stage in which all participants studied and self-explained instructional materials to themselves and a problem-solving stage in which participants performed corresponding programming exercises which related to the material examined. The Instructional Intervention Phase utilized Carnegie Mellon University's Lisp Tutor, an intelligent tutoring system. Each participant received identical training materials and programming exercises. Participants within the experimental group were trained to use the self-explanation and self-regulation strategies that prior research had determined to be beneficial for high-performing students (Pirolli & Recker, 1994). Information on the strategy such as purpose, form, context, demonstration of explicit examples, and guided practice was given to the experimental group. The control group received training on time on task and programming related content and not on self-explanation or self-regulation. The results indicated that the experimental group, trained in self-explanation and self-regulation, showed greater performance on problem-solving than the control group. The participants demonstrated higher frequencies of elaborations and connecting ideas from text to application. While this study examined both self-regulation and self-explanation, the study did not allow for the differentiation of the two influences to be separated.

Research about self-explanation training illustrates that training the learner to self-explain can lead to greater comprehension, higher transfer problems, and more procedural accuracy. Renkl et al.'s (1998) study provided an efficient and effective model for self-explanation training which can be easily integrated into a classroom setting.

Attitudes on Mathematics

In 1969, Neale characterized mathematical attitudes as "liking or disliking mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless" (p. 632). Today, students continue to struggle with similar feelings of negative mathematical attitudes as they engage in mathematical instruction. Educators have used attitudes to explain success or failure within mathematics. However, since Neale's observation, educators have realized two important factors: (1) assisting students with their mathematical achievement can include changes in attitude (Di Martino & Zan, 2010), and (2) support of the learner can begin with addressing these attitudes as they progress through their mathematics curriculum (Tobias, 1993).

Development of classroom initiatives and strategies can affect attitudes. Classroom practices that involve collaboration and verbalization can assuage negative attitudes (Dees, 1991). Use of collaboration in a group setting can assist learners to integrate new knowledge with prior knowledge as they work together to form individual meanings (Artzt & Newman, 1990) which mimics the role of generative learning strategies which uses active construction of knowledge to make associations from the current content to prior knowledge or experiences (Wittrock, 1974a).

Vail (1994) indicated that emotions can alter the course of learning. Emotional skills, such as self-awareness, self-regulation, motivation, empathy, and social skills can be developed and improved over time (Bower, 1992). To take advantage of learning, students must be active participants within that exchange. “The learning-teaching process is interactive in nature and involves the implicit and explicit negotiation of mathematical meanings” (Cobb, Yackel, & Wood, 1992, p. 10). This constructivist process works when learners are able to put aside negative feelings about mathematics in order to accept the instruction that has been crafted for the educational experience.

Researchers have shown that mathematical attitudes, such as motivation, engagement, and positive attitude, are important factors in learning and persisting in mathematics (Singh, Granville, & Dika, 2002). Affective barriers can have an effect on mathematical achievement and experiences and differ with respect to gender (Odell & Schumacher, 1998).

Mathematical anxiety has been related to mathematical thinking and mathematical attitudes (Kargar, Tarmizi & Bayat, 2010). In their study, 203 university students from Malaysia were sampled and the results indicated a strong positive relationship ($r = 0.856$, $p<0.05$) between mathematical thinking and mathematical attitudes. Students with high mathematical anxiety tended to score low on both mathematical thinking and mathematical interest, while those with low mathematical anxiety scored high on both mathematical thinking and interest. The study also found a negative correlation ($r = - 0.576$, $p < 0.05$) between mathematics anxiety and mathematical thinking, and a negative correlation ($r = - 0.509$, $p < 0.05$) between mathematics anxiety and mathematics attitudes. The students whose attitudes were positive became more committed to their class, think mathematically, and dedication to learning the mathematical content.

Positive mathematical attitudes have been associated with an increase in higher standardized test scores, classroom performance and achievement (Aiken, 1976; Singh et al., 2002; Stankov & Lee, 2014). Negative mathematical attitudes, such as math anxiety, can affect mathematical confidence ($r = -0.65$), motivation ($r = -0.64$), and test anxiety ($r = 0.52$) (Hembree, 1990). Women are 1.5 time more likely than men to leave a STEM track after calculus, even controlling for mathematical ability (Ellis, Fosdick, & Rasmussen, 2016). The exodus is attributed to lack of mathematical confidence.

Negative feelings regarding mathematics have an effect on performance and behavior. Poor mathematical self-esteem and feelings of being incapable of performing mathematics can affect learning and behavior in the classroom (Yusha'u, 2012). Mathematics anxiety can affect mathematical thinking, commitment to learning, and mathematical attitudes (Kargar et al., 2010). Núñez-Peña, Suárez-Pellicioni, and Bono's (2013) research examined the role that student mathematical attitudes have on learning outcomes. They found that students who have negative mathematical attitudes tend to perform lower on final exams.

Understanding a student's non-academic needs is an important consideration as academic struggle can occur from a combination of academic and non-academic factors. When educators understand the mathematical attitudes that exist, specific instructional strategies can be created to generate meaning, interest, persistence, and involvement in mathematics (Singh et al., 2002). Learners, who have the aptitude but not the desire, can fail. Once these attitudes are mediated, learners can strive to achieve their potential (Higbee & Thomas, 1999). To facilitate this learning, educators must assist the learner to develop skills and strategies.

Recent studies have begun to focus on mathematical attitudes, in addition to content, as a way to encourage overall success for underprepared mathematical learners. One study completed by Benken et al. (2015) examined how underprepared learners experiences enhance their overall understandings and perceptions of mathematics. Conducted at a large, urban university, 376 students participated within the study from one of 11 sections of a developmental Intermediate Algebra class. Data collected included pre- and post- surveys, email survey, student artifacts, and institutional data. The results indicated that many of the reported positive mathematical attitudinal increases by the completion of the course which included skills, confidence, enjoyment, and support. A disconnect existed within the participant's perception of their ability to pass the course versus how many actually passed the course on the first attempt. Eighty-two percent of the participants indicated they would pass while actual passing rates were approximately 78%, with some sections having a 60% successful passing rate. Most participants indicated they felt their skills and confidence improved within the course. However, there was an increase in the beliefs that some people have more mathematical aptitude than others. Another interesting finding was the three perceptions which were found between learning and remembering for the participants. Some students felt their learning had increased due to recall of prior knowledge from high school, (mean = 4.42), a similar number did not feel their learning had improved (mean = 4.23), and the last group indicated that new learning had resulted in their increased skills (mean = 4.11).

Hodara (2011) recommends future research to focus on both the intervention under study and the attitudinal effect that the course redesign has on developmental students or any student subgroups. This information can be shared within professional development to encourage more effective classroom practices and a better learner experience. These concerns are particularly important to learn how instructional strategies either motivate or frustrate the discouraged learner as they struggle to remediate.

Research on mathematical attitudes indicate they are not fixed. Attitudes can affect performance. Mathematical attitudes, such as motivation and engagement can affect learning and persistence in mathematics. When helping underprepared learners, it is important to consider attitudes as part of the curriculum strategy.

Various types of worked examples have been shown to be effective for underprepared learners. The completed solution provides support as learner engages in a new concept, more so than open-ended problems. By combining self-explanation with worked examples, the acquisition of knowledge is increased by offering benefits to performance, transfer, and metacognition. This supportive intervention has been used for all learner levels. By becoming an active participant within their knowledge creation, they can document individual experiences and personal learning within their construction. However, generative learning theory indicates that the instructional climate should lead them to generate explanations that they would not generate on their own. This ability for the educator to design engaging interventions which encourage generations is at the heart of its usage within the classroom. However, Wittrock (1990) indicates that the learner should be trained in how to generate by first learning from the instructor so that individual mastery can be achieved.

Research Questions

Against the background of the preceding discussion, much of the prior research emphasis has been devoted to mathematical performance. Despite research on self-explanation, when combined with worked examples, little is known whether training the learner in how to construct a generation affects the quality of a self-explanation. Additionally, little research has been conducted on attitudinal data of underprepared learners as they engage with a generative instructional strategy. This investigation will add to the body of literature of self-explanation to show the influence that training has on the construction of the learner's generation. It will also add to the underprepared mathematical learners' body of literature, specifically on how they view an instructional strategy as its introduced, and the influence the strategy has on their perceived mathematical attitudes. To this end, the research questions are as follow: (1) How did the training condition influence the instructional strategy of self-explanation when combined with worked examples? (2) What were the corequisite students' perceptions of self-explanation when combined with worked examples as an instructional strategy (3) How have students' mathematical attitudes changed by learning a new instructional strategy?

Significance of the Study

This study is important as it identifies effective and efficient teaching strategies for underprepared mathematics students in higher education. While several studies have examined self-explanation with respect to training, very few have examined student perceptions of the strategy and their perceived benefit to learning. This information can help instructors choose interventions, and how they can be introduced, to address the needs of the students (Holt, Holt, & Lumadue, 2012).

By examining the attitudinal effects when these strategies are introduced, more will be learned of the student's acceptance and beliefs of strategies which are presented to assist them within their learning. If student attitudes are static or fixed, then these attitudes may pose an insurmountable barrier to learning, regardless of the prior success of the initiative.

The results can assist educators to identify, develop, and introduce instructional strategies, each of which can help learners connect prior knowledge to mathematical course content. By examining the role that training, environment, and use of types of prompts have with the implementation of generative strategies, educators can improve the integration of this instructional method within their curriculum.

CHAPTER III

CONTEXT

This chapter provides context to the research study by describing the learning environment which preceded the study. Examination of statewide and university initiatives for the College Algebra underprepared learner population is discussed.

Understanding the needs of the underprepared mathematics learner has been a multi-year state-wide initiative for the mid-Atlantic university. Given the economic make-up of the state and the large percentage of first-generation students, many learners enter college in need of mathematical remediation.

College Algebra provides a challenging environment for underprepared learners due to the amount and difficulty level of the content. The university has designed their remediation programs based on the needs and support structure of the university. Many pilot studies were conducted to determine course structure and pedagogical approaches which best support a diverse set of mathematical learners present within the same classroom.

MTH 127 Established

College Algebra is a foundational course used as both a terminal course within several degree plans and an anchor to the Calculus sequence required for STEM degrees. Due to these divergent student paths within the same course, finding pedagogies to make connections within the College Algebra content, yet assist those who need a solid mathematical structure and scaffolding for future courses, has been challenging. Historically, College Algebra was offered as a 3-credit hour MTH 130 courses for ACT mathematics test score 21 and above. However, the university realized that some students, who tested near MTH 130's ACT 21 cut-off, could be successful with support. In the spring semester 1998, the university created a new version of

College Algebra to support learners who were underprepared for College Algebra. This 5-credit hour version called MTH 127 - College Algebra Expanded, was created for learners who scored either a 19 or 20 on the ACT Mathematics test score. While both 19 and 20 are considered college-level in mathematics, the scores do not meet the prerequisite for MTH 130. Both versions of College Algebra, MTH 130 and MTH 127, feature the same content and comprehensive final exam. The expanded course was established as a stretched version of MTH 130 giving two extra days of lecture. Both courses operated for many years helping learners to find success in College Algebra.

Corequisite Initiatives

The mid-Atlantic university, like other universities across the nation, has struggled to find the best academic structure which remediates the underprepared mathematical learner. In 2012, the West Virginia Higher Education Planning Commission (WVHEPC) received a grant from Complete College America and the Bill and Melinda Gates Foundation to sponsor a statewide initiative of corequisite education models for underprepared learners below an ACT Mathematics test score of 19.

Since the 2012 initiative, the university conducted several pilots which resulted in changes to the original MTH 127 structure. The changes in course structure and pedagogies were initiated to support the underprepared learners as they navigated the corequisite College Algebra course structure. A significant change occurred when the ACT prerequisite for MTH 127 was decreased to enable underprepared mathematical learners who possessed an ACT Mathematics test score of 17 – 20 to enroll in MTH 127. This modification precipitated changes in class meeting times and structure. The five fifty-minute class meetings were changed from lecture to a model which consisted of both lecture and recitation lab experience. The new model reserved Monday, Wednesday, and Friday class meetings for lecture classes while Tuesday and Thursday classes were used for active learning in a recitation lab experience using computerized learning tools. This current structure has remained in effect for several years and has proven to be successful for the learner as they can practice with problems in the presence of their instructor who also conducts the lecture. Lab assistants are available to help with large size classes. Typically, the College Algebra corequisite courses have a pass rate of 70%.

Other opportunities for change within the course were the redefining of instructional strategies and ways to address non-cognitive issues viewed during the previous pilots. As experienced teachers for the underprepared learner population, the pilot instructors knew the problems that the population faced in the classroom: difficult topics, fast pace, self-doubt; poor study skills; and lack of motivation. The first year of a pilot focused on the reorganization of the curriculum to a more foundational approach in which students began with the basic construct of functions and then learned about the different types of functions afterward.

The second year of the pilot tested opportunities for more active learning to be incorporated within the lecture classes. These efforts were taken to encourage learners to remain engaged during each lecture session. The lecture class featured a short introductory "conversation" in which the day's topics were introduced. Students remained verbally active within the presentation by providing details from previous instructional material, questions, or observations. Immediately following the short lecture, students worked in groups using worksheets with the instructor facilitating learning by helping and supporting the learner academically and non-cognitively. Group members were encouraged to be engaged throughout the class by sharing their work with group members or other student groups. In addition to groupwork, in-class reflections, Desmos activities, and polls were also added.

The pilot incorporated opportunities for students to share their personal journey via growth mindset reflections with importance placed on learner's understanding their own knowledge, strengths, and challenges. Within these opportunities, learners gave feedback to the teacher on their mindset, goals, and perceived performance. These private conversations, using assignments and journals, assisted the instructor to understand student cognitive and non-cognitive issues. While tweaks may always be needed as new observations and facets about the population are learned, the course is now a vibrant mix of active learning which features peer-to-peer learning, group work, metacognitive activities, and mentoring from the instructor.

Given this period of experimentation, instructors created a challenging, informative environment to meet the needs of the learners. However, due to the fast pace necessary to cover the content and the rapid change during the years of pilots and reorganizations, instructors may not have had ample time to instruct learners on best practices, but assumed that learners could naturally have success with the intervention.

The overestimation of the student's ability to naturally perform the task, can risk the student failing with an intervention, despite it being a proven strategy. One example seen was in the use of Desmos related activities used during the recitation portion of the course. Desmos provides a mathematical playground for learners to actively engage in understanding the meaning behind mathematics. Many of the activities required open-ended conclusions or rationale. Students, without training in what was required, were unsure whether their explanations should include mathematical properties as justification for their answer or whether only an opinion was required. This lack of specificity as to what was required led to a missed opportunity to make mathematical connections within this active learning experience and was addressed in a later course refinement.

Nonacademic factors were an issue as well. The pilot instructors saw students start out strong but waver due to a variety of causes, such as the inability to manage study skills when living away from parental structure, lack of motivation to succeed, fear of failure, boredom for the higher-level students, and anxiety carried over from prior mathematical instructional experiences.

Students faced a variety of challenges in addition to the management of their academic needs. The university has a large percentage of the student population who are low-income and first-generation college students. As these students, with marginal financial means enter the university, many must work to support themselves, family, and/or their cost of education. Given these constraints, it is logical for an educator to develop instructional strategies which are easy to implement within the assigned classroom meetings, cost-effective for the university and student, adaptable, and easy-to-train.

Much was learned by the university administration and instructors as they diligently worked to define the necessary combination of content, structure, and environment to maximize the learner's potential. Based on the previous pilots, developing the course structure is only a portion of what is required to help underprepared learners succeed. Creating a classroom experience which presents content in an understandable manner to maximize the strengths of the learners is necessary. Scaffolding the learner within their initial attempts provides opportunities for independence as the course goes along. The classroom environment must also address mathematical attitudes in which students are motivated to learn and succeed. However, this has proven difficult to preplan as students have different motivating factors. By understanding the underprepared learner population before, during, and after an initiative, one can gauge the motivational factor of the strategy.

Student attitudes regarding mathematics, instructional strategies used, and perception of their mathematical ability play a part within the student's academic experience. These factors can determine the amount of effort that is expended within a class. After years of mathematics struggle, students become wary of mathematics, new strategies, and their ability to have success. In many instances, the lack of motivation affects the ability for the learner to stay on task, complete assignments on time, and attend lectures and lab classes, all of which is within their control and does not depend on mathematical ability.

Ameliorating these negative attitudes can improve the student's desire to persist. By understanding the at-risk learner's academic and support needs, they can be buoyed through the successful navigation of a college level mathematics class. Stakes are high; underprepared learners feel the pressure - academically, emotionally, and financially. Learners may resist the new experience or strategy because many of their prior mathematical experiences were poor. Administrators and faculty must understand the student's perceptions and experiences as unfamiliar instructional strategies are introduced. This understanding will help to shape future support structures, scaffolding, study skills, and strategies which can help the learner.

CHAPTER IV

METHODOLOGY

Chapter One and Two examined factors which affect teaching the underprepared learner in higher education. Understanding the role that training has on the intervention can assist teachers of underprepared learners as they develop courses. Use of self-explanation in combination with worked examples can assist learners as they struggle to make meaning and remediate in a short amount of time.

The purpose of the multi-case study was to examine the role that training in self-explanation, when combined with worked examples, had on the quality of the self-explanations that a student creates. In addition, student perceptions of the instructional strategy and mathematical attitudes were captured as the strategy unfolded to document attitudinal changes as the intervention was in use. This chapter discusses the research design employed within the study, sampling procedures, instruments, and procedures for data collection and analysis. The methodology section is organized with the following structure: research design, timeline, participants, setting of the study, data collection methods, procedures used, trustworthiness, and data analysis methods.

A case study was used to examine the two sections. Quality of self-explanation artifacts, experiences with the intervention, and mathematical attitudes were captured for each section. Several sources of data were used within this study: pre- and post-intervention survey; a participant journal reflection; self-explanation artifacts; selected semi-structured interviews; researcher's field notes; and observations. All methods of data collection, with the exception of semi-structured interviews, were course assignments.

Research Questions

This study explored results to the following research questions:

1. How did the training condition influence the instructional strategy of self-explanation when combined with worked examples?
2. What were the corequisite students' perceptions of self-explanation when combined with worked examples as an instructional strategy?
3. How have students' mathematical attitudes changed by learning a new instructional strategy?

Research Design

Case Study

This study used a multi-case study research design to investigate the role that training has on quality of generation produced and attitudes surrounding the introduction of self-explanation, when combined with worked examples, to underprepared learners. Case study research is a widely used methodology for examining research questions in the social science field and investigates single or multiple cases in a real-world, authentic setting (Yin, 2017). Robert Stake (1995), uses constructivism and existentialism to inform the qualitative case study as "knowledge is constructed rather than discovered" (p. 99). The role of the researcher as one of translator who gathers interpretations as they investigate "the puzzlement" (p. 97).

Stake (2006) indicated that research can understand the quintain, the entirety or whole, through the exploration of cases. Multiple case study research is used when more than one case is examined (Stake, 1995). By observing and collecting data from each case, the researcher can develop an understanding of how the case is influenced by its own context and situation. This information forms an understanding and appreciation of the quintain as similarities and differences among the cases are discovered. A case, the unit analyzed, occurs in a bounded, or specified, context. The researcher may not be able to discern the line of demarcation between case and environment but by establishing boundaries of the case, the researcher can begin to recognize attributes and elements of the case. Stake indicates that multi-case research involves more than one case that possesses some similarity, such as setting, curriculum, or teacher. The two cases examined with the present study were two College Algebra courses taught at the university. Boundaries for the case study include the following: (1) the learner was registered within one of two sections of a corequisite 14-week College Algebra course. The two sections, each comprising a case, were taught by the researcher. (2) Participants were considered as underprepared either by ACT mathematics test score or by self-selecting into the corequisite College Algebra course.

The examination of a case begins with the understanding of the case and how it works. The examination must include the organic and complex elements of the case, not the methods (Yin, 1994). Situational awareness of the case is key to understanding and interpreting events (Stake, 2006). How the case resonates within its environment is a cornerstone of the qualitative portion of the case study. The interaction of the moving parts between the environment and members, show the interrelated nature of the system.

Case study methodology was appropriate for this type of research as stakeholders keep in constant focus the examination of interventions for underprepared learners to determine their merit. The use of multi-case analysis allowed the researcher to examine cases within their own context as training was used to introduce the intervention to one of the cases. This was beneficial as higher education course sections run independently in terms of interventions and pedagogy.

The study investigated how the provision of training influenced the learner's ability to maximize the benefit of the intervention. Although student attitudes and perceptions may vary from learner to learner, understanding this information can help stakeholders convey the value of the intervention to the learner, the benefit of the intervention within the course, and the influence the intervention has on student attitudes. This knowledge can assist stakeholders as they glean areas for improvement or new opportunities for scaffolding which can be offered in future course iterations.

Use of qualitative data allows for text-based analysis from interview transcripts and reflections (Creswell, 2014). This subjective analysis allows the researcher to examine the participant's experience to more fully provide insight into the intervention which covered the majority of the semester. A timeline for the study is shown below in Table 1.

Table 1

Timeline of Study

Task	Date (Week of Course)
Proposal Defense	November, 2019
IRB Submission	December, 2019
Start of Research Module in MTH 127 course	February, 2020 (Week 5)
Math Attitudes and Perceptions (MAPS) Pre-Intervention Survey	February, 2020 (Week 5)
Artifact 1	February, 2020 (Week 7)
Artifact 2	April, 2020 (Week 13)
Reflection	April, 2020 (Week 13)
Math Attitudes and Perceptions (MAPS) Post-Intervention Survey	April, 2020 (Week 14)
Post-Intervention Interview	April, 2020 (Week 14)
Transcription of Interview	May, 2020
Verification of Transcript with Participant	May/June, 2020
Coding of Artifact 1 and 2	May/June, 2020
Member Check	June, 2020
Final Data Analysis	May – August, 2020

Participants and Setting

The participants (N = 43) were undergraduate students at a mid-sized university in the mid-Atlantic region during the spring semester of 2020. Boundaries for the case study include the following: (1) the learner was registered within one of two sections of a corequisite 14-week College Algebra course. The two sections, each comprising a case, were taught by the researcher. One section was trained in the construction of self-explanations, while the other was untrained. (2) Participants were considered as underprepared either by ACT mathematics test score or by self-selecting into the corequisite College Algebra course.

MTH 127 College Algebra has the following prerequisites: 1) an ACT mathematics test score between 17-20, or, 2) SAT Math score less than 530, or 3) successful completion MTH 102/B Prep for College Math B with a C or higher. MTH 102/B, a remediation emporium style course, is designed for learners whose ACT math test score is between 12 and 16 and desire a STEM degree. Upon successful completion of the course, students were allowed to enroll in MTH 127.

Demographics of the two sections is presented in Table 2. Twenty-three participants were enrolled in the Trained section, while twenty participants were in the Untrained section. The demographics indicated that the majority of students from both sections were freshmen with 82.6% (Trained) and 70% (Untrained) and female with 61% (Trained) versus 55% (Untrained). Mean age of the participants was similar, with 19.22 years (Trained) and 19.15 years in the Untrained section.

Table 2

Descriptive Statistics - All Participants

	Section			
	Trained	%	Untrained	%
Gender				
Male	9	39.1	9	45.0
Female	14	60.9	11	55.0
Academic Standing				
Freshman	19	82.6	14	70.0
Sophomore	2	8.7	5	25.0
Junior	2	8.7	1	5.0
Senior	0	0.0	0	0.0
Age				
18	3	13.0	5	25.0
19	15	65.2	11	55.0
20	2	8.7	2	10.0
21+	3	13.0	2	10.0

Mathematical Readiness

Table 3 details the mathematics standardized test scores of the participants. The West Virginia Higher Education Policy Commission Series 21 Freshman Assessment and Placement Standards was used to determine SAT Math assessment scores as underprepared for College Algebra (Series 21, n.d.). Both sections were academically similar in terms of class demographics and performance ability. Using ACT test scores on file and a concordance table to covert the SAT scores, means for the ACT mathematical subtests were 17.65 (Trained) and 17.79 (Untrained) which indicate similar performance abilities between the two sections involved within the study.

Table 3

Mathematical Readiness by Section

		Trained *N = 23*		Untrained *N = 20*	
		f	%	*f*	%
ACT Math					
	No Score	0	0.0	1	5.0
Remedial, did not initially meet MTH 127 prerequisites	SAT < 530	4	17.4	1	5.0
	15	2	8.7	1	5.0
	16	8	34.8	6	30.0
Underprepared, met the MTH 127 prerequisites	17	3	13.0	3	15.0
	18	0	0.0	1	5.0
	19	2	8.7	3	15.0
	20	1	4.3	2	10.0
Considered College Level in College Algebra	21+	1	4.3	1	5.0
	SAT > 530	2	8.7	1	5.0
% of Remedial		60.7		45.0	
% of Underprepared		26.1		45.0	
% of College-ready		13.0		10.0	
Mean Math ACT		17.65		17.79	

Even though the overall mathematical performance of the two sections were similar, a difference could be seen within the proportion of the student mathematical levels as measured by their incoming ACT test scores. Based on the course prerequisite, each section had three categories of participants: (1) *Remedial* – the participant entered the course with a standardized test score below the MTH 127 course prerequisite of ACT 17 and would have taken the emporium course a prior semester; (2) *Underprepared* – the participant's ACT mathematics test scores fell between the range of 17 – 20, and indicated that the student met the ACT prerequisite requirements for the course; and (3) *College-level* – the participant's ACT score was 21 or above was considered "college-level" for College Algebra and qualified for MTH 130. One participant, from each section, was considered College-level.

Both the Trained and Untrained sections featured a diverse set of mathematical learners. For the Trained section, the ACT mathematics test scores ranged between 15 and 23, while the Untrained section ranged between 15 and 21. The Trained section had a higher percentage (60.7%) of Remedial learners than students who were enrolled within the Untrained section (45%). The percentage of College-level learners was similar between the two sections with 13% in the Trained and 10% in the Untrained Sections.

Using SAS, an independent-samples *t*-test was conducted to compare the ACT Mathematics scores between the Trained and Untrained sections. There was not a significant difference in ACT Mathematics scores for the Trained (M = 17.65, SD = 2.55) and Untrained (M = 17.79, SD = 1.99) sections; $t(40) = -0.19$, p = 0.85.

Verbal Readiness

Perin and Holschuh (2019) indicated that only 25% – 38% percent of high school graduates who enter college are proficient in reading and writing. Hayes (1996) identified a component of writing called "the individual" (p. 10) which affects a student's schema for writing, carrying out writing behaviors such as planning/drafting/revision, metacognition, beliefs regarding writing, and motivation to write. Given that students would be creating written explanations, verbal readiness via the participant's standardized verbal test scores was compared between the two sections.

College-level English scores are determined by either an ACT verbal score greater than or equal to 18 or a SAT Evidence-Based Reading & Writing greater than 480. Therefore, any

ACT below 18 is considered underprepared for verbal ability. A wide range of verbal ability existed between the participants within each section. Participants within the Trained section had ACT verbal scores with a mean of 17.35, with scores ranging from 12 to 25 while the Untrained section's participants had a mean of 19.53 with scores ranging from 13 to 25. Table 4 breaks down the participants readiness for college-level English. Both sections were approximately evenly split between college-level and underprepared learners in terms of verbal ability.

Table 4

Verbal Readiness by Section

		Trained *N = 23*		Untrained *N = 20*	
		f	%	*f*	%
ACT Verbal					
Considered Underprepared for English	SAT < 470 or ACT 17 and below	12	52.2	9	45.0
Considered College-level in English	SAT ≥ 480	11	47.8	11	55.0
Mean English ACT		17.35		19.53	

Setting

Each of the Trained and Untrained sections each met daily for a fifty-minute class scheduled in the morning. The sections followed the 3-2 model of instruction with Monday, Wednesday, and Friday as lecture days in the classroom and Tuesday and Thursday as a recitation session within a computer lab. While in the recitation lab, participants worked on Knewton Alta, an adaptive computerized learning product.

Data Collection Methods and Procedures

Multiple data collect methods were used to examine the research questions. These include surveys, interviews, researcher's field journal, and submission of participant artifacts. All data collection methods, with the exception of the semi-structured interview and researcher's field journal, were class assignments.

Mathematics attitudes & perceptions survey (MAPS). To measure mathematical attitudes over time, an adapted form of the Mathematics Attitudes and Perceptions Intervention Survey (MAPS), designed by Code, Merchant, Maciejewski, Thomas, and Lo (2016) was used. The original MAPS survey instrument is a 32-item questionnaire, which features seven factors of expert attitudes in mathematics examined within the instrument: growth mindset, confidence, mathematical interest, real-world applications, sense making, problem solving, and answers of mathematical problems. The survey includes one filter question, and uses a 5-point Likert scale, ranging from Strongly Agree to Strongly Disagree.

Developed in 2010 through multiple pilot tests on undergraduate mathematical students, Code et al. determined the survey to have good reliability with a Cronbach's alpha value of 0.87 which represents a 95% confidence interval for the entire instrument. The alpha values for the categories or factors ranged from 0.55 to 0.70, due to the limited number of questions in each category. Questions on the survey were developed to either align (agree) or diverge (disagree) with the mathematical expert attitudes. Underprepared mathematical learners may have developed negative connotations with mathematics based on prior experiences and therefore it is important to examine how their attitudes compare to a mathematical expert and whether these attitudes change over time.

Although the original survey is considered brief with 31 mathematical attitude questions, an adapted form of Code et al.'s survey was developed to focus on sixteen of the original 31 questions and four of the 7 factors of expert mathematical attitudes: growth mindset, confidence, persistence, and mathematical interest. The participants took the surveys at the beginning and end of the study (Appendices A and B). Table 5 presents the questions used within the adapted survey along with their attitudinal categories. Analysis of the survey responses included the assignment of scores relative to expert consensus which were found through interviews with mathematicians. A score of 1 was awarded when the response was aligned with the direction of the "expert" conclusion. Responses which were not aligned in the direction of the "expert" or which were "Neutral" received a score of 0.

Table 5

Distribution of MAPS questions and factors

Factor		Question
Growth Mindset	3.	Math ability is something about a person that cannot be changed very much.
	4.	Nearly everyone is capable of understanding math if they work at it.
	12.	Being good at math requires natural (i.e., innate, inborn) intelligence in math.
	16.	For each person, there are math concepts that they would never be able to understand, even if they tried.
Confidence	2.	After I study a topic in math and feel that I understand it, I have difficulty solving problems on the same topic.
	8.	I often have difficulty organizing my thoughts during a math test.
	9.	No matter how much I prepare, I am still not confident when taking math tests.
	11.	I can usually figure out a way to solve math problems.
Persistence	5.	If I am stuck on a math problem for more than ten minutes, I give up or get help from someone else.
	6.	If I don't remember a particular formula needed to solve a problem on a math exam, there's nothing much I can do to come up with it.

	13.	If I get stuck on a math problem, there is no chance that I will figure it out on my own.
	15.	I get upset easily when I am stuck on a math problem.
Mathematical Interest	7.	I enjoy solving math problems.
	14.	I avoid solving math problems when possible.

Student artifacts analysis: Participants from both sections submitted a self-explanation artifact at the beginning and end of the study. The participants were asked to correct and self-explain each step of a fictitious student's incorrect worked example (Appendices C and D). The researcher and two mathematics instructors, who routinely work with the underprepared learner population, independently analyzed and rated the quality of the self-explanations from both cases using a coding system adapted from McNamara, Boonthum, Levinstein, and Mills' (2007) 4-point coding system. The codes were adapted as McNamara et al.'s codes did not provide a code to account for a worked step that lacked a self-explanation. Given that this initiative is directed toward underprepared mathematical learners, it was important to be able to differentiate between a vague or missing self-explanation. Therefore, the code of "0" was reassigned from "Vague" to the code, "Blank". This resulted in all other codes increased by one. The altered coding structure used in this research is a 5-point scale (Appendix E): 0 = *Blank*; 1 = *Vague or irrelevant;* 2 = S*tep-focused*; 3 = *Local-focused;* and 4 = *Global-focused*.

The coding structure examined the extent to which the participant self-explained the steps of the worked example and the connection that the participant made to prior knowledge or experience. *Vague or Irrelevant Explanations* code indicated that the participant did not express relevant mathematical knowledge regarding the prompt or step's sub goal (purpose of the worked example step). *Step-focused Explanations* were restatements of the prompt or sub goal and did not provide any new information. *Local-focused Explanations* made reference to earlier concepts presented within a previous step of the worked example. *Global-focused Explanations* linked the theme of the self-explanation to concepts or events that were outside of the worked example, such as within a lecture, lab experience, or real-world knowledge.

Interviews. A semi-structured interview style was utilized to provide opportunities for a more in-depth data collection. While providing an overall framework for the interview, the researcher had the flexibility to follow-up on relevant areas of interest or alter questions based on a participant's answer or experience. Additional questions were used to better understand the experience of the participant and to formulate an understanding of that experience (Seidman, 2006). Interview questions (Appendix F) were developed which invited participants to reflect on their experience with the self-explanation, when combined with worked examples intervention, how the intervention was presented (training or lack of training), integration of the intervention within other aspects of the course and/or their study habits, and how these experiences affected feelings towards mathematics. Participants were also given the opportunity to reflect on their prior mathematical experience to provide context of how the intervention shaped any changes within their mathematical attitudes for the course.

Participant reflections. Participants were asked to reflect on questions at the conclusion of the study (Appendix G) to gain insight into their experiences with the intervention and student attitudes. As students encounter educational situations and strategies, reflective activities provide a structure to document details of their experience, attitudes, and impact of learning (Moon, 2013). The reflections used open and prompted questions which allowed the participants to reflect on topics they deemed important (Wallin & Adawi, 2018).

Researcher field journal. An electronic reflective journal was kept by the researcher to allow for the collection of observations, modifications, or other notable themes observed as the study unfolded. Entries included: (a) day-to-day log of activities, (b) personal observations of the intervention as it was unfolding, and (c) methodological log (Lincoln & Guba, 1985).

Procedures

This section details the procedures used to collect and analyze the data gathered within the study. Prior to the spring 2020 semester, one section was randomly selected, using a coin toss, to be the Trained section which received the self-explanation training and materials. Module 2, 3, and 4, of the College Algebra curriculum were designed for the study. While these modules did not begin until Week 5 of the semester, this was a purposeful decision to allow the participants to utilize the intervention when multi-step algebraic solutions were required. The delayed start enabled the researcher to build trust with each participant over the first several weeks of the course.

IRB Approval

IRB approval was granted from both universities involved with the study prior to the spring 2020 semester. Participants were enrolled within two sections of College Algebra at the participating institution. A proxy was used to explain the Informed Consent (Appendix J). All students received information regarding the study within their respective class and their rights. Participants could opt out at any time without penalty. The researcher’s contact information was provided to answer any questions during the decision-making timeframe and/or during the study. All students were given one week to complete the Informed Consent documents. Participation was voluntary, though 5 points extra credit on their lowest in-class exam was offered as an incentive. Alternative assignments were provided to those who wished to receive extra credit but not participate.

MAPS Survey Data Collection

At the start (Week 5) and completion of the study (Week 14), participants were asked to complete the adapted form of the MAPS survey developed for the study. The survey was administered by the university's Qualtrics software system. Participants were given the survey at the beginning of the week with other class assignments and were allowed to complete all assignments by Sunday at 11:59 pm during the respective weeks. Reminder emails were sent out prior to the last day of the week to remind participants to complete all assignments for the week, which included the MAPS survey. At the end of the respective weeks, the surveys were closed and downloaded to Excel for data analysis.

All participants were assigned a unique identifier which identified the participant by section, yet allowed the participant to be anonymous during data collection and analysis. The use of the identifier allowed the researcher to track the participant's data throughout the study.

Self-Explanation Introduction

Self-explanation was introduced to the Trained section via a training on the first lecture day of the second College Algebra module, which occurred during the fifth week of the semester. The training was conducted by the researcher. The brief 25-minute training, consisted of a review of the content presented within an adapted version of Alcock, Hodds, and Inglis (n.d.) Self-Explanation Training for Mathematics Students handout created for Loughborough University (Appendix H). The booklet is licensed under the Creative Commons Attribution – ShareAlike 4.0 which allows for modification of the document given the original work is credited and licensed under the same terms as the original. The handout served as a guide for participants in the Trained section as they created self-explanations throughout the course.

The instruction consisted of several parts: (a) how to construct a self-explanation of a worked example using properties, principles, or prior experiences; (b) relevancy to learning mathematics; (c) modeling how to self-explain a mathematics problem, when using a completed worked example; and (d) participant practice. During the practice, participants reviewed the last page of the job-aid which consisted of two mathematics worked examples. The first example was a fictitious student's self-explanation of a problem from the previous day's lecture which they could review. Participants could ask questions about the explanations presented or could make suggestions of additional information that could be added.

A second example was presented from content covered during the lecture which preceded the training and was void of any explanations. Participants were asked to self-explain the steps in class and were allowed to discuss their explanations within their groups. The instructor provided assistance by answering questions and gave feedback on the participant's self-explanation as needed (Renkl et al., 1998). Any unfinished steps were assigned as homework. Participants were encouraged to study the handout as they constructed their self-explanation. The following day in lab, the students turned in the assignment and detailed feedback was given to each student regarding the construction of their self-explanation.

Participants in the Untrained section did not receive training in the construction of self-explanation nor received a handout to guide in the construction of self-explanations. They were informed that self-explanation is a useful strategy to construct meaning when using worked examples. The participants were given the same second example presented within the Trained Section's handout. The example, void of any self-explanations, was from their current day's lecture material and was given to them as an assignment (Appendix I). The following day in lab, participants turned in the handout and received feedback on the mathematical steps but were not given feedback on the construction of self-explanations.

Upon completion of the study, all students enrolled within the Untrained section were provided the self-explanation training as previously given to the Trained section. This experience enabled them to gain proficiency with the method and access to the intervention as a way to assist them in future classes.

Daily Instruction

Participants within both sections received identical instruction during lecture classes (Monday, Wednesday, and Friday). Participants actively engaged in mathematical problem solving by completing problems based on the lecture material presented. Each lecture featured correct, incorrect, and/or faded worked examples within the lecture material. Participants were given opportunities to individually self-explain either all solution steps or selected steps of the worked examples. Those in the Trained Section could use the self-explanation handout as they created their self-explanations. All participants from both sections were allowed to work collaboratively in pairs or groups to share and discuss their self-explanations after the initial independent work was completed. A whole class discussion provided verification of their solution steps for faded or incorrect worked examples. If additional time was needed for review of the worked example, students were allowed to take the problem home to study the individual steps as they constructed their self-explanations. The groups conferred the following day and were allowed to collaboratively share and discuss their self-explanations and problem answers. No self-explanations were assigned to participants during the Tuesday, Thursday recitation lab classes.

At the conclusion of Week 9, the university closed face-to-face instruction due to the Corona Virus pandemic. For the remainder of the semester all instruction occurred online. Students watched pre-recorded video lectures in which problems were presented to self-explain. Students were asked to pause the video and then could check their solutions to the correct solution. Students were able to meet synchronously each day although attendance was not mandatory in order to be responsive to student's technology, health, and environmental needs during this difficult time.

Self-Explanation Artifacts

In Weeks 7 and 13, participants were given a self-explanation assignment in which they were presented with a fictitious student's incorrect worked example based on recent material presented within the lecture classes. The problems were chosen as they represented challenging material which was frequently missed by prior student cohorts. The engagement with the worked examples helped the participants to understand why the fictious student made the common error, with the hope that the participant would understand the error so as not to repeat the same mistake. The problems were utilized as a mechanism to practice these concepts prior to the exam. Participants were asked to review the incorrect example, find and correct the error, and self-explain each step. The participants in the Trained section were encouraged to use the handout in the construction of the self-explanations. Participants in the Untrained section were not given this reminder. The assignment, for both cases, was graded with mathematical feedback provided.

Semi-Structured Interviews

During Week 13 and 14, the researcher sent out a call for volunteers to participate in semi-structured interviews. Of the two sections, eight of the 23 Trained students and nine of the

20 Untrained students participating within the study completed a semi-structured interview. The interviews were recorded with permission on Zoom and were later transcribed and verified by reviewing the recording for accuracy. Participants were emailed the transcripts in order to review it for further elaborations or corrections.

Student Reflection

Participants were assigned a student reflection during Week 13 in conjunction with the second self-explanation artifact assignment to avoid assignment overload during the stressful ending to the spring semester due to the COVID-19 shutdown. The reflection was read and comments were made if the reflection required feedback. Participants received credit for their assignment submission and not on its content. All participants within both sections completed the reflection.

Trustworthiness

Qualitative research requires multiple standards of quality. Within this research project, multiple sources of evidence were used to establish trustworthiness necessary for the methodological rigor of a qualitative study (Yin, 2015). Those criteria were: (a) credibility, (b) dependability, (c) confirmability, and (d) transferability (Lincoln & Guba, 1985).

Credibility. Four techniques addressed confirming the results of the study: (a) prolonged engagement, (b) persistent observation, (c) member checks, and (d) triangulation (Yin, 2015).

Prolonged engagement. While the study ran for 9 weeks during the 14-week semester, the seeds of trust were planted prior to the start of the study during the first five weeks of the course as the researcher began to establish a rapport with all students. Participants met daily with the researcher during class or lab time until the COVID-19 pandemic resulted in all face-to-face classes to become virtual for the remainder of the semester. Once virtual, the researcher was available synchronously in Blackboard Collaborate to meet, discuss, and understand the needs of all learners. This relationship, before and during the study, helped to establish confidence from the participants as they learned the purpose and context of the study. The rapport was important as participants knew their trust would be honored as they shared details about their mathematical experiences prior to and during the course, and that their anonymity would be valued (Lincoln & Guba, 1985).

Persistent observation. During the study, each participant had two opportunities (Week 7 and 13) to submit a self-explanation of a worked example artifact. These assignments, which bookended the study, illustrated the progression of the participant's self-explanation technique during the study. Daily classroom observations allowed the researcher to glean important details that were present throughout the study. Upon completion of the study, participants were interviewed to better understand each participant's experience with the strategy.

Member checks. Upon completion of each interview, the transcripts were verified with the video recording for accuracy of the transcription. The verified transcripts were emailed to the participants to review the interview summary document for accuracy. During the review, the participants were encouraged to correct errors, provide additional context or information, and to validate the discussion summary.

Triangulation. Triangulation was achieved from examining the research questions from multiple viewpoints using methodological triangulation (Table 6). Triangulation of data was satisfied as different data collection methods (semi-structured interviews, student reflections, survey data, researcher reflective field notes, and self-explanation artifact analysis) were used during the study to examine the research questions. Member checking allowed each participant interviewed to check for accuracy, elaborations, and omissions.

Table 6

Methodology Sources and Analysis

Research Question	Data Source	How Collected	Method of Analysis
(1) How did the training condition influence the instructional strategy of self-explanation when combined with worked examples?	Participants Researcher	1. Artifact Analysis 2. Participant reflection 3. Participant Interview 4. Researcher Journal	1. Three mathematics faculty will independently examine using the coding system. 2. Constant Comparative Method 1. Comparison of units which are applicable categories 2. Integration of the properties of categories 3. Setting of limits on categories
(2) What were the corequisite students' perceptions of self-explanation when combined with worked examples as an instructional strategy	Participants Researchers	1. Participant reflection 2. Participant interviews 3. Researcher Journal	Constant Comparative Method 1. Comparison of units which are applicable categories 2. Integration of the properties of categories 3. Setting of limits on categories
(3) How have students' mathematical attitudes changed by learning a new instructional strategy?	MAPS Survey Participants Researcher	1. MAPS Survey 2. Participant reflection 3. Participant Interview 4. Researcher Journal	1. Descriptive Statistics of MAPS 2. Constant Comparative Method 1. Comparison of units which are applicable categories 2. Integration of the properties of categories 3. Setting of limits on categories

Dependability and confirmability. To ensure dependability and confirmability, an external audit of the research study was conducted. The audit was conducted by a researcher experienced in qualitative coding and provided feedback and confirmation of the codes and findings. The review helped to confirm the accuracy of the codes and that the findings were supported by the data collected.

The researcher's journal provided an opportunity to record notes, observations, and reflections of the study as it unfolded. These reflections helped to make insights to better understand the evolving nature of the strategy as it was implemented within the two MTH 127 sections (Lincoln & Guba, 1985). The methodological log section helped to track decisions made during the study and the reasoning behind those decisions.

Transferability. The use of a "thick description" provided a full and robust detailed account of the research setting and how the research was conducted (Lincoln & Guba, 1985, p. 316). This will help others interested in the research to attain their own conclusions whether or not transfer is a possibility to a new situation.

Data Analysis

The researcher removed all student identification information during the data analysis process and used a unique alphanumeric identifier. The code and the data were kept separate and stored securely. All files were saved on the co-investigator's OneDrive, provided by the participating university. The researcher destroyed the data after the research concluded by deleting all files from the computer and permanently deleting them from the Recycle bin.

Demographics

Data analysis began with examining the demographic data, such as ACT mathematics test scores, class standing, and age on the students by section. This data was downloaded from the Banner student registration database at the university.

MAPS Survey Data

The Pre- and Post- MAPS survey data was downloaded from Qualtrics and into Microsoft Excel. Student responses were coded according to the methodology developed by Code et al. (2016). Responses which were aligned with the direction of the expert-like response received one point. Responses which were not aligned or “Neutral” received zero points. The coded data was imported into SAS and descriptive statistics, along with gains or losses, were generated by section for the Pre- and Post-Intervention MAPS surveys. Descriptive statistics were also generated for each section on each of the four factors: growth mindset, confidence, persistence, and mathematical interest.

Several situations resulted in data being excluded for review. Both the Pre- and Post-Intervention MAPS surveys contained a filter question which directed participants to respond with using “Agree”. Individuals who did not comply with this direction were removed from the MAPS data. Analysis was conducted on students who completed both the Pre- and Post-intervention MAPS survey. Students who did not complete both were removed from the data. Other situations which caused the removal of data included the omitting of the unique identifier. This yielded the analysis of 18 participant’s MAPS data from the Trained Section and 16 participants from the Untrained Section.

Self-Explanation Artifacts

The artifacts were analyzed by the researcher and two additional mathematics professionals. All reviewers were full-time instructors in the Mathematics Department who regularly teach corequisite courses with underprepared mathematical learners. Each reviewer was trained in the construction of self-explanation and the coding structure that was used for the data analysis. Participants who did not complete both Artifact 1 and 2 were eliminated from the review.

Due to the restrictions imposed due to the COVID-19 pandemic, the artifacts were delivered to the reviewers at the end of the semester for analysis. Each reviewer independently analyzed each artifact by section. Anonymity of the participants was protected through the use of the unique identifier which was the only identifier on the student assignments. Using the adapted coding system, the reviewers rated the quality of the self-explanation using the following codes: 0 = *Blank*; 1 = *Vague or irrelevant;* 2 = S*tep-focused*; 3 = *Local-focused;* and 4 = *Global-focused*. Participants explained each step of the worked example and the reviewers evaluated the quality of the participant's self-explanation using the adapted coding system. Interrater reliability was determined for each artifact. Table 7 presents examples of participant's self-explanations from Artifact 1 demonstrating each code.

Table 7

Self-Explanation Examples by Code

Code	**Quality Type**	**Self-Explanation**
4	Global-Focused	Example: "I learned in class that h and k are part of the vertex. To find the vertex, we use the formula h = -b/2a. So, in this step, h or the x in the ordered pair can be found."
3	Local-Focused	Example: "In the last step, a and b were identified. Now, they should be plugged into the formula that lets us find the vertex so that we can find h."
2	Step-Focused	Example: "For this step, I distribute the x to both things in the parenthesis."
1	Vague or Irrelevant	Example: "To find width."
0	Blank	Example: (No self-explanation provided)

The data was entered into Excel and then uploaded into SAS for analysis. A mean score for each participant was created by averaging the three reviewer's scores. Descriptive statistics were generated for each class' artifact. A mean of the step score was created by averaging the overall mean of the artifact (created from the three reviews) and dividing by the number of steps within the worked example. The use of the step mean allowed the two artifacts to be compared as they had different numbers of steps within the worked example.

Reflection and Interview Data

The reflection and participant interview session data were analyzed using comparative analysis to identify patterns and relationships between the sections (Yin, 2017). Use of the constant-comparative method for analysis of this data-set allowed for specific themes to emerge in relation to prior sets (Creswell, 2014). An emergent theme analysis approach analyzed participants' responses in both the reflections and interview sessions.

Each participant's student reflection and interview transcript were placed in a document. The discussion of the participant's experiences utilized quotes and use of thick descriptions. Upon completion of all reflections and interviews, the researcher manually coded the qualitative data using open and axial coding (Corbin & Strauss, 2014). During the open coding process, keywords, phrases, and paragraphs were defined as coded information units. A unit was a chunk of data that was connected to a specific context (Miles & Huberman, 1994) and that could be interpreted without additional information (Lincoln & Guba, 1985). Each unit was identified by the case, participant number, and data collection method, for example, Trained Section, Participant 4, Interview.

In axial coding, each unit was refined to note relationships between the units. Units were organized under one of three categories. Categories were the three research questions. When later coded units were found, a comparison was made to the previous units and also placed within a category. Themes were developed as the data was coded. An iterative process of constant comparison was used as the data was revisited multiple times as initial and refined units were compared. Units which did not fit an existing theme or the development of a new theme, were placed under a Miscellaneous Theme within the category (Lincoln & Guba, 1985) to ensure that the unit could be tracked to determine if it were needed within a later developed theme during coding. Repeated codes, ideas, and concepts were used to generate themes to form key findings. Table 8 indicates how codes were utilized to generate the Obstacles Faced theme, by showing a portion of the codes for illustration.

Table 8

Example of Codes which Led to Obstacles Faced Theme

Data Source	Open Code	Axial Code	Data
Researcher Field Journal, Trained Section	Difficulty with intervention	Effort	“This seems like more work.”
Researcher Field Journal, Trained Section	Difficulty with intervention	Time	“Why do we have to take the time to explain it. I just want to try to solve it.”
Researcher Field Journal, Untrained Section	Difficulty with intervention	Time	“This takes too much time.”
Student Reflection, Participant 17, Trained Section	Difficulty with intervention	Time High Prior Knowledge	“Self-explanation takes too much time and students should use it unless they really didn’t know how to do the problem. Because I felt that I already knew what was going on with a lot of the problems. Explaining all of the steps was not always needed.”
Interview, Participant 4, Trained Section	Difficulty with intervention	Time Low Prior Knowledge	“I had a hard time initially because I didn’t like doing it. It was an extra step. I was just wanted to get it over with and figure out the way to do the problem. But, when I would do a similar problem, I couldn’t do it. So, I struggled.”
Interview, Participant 7, Untrained Section	Difficulty with intervention	Construction of SE	“I do feel like self-explanation helped. I could kind of see (in the worked example) why the step was happening and the result of it in the

Data Source	Open Code	Axial Code	Data
			next step. But, to explain it was hard when we didn't know what we should write about in the self-explanation. We would hear other group's self-explanation but I just wasn't sure if I was explaining things right."
Student Reflection, Participant 1, Untrained Section	Difficulty with intervention	High Prior Knowledge	"I found that I had a hard time using self-explanation on a problem that I already knew how to do. I spent more time on trying to figure out how to word the self-explanation than it took me to answer the problem."
Interview, Participant 3, Untrained Section	Difficulty with intervention	Low Prior Knowledge Group Collaboration	"The self-explanation was hard because I really didn't know how to explain it even though I could see the math in front of me. When I didn't know what the math meant, I just talked it out with my group members."

Continually refining and analyzing, themes were defined using a title, rules and definitions. Each unit was analyzed and compared to the rule to determine if the information reflected this set of defined standards. For data that did not fit the defined standard, the researcher examined the chunk to determine if the defined unit was too broad. The existing categories and themes were evaluated to determine if a new category or theme was warranted. Coding ceased when all themes were well saturated and defined.

Upon conclusion of the data analysis, the themes were reviewed by a fellow researcher for audit. Within the external review, the researcher did identify two examples of self-regulated learning among the participant's responses. The researcher and external reviewer conferred and determined that the two incidents did not warrant a new theme as they were an observation by the external reviewer of incidents of self-regulated learning, a topic of which the external reviewer was motivated to research. Therefore, the observations were not defined as a theme.

CHAPTER V

RESULTS

This chapter presents the results of the statistical analyses and qualitative results which examined the role that training the participant in the construct of self-explanation, when combined with worked examples, has on the quality of the self-explanation constructed. Mathematical attitudes, relevant to a corequisite course for underprepared learners, were examined as the training provided information on relevancy to learning mathematics. The attitudinal information regarding the information was observed to determine if a change existed from the beginning to the end of the study.

Two sections of a College Algebra course at a mid-Atlantic university, each comprising a case, were studied to determine the effects when training was introduced to one of the sections as the intervention was introduced. The study was examined for nine of the 14 weeks of the semester. This chapter outlines the findings for each section. The results are presented according to the three research questions. This study addressed:

Research Questions

1. How did the training condition influence the instructional strategy of self-explanation when combined with worked examples?
2. What were the corequisite students' perceptions of self-explanation when combined with worked examples as an instructional strategy?
3. How have students' mathematical attitudes changed by learning a new instructional strategy?

Research Question One

The first research question investigated the influence that the training of self-explanation, when combined with worked examples, had on the intervention used within the two corequisite College Algebra courses. Using two sections, in which training was provided to only one, the quality of participant's self-explanations was examined and compared. Perceptions on training were captured during the personal interviews and reflections.

Artifact Analysis

The participants submitted two self-explanation artifacts, Artifact 1, at the beginning of the study and Artifact 2, at the conclusion. The submissions were evaluated using the adapted coding system from McNamara et al. (2007). Self-explanation artifacts were examined from participants who completed both submissions. This filter resulted in 18 submissions from the Trained Section and 12 from the Untrained Section. The reviewers used the coding system to assign codes relating to the quality of each step of the participant's self-explanation. These numerical codes were averaged together to create a mean score for each participant. This value represented the self-explanation quality for the participant's submission and reflected the amount of information the participant referenced within their explanations. A greater score would indicate more references, either internal to the worked example from a prior step or external to the problem, added to the explanation.

Table 9 provides the descriptive statistics of the participant's artifacts by section. Artifact 1 consisted of 8 steps in which the participant's self-explained. A higher mean was earned by the Untrained Section (19.53) than the Trained Section (19.11). The median score for the Trained Section Artifact 1 was 19.17 with the Untrained Section having a median of 20.00. The interrater reliability for Artifact 1 was 0.89.

Table 9

Artifact 1 Statistics by Section

	Artifact 1	
	Trained Section N = 18	**Untrained Section N = 12**
Mean	19.11	19.53
SD	3.19	3.15
Median	19.17	20.00

Table 10 details the descriptive statistics for Artifact 2, which had 7 steps. The Trained Section had a higher mean of 19.91 (s = 2.55) than the Untrained Section mean of 16.19 (s = 3.18). The median Trained Section score was 19.50 with the Untrained median score of 15.67. Interrater reliability was 0.86.

Table 10

Artifact 2 Statistics by Section

	Artifact 2	
	Trained Section N = 18	**Untrained Section N = 12**
Mean	19.91	16.19
SD	2.55	3.18
Median	19.50	15.67

Mean step score by artifact. To compare Artifact 1 and Artifact 2 by section, a mean step score was calculated (Table 11). As the two artifacts had different numbers of steps, the mean step score allowed for a comparison between the two submissions. The mean step score was calculated by dividing each participant's mean score, determined from the three reviewer's scores, by the number of steps within the worked example. This resulted in the participant's mean step score for each artifact. Using these, an overall mean step score was calculated for each section.

The mean step for each artifact for both sections were between a score of 2 (*Step-focused Explanations)* which were restatements of the prompt or sub goal and did not provide any new information and 3 (*Local-focused Explanations)* which made reference to earlier concepts presented within a previous step of the worked example. The mean step score of the Trained Section increased from 2.39 to 2.84 from Artifact 1 to Artifact 2, an increase of 18.8%. The Untrained Section's mean step score decreased from 2.44 to 2.21 from Artifact 1 to Artifact 2, a decrease of 5.3%.

Table 11

Artifact Step Statistics by Section

	Trained Section N = 18			**Untrained Section N = 12**		
	Artifact 1	**Artifact 2**	**Gain/Loss**	**Artifact 1**	**Artifact 2**	**Gain/Loss**
Mean	2.39	2.84	0.45	2.44	2.31	-0.13
SD	0.40	0.36		0.39	0.45	
Median	2.40	2.79		2.50	2.24	

Examination by incoming mathematics ability. To further examine the participant's proficiency on the artifacts, the participants were categorized by their incoming mathematics standardized test scores. The category of *Remedial* was used when a participant entered the course with a standardized test score below the MTH 127 course prerequisite of ACT 17, and referenced that the participant did not initially meet the ACT requirements of MTH 127 and would have taken the emporium course the previous semester.

The category of *Underprepared* used for participants whose ACT mathematics test score was within the range of 17 – 20, and indicated that the student met the ACT requirements for the course. *College-level* was determined if the student was considered “college-level” for College Algebra, which occurred when the participant entered the university with an ACT score of 21 or above. These individuals qualified for a faster paced College Algebra but chose the corequisite version. One participant from each section was considered College-level.

Using these categories, the means for each section was compared by artifact. Table 12 showed the results for Artifact 1. While the Trained Section’s overall quality score was lower than the Untrained Section on the first artifact, the examination of mathematical standardized test scores indicated that the Remedial and College-level categories created a higher quality self-explanation at the onset of the study in Artifact 1. The Untrained Section’s category of Underprepared scored measurably higher, in terms of self-explanation quality, than did their counterparts in the Trained Section.

Table 12

Artifact 1 Mean by Standardized Test Range

	Remedial ACT < 17		**Underprepared ACT 17 - 20**		**College-level ACT > 20**	
	Trained	**Untrained**	**Trained**	**Untrained**	**Trained**	**Untrained**
Mean	19.43	18.50	18.33	21.05	17.00	13.00
SD	3.47	2.25	2.08	2.14		
N	14	4	3	7	1	1

Table 13 displays the quality mean scores by ACT categories for Artifact 2. Upon the conclusion of the study, the Trained Section created artifacts of a higher quality than did the Untrained Section participants within the same categories. Those who were trained in self-explanation earned a mean of 20.33 in the Remedial category, while those not trained, a 14.00

mean. The Trained Section had a mean of 18.89 as compared to the Untrained Section's mean of 16.76. The College-level category had one participant within each section but also showed the Trained Section had a higher quality score.

Table 13

Artifact 2 by Standardized Test Range

	Remedial ACT < 17		**Underprepared ACT 17 - 20**		**College-level ACT > 20**	
	Trained	**Untrained**	**Trained**	**Untrained**	**Trained**	**Untrained**
Mean	20.33	14.00	18.89	16.76	20.00	15.00
SD	2.65	1.36	1.54	3.85		
N	14	4	3	7	1	1

Mean step score by mathematics ability. The mean step score step score was examined by mathematical ability to compare the two artifacts by category in Table 14. All Trained Section means approached a quality score of 3 (*Local-focused Explanations,* which made reference to earlier concepts presented within a previous step of the worked example) mean step scores for the Remedial, Underprepared, and College-level categories increased from Artifact 1 to Artifact 2.

From the first artifact to the second artifact, the Remedial category for the Trained Section had a gain of 0.47, while the Untrained Section had a decrease in explanation quality of -0.31. Gains were also seen between the two artifacts for the Underprepared Category with the Trained Section showing a gain of 0.41 while the Untrained Section decreased by -0.22. Both the Trained and Untrained Section showed gains within the College-level category, with the gain for the Trained Section larger at 0.73.

Table 14

Mean Step Score by Artifact and Standardized Test Range

	Remedial ACT < 17			Underprepared ACT 17 - 20			College-level ACT > 20		
	Artifact 1	**Artifact 2**	**Gain/ Loss**	**Artifact 1**	**Artifact 2**	**Gain/ Loss**	**Artifact 1**	**Artifact 2**	**Gain/ Loss**
Trained									
Mean	2.43	2.90	0.47	2.29	2.70	0.41	2.13	2.86	0.73
SD	0.43	0.38		0.26	0.22				
N	14	14		3	3		1	1	
Untrained									
Mean	2.31	2.00	-.031	2.63	2.39	-0.22	1.63	2.14	0.51
SD	0.31	0.17		0.27	.55				
N	4	4		7	7		1	1	

In-Class Exams

Both sections were given the same course materials and exams. Exam 1 occurred before the training on self-explanation and daily use of self-explanation of worked examples. Exam 2 was conducted in the classroom prior to the quarantine. Exams 3, 4, and the Final, occurred after the course's modality had changed to virtual due to the COVID-19 pandemic.

Table 15 documents the mean exam score by sections. This data was used to anecdotally examine the learning surrounding the two sections. No conclusions are made from this data; however, it provides an interesting insight to the learning experience of the participants as they explored the same content and assessments.

The two sections were statistically similar with the Trained Section Exam 1 mean score of 70.1 and the Untrained Section of 69.9. The remainder of the exams and Final conducted after the use of self-explanation found the Trained Section's mean score larger than the Untrained

Section. The largest difference in scores occurred with Exam 3 and 4 with a 13.0% and 14.3% difference in means between the Trained and Untrained Sections.

Table 15

Exam Scores by Section

	Exam 1	Exam 2	Exam 3	Exam 4	Final Exam
Trained	70.1	72.4	72.3	75.8	75.5
Untrained	69.9	71.4	64.0	66.3	72.9
% Difference	0.3%	1.4%	13.0%	14.3%	3.6%

Qualitative Themes

Through interview and reflection data analysis, themes were identified from participant interviews and reflections. Within the Trained Section, eight participants were interviewed and 23 completed reflections. Nine participants were interviewed in the Untrained Section, with 20 participants completing reflections. Themes were identified which related to the research questions. Quotes were included to illustrate the participant's understanding or views regarding the intervention and insights on mathematical understanding. Two themes were observed which related to the participant's perceptions of the training condition which included the manner in which they learned and how the training experience affected their learning of the intervention.

Theme: Scaffolding Student Learning

Trained Section

Participants within the Trained section, benefitted from a training which introduced the intervention. The training included information about self-explanation, its relevancy to learning mathematics, modeling of an example, and opportunities for student practice with instructor feedback.

Eighteen of the 23 (78%) participants viewed the training as a foundation which allowed the learners to “get started on the right foot” (Participant 10, Reflection) and helped the participants to understand the process of how to self-explain. The training mitigated the uncertainty that the learners felt as they navigated a new intervention in addition to understanding mathematical topics in which they may be unprepared.

> To me the training was essential. I like to know the rules and what I need to do. That helps me feel sure of what I’m doing, especially in math – where I really feel unsure about a lot of things. (Trained Section, Participant 6, Interview).

This shared understanding of the mechanics of the intervention instilled confidence. Twelve of the 23 (52%) participants referenced having confidence, both within the intervention and their ability to perform it, after the training. One participant indicated:

> I think the training helped me to be confident. I knew that after that, I could do it and I knew the right way to do it. That’s important. Whenever you learn a new skill, you need to learn how. So, I liked that the training made self-explanation easy to learn and to feel like it was something that I could try immediately. (Trained Section, Participant 2, Interview)

The Trained participants referenced one or more elements of the training which supported their learning during the novice state and throughout the intervention.

Practice and feedback. Fifteen of the 23 (65%) participants cited the training’s initial practice and receipt of feedback as instrumental in understanding how to self-explain a worked example. Participant 10 said in a reflection, “I didn’t know that I needed to put in math that I had learned in high school. That was new to me. Without knowing that, I would have just written out what the step was doing.”

The individualized feedback on the participant's initial attempt allowed them to make early corrections and adjustments to their efforts as they fine-tuned their self-explanations. Participant 3 indicated in an interview, "I liked that you told me where my self-explanations needed work like if I forgot to self-explain something. That helped me see how I could improve."

For one participant, the feedback from their practice self-explanation had a wide-ranging effect on their mathematical outlook. The instructor's feedback to the student identified the need for additional mathematical information within their self-explanation. This challenged the participant to generate additional sentences, describing how their prior knowledge related to the worked example step. As a result, the learner began to see how much mathematical knowledge he possessed, a new feeling after years of mathematical struggle. This important realization was one which allowed his mathematical attitude to begin to change from the early stages of the intervention. The participant said:

> It helped me to see what I was doing wrong. I still struggled with explanations, especially when we first were doing it. When you said that I needed to write more information, it helped me to know what I had put down wasn't enough. I just started to write stuff down after that. I never thought of all of the math that I know. I usually only think about things that I don't know when it comes to math. It felt good to realize this and it made me feel more confident about what I know. (Trained Section, Participant 7, Interview)

Relevancy to learning. Eleven of the 23 (48%) participants cited the training's component of 'relevancy to learning mathematics' as beneficial when navigating the uncertainty of a new intervention. Understanding "why" helped the students to determine whether the effort to learn the intervention was worth the benefit received. Two of the participants summarized the wariness experienced by students as they evaluate a new intervention:

> It (the training) helped me see why I was doing it. If it doesn't make sense as to why I'm doing it and how it's going to help me then I probably won't want to do it (Trained Section, Participant 2, Reflection).
>
> Before I want to invest in something new, I need to know why I should do it. That's important to me, especially in math. I struggle so I want to know how it's going to help before. I don't like to do math but if something can really help me, I'll try it. (Trained Section, Participant 23, Reflection)

For each of the participants, the knowledge of how the intervention assisted them in learning mathematics provided them with a reason as to why they should try the intervention. This information led them to initially try the intervention, whereas another component was mentioned as helping participants sustain this early momentum in times when they needed a reminder of the training.

Training Handout. Ten of the 23 (43%) participants identified the handout as beneficial during the novice stage of the intervention and during the portion of the semester when students were separated due to the COVID-19 pandemic. This resource helped participants apply the training to their daily application of self-explanation when combined with worked examples, as needed. Two of the participants summarized the feelings of many when they indicated:

> I really liked the handout. It helped me stay on track. I could look at it and it helped me remember all of the things that we talked about on that first day during the training and it would help me see if I explaining correctly or not. (Trained Section, Participant 6, Interview)

> I think that the training helped remind me how to do it. It was helpful to be able to look at the handout when I needed a refresher, especially after we left class (due to the quarantine.) When we were all apart, if I'd forget something, I'd look at the handout and remember. (Trained Section, Participant 1, Interview)

Untrained Section

Participants within the Untrained section did not receive training on the intervention but were told that it was a beneficial activity to learning mathematics. The analysis of participants' interviews and reflections indicated that, in the absence of training, participants used collaboration with others to scaffold their efforts as they navigated the new intervention.

Prior to the introduction of the intervention in Week 5, the students participated within collaborative classroom activities. After the intervention was introduced, the students utilized this existing classroom community as a support structure to negate any uncertainty surrounding the mechanics of the intervention.

C**ollaboration.** Fifteen of the 20 (75%) participants indicated that collaboration with other learners scaffolded them as they learned how to construct a self-explanation of a worked example.

The researcher's journal captured some of the early interactions of the Untrained participants as they navigated the uncertainty which surrounded the intervention and moments of early collaboration. These entries included:

> "Are we supposed to write down what the step means?" (Researcher's Journal, Week 5)
>
> "What stuff are you writing about in your self-explanation?" (Researcher's Journal, Week 5)

"Does this (self-explanation) sound good?" (Researcher's Journal, Week 7)

"I wrote this out so I would remember." To which a group member replied,

"That's a good idea!" (Researcher's Journal, Week 8)

The organic adoption of collaboration as a scaffolding method helped learners as they determined what information should be included within their individual self-explanations. One participant shared the connection and support felt within the group. The participant said, "I enjoyed working with my group to bounce ideas around. We all relied on each other. I really missed them when we left face-to-face classes. (Untrained Section, Participant 9, Interview)

The collaboration among participants had positive and negative effects. Fifty percent (10 of the 20) participants indicated they were able to better understand the mathematics within the course with the assistance of their group members. Participant 4 illustrated this point within their class reflection when she remarked, "I liked going over the worked examples with other people as it helped me to figure out what they meant."

Several unintended outcomes occurred as a result of students working together, without formal training, as they navigated the new intervention. These occurrences may have altered the self-explanation created by the participant.

Revisions. As the participants compared their self-explanations, those which were similar in content were viewed to be "correct" whereas dissimilar explanations were "incorrect" and in need of revision. Twelve of the 20 (60%) Untrained participants indicated that they changed their self-explanations as a result of group collaboration. One participant noted:

> After I wrote down my self-explanation, we'd compare it. When we agreed, I felt like I had done it right. When they didn't have what I had, I would either change mine or we'd

> come up with something together as a group to make it better. (Untrained Section, Participant 3, Interview)

As participants altered their prior self-explanation to be more like the group consensus, the revision may have removed information, personal to a participant's own learning or added information of which the participant had no prior knowledge. Participant 6 illustrated this point within an interview, "I changed my self-explanations after hearing everybody else's explanation from my group. After that it was more like theirs."

Restatements. A second consequence of participants collaborating, without interventional training, occurred with the increased use of restating worked examples steps without adding new or prior personal information. An overwhelming 15 of the 20 (75%) participants expressed doubt as to what constituted a self-explanation and described self-explanations which resembled restatements of mathematical operations displayed within the line of the worked example, without adding prior or new information. Statements which explained the mathematical operation of the step, in isolation, without reference to personal information were created. One participant remarked:

> I really didn't know how to self-explain. We (the group) looked at each line of the worked example and just wrote about what the step was doing. I didn't put anything else but that. I really didn't know what else to put. (Untrained Section, Participant 1, Interview)

As participants worked together and shared their generations, or when they received assistance from a group member or the instructor, the participants, in general, would not include the new learned information into the self-explanation. Participant 5 indicated in a reflection, "We talked about the problems and that helped me to understand and then I would write out what the step was doing."

Training desired. Nine of the 20 (45%) participants indicated that training, or some component of training, was desired to learn self-explanation when combined with worked examples. While many of the Untrained section's participants valued the intervention, the formal knowledge of the intervention would have provided more confidence within their skill to perform the generative learning task. One participant's remarks illustrated how the intervention had merit but their experience with the intervention could have been improved with training:

> Self-explanation does help but I struggled with it. I wish that there was some training or sample that we could have had that would help me to make mine better. I just kind of struggled to create them. But, towards the end, it helped me to see the problem in a written format. I found that I remembered why I was doing it better because of my words. (Untrained Section, Participant 3, Interview)

Two individuals made suggestions to offset the difficulty they had to perform an intervention without benefit of supportive resources.

> Self-explanation helped me but I struggled because I feel like I didn't know what I was doing. Maybe if we had a handout with keywords or a list of properties for the problem, then I could match up the explanation or rewrite it in my own words. (Untrained Section, Participant, 6, Reflection)

> I wish that there was a way for me to learn better how I could do a self-explanation. I would have liked to have an example to follow. I figured it out after a few tries but at first, I was lost. (Untrained Section, Participant 3, Reflection)

Research Question Two

The second research question examined participant perceptions of the self-explanation intervention as an instructional strategy to support learning mathematics. Even though training was provided to one section, both sections faced challenges as they implemented the intervention into the daily exploration of mathematical topics. Yet, even though both struggled, differences between the two sections emerged as the participants experienced uncertainty for different amounts of time during the intervention.

The researcher's field journal captured information as the intervention unfolded which documented the uncertainty and journey that each section experienced with the intervention. One researcher's field journal entry reflected an impression that pertained to both sections, regardless of the training condition: "participants do not always enjoy interventions that are beneficial to them, particularly at first, until the benefit can be seen."

Theme: Obstacles Faced

Figure 1 illustrates similarities and differences among the two sections with regard to the Obstacles Faced theme.

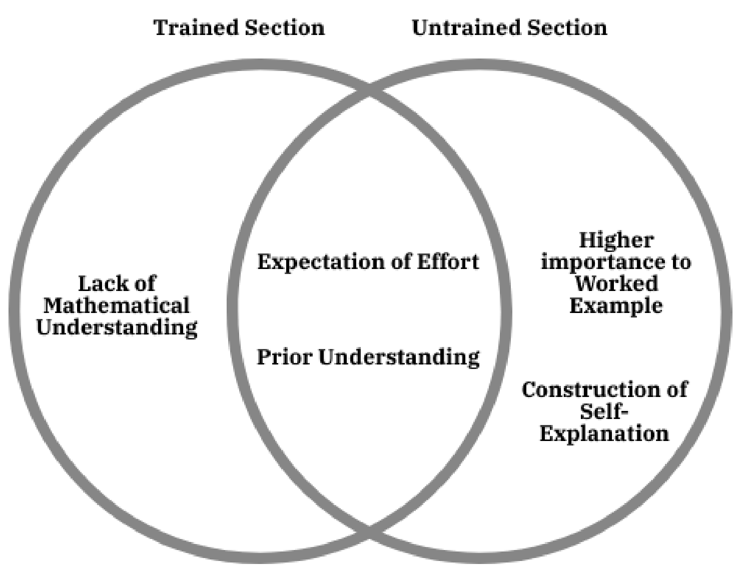

Figure 1

Obstacles Faced Theme and Subthemes by Section

Trained Section

Student expectation of effort. As the participants put forth into practice what they learned within the training, the intervention was met with resistance. Fifteen of the 23 (65%) participants indicated that the intervention was viewed negatively due to the increased time and effort required. Comments from the researcher's journal documented these initial perceptions of the participants within the class meetings:

"I don't really like doing this." (Trained Section, Week 5, Researcher Journal)

"This seems like more work." (Trained Section, Week 5, Researcher Journal)

"Why do we have to take the time to explain it. I just want to try to solve it." (Trained Section, Week 6, Researcher Journal)

"Why do we have to write so much?" (Trained Section, Week 6, Researcher Journal)

The aversion was also due to the underlying frustration of mathematical challenges that still existed. One participant's remarks within their interview were similar to comments expressed by many participants:

> I had a hard time initially because I didn't like doing it. It was an extra step. I was just wanted to get it over with and figure out the way to do the problem. But, when I would do a similar problem, I couldn't do it. So, I struggled. (Trained Section, Participant 4, Interview)

Short-lived. The feelings of frustration were steady during the first two weeks of the intervention. However, the researcher's field journal noted that learners began to see the benefits to their understanding. The following comments from the researcher's field journal document the progression as the benefits of self-explanation was first noticed by the learners:

"Even though I wrote a lot, I was able to write myself some notes of why it's happening." (Trained Section, Week 6, Researcher Journal)

"I'm going to write why they are using that factoring method. That will help me to remember." (Trained Section, Week 7, Researcher Journal)

"Wow! Look at all I know!" (Trained Section, Week 8, Researcher Journal)

Three mathematical levels (Remedial, Underprepared, and College-level) existed within the MTH 127 sections. Based on the incoming ACT Math sub score as defined by course prerequisites, the mathematical aptitude levels affected the initial number of prerequisite topics mastered and the College Algebra topics understood. Two themes were observed across both sections based on the participant's incoming mathematical level. Learners who had high mathematical aptitudes (College-level category), faced challenges as their mathematical understanding enabled them to solve the problem without need of the intervention. Learners with lower mathematical aptitudes (Remedial category) were challenged to create mathematical explanations given their mathematical deficits.

Prior understanding of mathematics. In addition to the increased workload, 14 of the 23 (61%) Trained participants indicated that, at times, they created less detailed self-explanations when their mathematical knowledge allowed them to solve the problem using other methods. As participants encountered problems which could be performed without the intervention, they struggled to fully engage within the critical analysis of the worked example steps to form a robust self-explanation and the actual creation of the written self-explanation. This could hamper the learner to understand the mathematical connections that were necessary for more difficult problems. Participant 1 indicated within an interview, "I didn't like doing it for the problems I already knew how to do. Sometimes I wouldn't explain those as well as the ones that I was trying to understand because I already knew how to do them."

When prior knowledge allowed the student to successfully perform the mathematical problem, time to perform the intervention became the deciding factor as to whether they chose to fully analyze and construct a quality self-explanation. One participant expressed the views of many when she indicated:

> Self-explanation takes too much time and students should use it unless they really didn't know how to do the problem. Because I felt that I already knew what was going on with a lot of the problems. Explaining all of the steps was not always needed. (Trained Section, Participant 17, Reflection)

Perceived benefit. Twelve of the 23 (52%) participants indicated that using the intervention as needed, on a selective basis, was perceived as a benefit when determining if the intervention would be added into future study skills efforts. The intervention was deemed most helpful during times when participants required the analysis to better understand the mathematics necessary. Participant 6 indicated in an interview, "If they were a difficult problem? Yes, but if I knew how to do the problem, I would've just used a normal way to solve it. It's easier for me to just use it as I need it."

Lack of mathematical understanding hindered construction of self-explanation. Fifteen of the 23 (65%) participants, indicated that, at times, they struggled to explain a worked example step due to a lack of conceptual understanding of foundational areas of mathematics. Participants were frustrated when they were unable to create detailed self-explanations which incorporated prior and new knowledge. One participant's remarks illustrated the feeling felt by participants when they did not understand the mathematics presented within the worked example:

> Where I think self-explanation was hard for me at first was when I didn't understand the (math) topic enough to either understand the steps of the problem or be able to explain it. That made me feel discouraged. I eventually learned that that's when I needed help. (Trained Section, Participant 4, Interview)

Whenever a lack of mathematical understanding occurs, it can be disheartening. For learners who encountered this, they sought help and relied on the worked example. This obstacle to learning was best illustrated during a remark from an interview:

> I felt that, well in the very beginning I was a little confused on it because I wasn't exactly sure how to explain each step. It was hard at first but practice helped me out a lot, just because of the math. When I asked for help it made it easier to understand the math well enough to be able to explain it. (Trained Section, Participant 7, Interview)

Untrained Section

Student expectation of effort. Similar to the Trained section, the researcher's field journal and participant's comments indicated that 65% (13 of the 20) Untrained participants had an initial negative perception of the intervention. The intervention was viewed as burdensome due to the time and effort needed to analyze worked example steps and to construct the written self-explanations. The researcher's journal entry noted the following:

> "This takes too much time" (Researcher Journal, Week 5)
>
> Why are we doing this? (Researcher Journal, Week 5)
>
> "I don't like writing!" (Researcher Journal, Week 6)

A number of participant responses, both in the classroom and within interviews and reflections, discussed time as a factor when examining the worked example and creation of the self-explanation. The perception was that the components "slowed down" the learning. One participant's remarks illustrated these feelings:

> It took some time to really think about it. It wasn't just like right off the bat like, why this was happening. I had to think about what was going on with each step and that took a lot of time. I was used to just figuring out the problem. All of that work that I had to do really slowed me down. (Untrained Section, Participant 6, Interview)

Long-term effect. Unlike the Trained section, who saw the benefits of the intervention was worth the expenditure of effort, the Untrained section's concern with time and effort spent, was a long-term concern and had an unintended negative long-term effect on the intervention.

The desire to reduce time led to a cursory examination of the worked example. This coupled with the lack of training on what information should be included within a self-explanation yielded limited self-explanations which did not contain much, if any, prior knowledge.

Construction of Self-Explanations. A theme, unique to the Untrained section, was the obstacle that participants faced when constructing their self-explanations without the benefit of training on the intervention. Sixteen of the 20 (80%) participants indicated they struggled to create self-explanations given the lack of knowledge regarding how to construct the self-explanation and what components should be included within their generation. The lack of instruction prevented many of the participants from feeling comfortable with their constructions and led participants to initially be frustrated. Participant 15 indicated within the class reflection, "I liked that I could write them (the self-explanation) in my own words but at first, I struggled a lot because I didn't know what to write." Another participant said:

> I do feel like self-explanation helped. I could kind of see (in the worked example) why the step was happening and the result of it in the next step. But, to explain it was hard when we didn't know what we should write about in the self-explanation. We would hear other group's self-explanation but I just wasn't sure if I was explaining things right. (Untrained Section, Participant 7, Interview)

Both of the comments reflect the uncertainty experienced by the participants within the Untrained section as they maneuvered through the intervention without training on how to construct as self-explanation and the information that it should contain. This uncertainty led them to doubt their generations and led the Untrained participants to rely on their group members during this time.

The lack of training affected the result of fruitful group collaborative discussions. While the conversations may have contained references to prior knowledge, or information about the worked example steps, the resulting self-explanations generated from these discussions were brief with limited internal or external knowledge added. Therefore, without the training, the participants did not include much, if any, of this relevant knowledge within their generation.

This led to another unintended consequence due to the lack of training. One facet of the training was instruction on how the two components of the intervention, worked examples and self-explanations, worked in harmony to facilitate scaffolding and forming connections between content. Participants, who did not receive this instruction, were free to create their own value system as to how each component benefitted their learning. This lack of specificity and latitude allowed the Untrained participants to regard the worked example as more useful to their learning and thus more attention was given to that specific component. This theme was documented within the researcher's field journal and within analysis of interview and reflection data.

Higher importance placed on worked examples. While the lack of training made construction of the self-explanations more challenging, it did not prevent the participant within their review of the worked example. In response to the difficulty that the Untrained participants had in creating self-explanations, the worked example was viewed as the most accessible component of the intervention. Fourteen of the 20 (70%) indicated that the worked example was the most beneficial component of the intervention in terms of learning mathematics. A Week 5 researcher's journal entry indicated, "Participants are asking why they need to write out the steps when they can view how the worked example shows how the solution was generated. They want to quickly apply the process to the new problem." The hasty examination led students to struggle when applying concepts learned within the worked example to new problems. Within the researcher's field journal, the researcher noted:

> The participants continue to struggle with open-ended problems after the examination of the worked example and creation of self-explanation. The explanations are brief and do not have much (if any) references to prior knowledge. The majority can do similar problems but not problems which have a slight difference. This can be compared to the Trained Section which did not have as many difficulties. (Researcher Journal, Untrained Section, Week 7)

Early within the intervention, differences between the two sections were seen as the amount of time devoted between the two components of the intervention began to change. An early researcher's journal entry captured this:

> Participants are eager to review the worked examples but less so to create the self-explanation. This is different from the Trained Section, who has been spending more time with the creation of their own self-explanations. The need for relevance is high. Participants keep asking why they need to explain and write a math problem. No complaints were given regarding the review of the worked example. The worked example portion of the intervention is highly relevant to them and makes them feel at ease. Without relevance, learners don't seem to want to expend the effort. (Researcher Journal, Untrained Section, Week 6)

A later pandemic related journal entry for the Untrained Section was included the following:

> A group of participants met virtually. When self-explaining a problem and sharing their solutions, one participant asked, "why do we need to self-explain? Can't we just memorize how to solve the problem?" (Researcher Journal, Untrained Section, Week 10)

As the participants questioned the benefit of the self-explanation, less attention was given to its construction and inclusion of information. This was seen within a journal entry during Week 8 by the researcher. In this journal entry, the researcher noticed rich group discussions which focused on prior knowledge between group members but participants did not weave this information into the self-explanations:

> The majority of participants are restating the step rather than creating self-explanations to include prior knowledge. Less time is spent on self-explanations. Even though conversations between participants may include these prior knowledge references, participants are not writing down this information but are more concerned with the

> brevity of the self-explanations than the content that they include. (Researcher Journal, Untrained Section, Week 8)

Perceived benefit. The ability to view the completed problem from start to finish was perceived as an advantage for the underprepared learners. The solution provided them with a correct solution path to understand and model. Once the participants viewed the worked example component as a model for future problems, they began to examine it more closely. This analysis helped with the completion of open-ended problems completed immediately after the examination of the worked example. One participant summarized the feelings of many as she compared the two components and their ability to help with mathematical understanding:

> Being able to see it all worked out, helps me personally piece everything together and remember things that I'd forgotten. In the later problems, I'd remember these things and it helped me. The self-explanation helped me to remember the step. It wasn't as helpful as just studying the problem that was shown. That really let me see what to do. (Untrained Section, Participant 4, Interview)

Prior understanding of mathematics. Similar to the Trained section, many different mathematical levels existed within the section. When participants had knowledge of the mathematical topic, they preferred to demonstrate that with open-ended problems rather than navigate the uncertainty of creating the self-explanation of a worked example steps. Eleven of the 20 (55 %) participants indicated their desire to problem solve as opposed to self-explain worked examples when they understood the mathematics being studied. Participant 15 remarked in a reflection, "It's hard for me to explain a problem rather than show you my work and how I got that answer."

This remark was revealing as it indicated that learners may know *how* to perform a mathematical action but not *why* the action is necessary. The inability to understand and describe how old and new knowledge interconnect is at the heart of not only the generative learning intervention but also what the training will instruct them to perform.

Perceived benefit. Similar to the Trained section, 12 of the 20 (60%) participants in the Untrained section also desired to use the intervention situationally, when problems are most challenging, as opposed to all problems. In this regard, the participants were most excited to use the intervention when they failed to initially grasp the mathematical concept.

> Using self-explanation might be helpful when you're talking yourself through how to do a problem that you're learning. I had a hard time using self-explanation on a problem that I already knew how to do. I spent more time on trying to figure out how to word the self-explanation than it took me to answer the problem. (Untrained Section, Participant 1, Reflection)

Lack of mathematical understanding hindered construction of self-explanation. Similar to the Trained section, the Untrained section had learners who struggled with self-explanations due to mathematical gaps. However, it is interesting to note that only 4 of the 23 (17%) participants indicated that their mathematical misunderstandings affected their ability to self-explain. Participant 14's reflection may shed light as to why the Untrained section had a lower percentage than the Trained section. The learner explained that when struggling with understanding the mathematics and the construction of the self-explanation construction was in doubt, they relied on the worked example to learn. This examination provided them with enough knowledge to restate the step. He indicated, "When I didn't understand the math, I just looked at the line of the problem and explained what was happening in it." Another participant also indicated:

> I struggled with it. Um, I guess in terms of what to write and how to do understand the math that I was writing about. Seeing the worked example helped me to kind of understand the math but I was still lost on what to write. (Untrained Section, Participant 8, Interview)

Theme: Intervention (Self-Explanation with Worked Examples) Assisted in Mathematical Understanding

Both sections identified the intervention as beneficial to learning mathematics. However, what differed between the two sections was the component(s) of the intervention which assisted their mathematical exploration.

Trained Section

As the Trained participants used the intervention within the daily practice until the pandemic forced the end of face-to-face classes, growth and maturity with the intervention was seen. The researcher's field journal entries illustrate the growing maturity that participants were finding with the intervention and within the mathematics discussed:

> Self-explanations are growing in terms of additional information being added. After the examination of the worked example and creation of the self-explanation, open-ended problems are presented. The participants are working well with those problems which are similar and those which were slightly different. (Researcher Journal, Trained Section, Week 7).
>
> Participants are engaged with the problems and although difficulties with mathematics have be encountered, students seem confident with the intervention as they work through

> the understanding of the mathematical principles. Students of all academic levels are able to construct self-explanations. Group based discussions are growing richer as participants recount prior knowledge to current knowledge. Some explanations are of a higher quality than others. Today's worked example featured factoring within the third step. Most participants were able to adequately self-explain the concept of factoring even though these concepts have not yet been fully discussed in lecture. (Researcher Journal, Trained Section, Week 9)

The Trained section utilized both the self-explanation and the worked example in concert as they navigated College Algebra concepts. The worked example provided the guidance and scaffolding to understand the problem and its solution for the underprepared learners while the self-explanation focused on creating mathematical connections personal to the individual. Seventeen of the 23 (74%) participants indicated the intervention benefitted mathematical understanding. One participant summarized the thoughts of many as he indicated how the two intervention's components complemented each other to form mathematical understanding. Participant 22 indicated in a reflection, "It's helpful because it forces you to think about *why*, not just *how*. This really helped me to understand it and remember it when things got harder. Another participant indicated:

> Yes, because I could see how you solve the problem step-by-step and I could understand each step and then the whole problem. I really started to explain it so that I would understand it. Seeing the worked example helped me understand it instead of just me solving the problem myself and having to worry about each step of it. (Trained Section, Participant 19, Reflection)

It was interesting to note that as the material became more challenging, the participants relied on the intervention's benefits even more to facilitate mathematical awareness. One participant remarked:

> Self-explanation helped me. Sometimes, I struggled to understand the mathematics but explaining it helped me figure it out. But, when I did see why a problem was worked out that way, I could remember why because I had written it down and that made sense to me. (Trained Section, Participant 14, Reflection)

Expanded Use. The intervention supported the participant's understanding of mathematics in such a way that 10 of 23 (43%) participants organically began to import the intervention, into other aspects of the course, such as the lab portion or within personal study habits, as needed. The ease with which the intervention was incorporated illustrated the support it provided the underprepared learners. Participant 1's remarks in the interview reflected the casual way it was incorporated into their learning habits, "Yes, I'd use it after class to redo my notes. I'd self-explain additional problems to help me understand problems I didn't get."

However, one participant selectively applied self-explanation to only the steps of a problem in which was misunderstood, as opposed to the entire problem:

> I used self-explanation if there is a problem that I was having really hard trouble with understanding what a certain number or certain thing would be, I would write a little arrow or star to that part of the problem. And I would explain that. I'm looking at my notes right and I put an arrow to it and then I wrote out information about the vertical asymptote, what it was and how you figure it out, to make sure I knew what that was. So, I would say that I used self-explanation a lot. (Trained Section, Participant 2, Interview)

Participants indicated they planned to use the intervention into future STEM classes. Thirteen of the 23 (57%) participants indicated that the intervention would be beneficial to incorporate into study habits in future classes which feature mathematics. Participant 5 said in an interview, “I would definitely use it in another class if I was struggling. It’s something that I can use as I need to.” One Trained participant found the intervention so helpful that she used it within a STEM class during the semester of the study. Participant 6 indicated in a reflection, “There’s a lot of math in chemistry and I actually started doing it in that (Chemistry) class. I use it for my calculations in chemistry. It helps.”

Metacognitive awareness. When participants were unable to self-explain a step within a completed worked example, this provided an “early alert” to a knowledge gap. Fourteen of the 23 (61%) participants indicated the intervention was useful in this manner. As the Trained participants became aware of their knowledge gaps, they were able to seek help or mathematical support. Participant 12 indicated in the class reflection, “It (self-explanation of a worked example) helps someone see the problem and how it is broken down which makes it way more understandable. When I can’t figure out the problem or the line and can’t explain it to myself, then I need help.”

The intervention facilitated a way for learners to gauge the amount of knowledge they actually possessed, even though they had faced mathematical failure in the past. This was a powerful moment for many of the underprepared learners who had struggled for years. One indicated:

> When I was writing my explanation, even if I couldn’t remember everything about the class instruction, I was able to tell the parts that I did know. This also helped me to figure out what I was still confused about. Because if I can’t explain it to myself, then I

> don't know it. It would point out what I understood and what I didn't. Then I knew that I needed to ask questions when I found that there were things that I couldn't explain and that I didn't understand. (Trained Section, Participant 1, Interview)

The awareness of gaps helped the participants be motivated to persist and feel confident that mathematical progress was occurring. One participant described a powerful moment within their learning when she could determine what concepts were understood versus what information was missing. While these remarks were regarding a specific student encounter, they represent the relief that other students felt as they pinpointed where their mathematical foundation was strong and where the gaps existed:

> I feel like I understood why I was doing it. Like better. I don't know how to explain it. When I was writing, when I was explaining, I was like, Oh, now I get why I'm actually doing this. Before, I didn't know the parts of it that I knew versus the parts that I didn't. It makes sense now because even if you know how to answer the questions, sometimes you just do it like robotically because you already know how to do it. You just don't think why are you doing it? And with this self- explanation, I was able to understand better why I was doing it. This gave me a lot of confidence. All of this work helped me do later problems. (Trained Section, Participant 6, Interview)

An important by-product of the early identification of gaps was that it allowed corrections of these misunderstandings to occur prior to an assessment. Nine of the 23 participants (39%) mentioned this as an advantage of being aware of their mathematical knowledge. One participant remarked:

> Usually, I find out that I don't know something when I get my tests back. Then it's too late to do anything about it. But now, I know when I don't know it. If that makes any

> sense! I want to learn. So, realizing that I don't know it enough to explain it to myself really helps me to want to get help. (Trained Section, Participant 8, Interview)

Recall of prior knowledge. Recall of prior mathematical knowledge was fostered through both components of the intervention. Seventeen of the 23 (74%) participants indicated that the examination of the worked example, together with the construction of the self-explanation reactivated prior knowledge as the participants created personal instructions for themselves as they connected prior learning to new concepts. One participant expressed the views of many who discussed reactivation of prior knowledge. She said:

> Whenever I use self-explanation, it would help me understand it a lot more, personally to me. Whenever I do some step by step, I'll always write down how I got it, what I did to get that answer. So, I guess it did make me kind of more confident because there were always these instructions there on how to do it and again, if I got another question like that, I'd go back and reference that question to that problem. (Trained Section, Participant 3, Interview)

The personal nature of the constructions removed the constraints of using appropriate mathematical language by allowing them to write sentences which made sense to them.

> Because I would sit there and think about the problem and when you write it all down and you're doing it yourself, then you start to understand it more, if that makes sense. I remembered things from high school and I'd add that in. I didn't need to find the right explanation with all the proper terms, although I did try to do that. I just needed to find one that made sense to me. (Trained Section, Participant 5, Interview)

Worked examples. Not all of the trained participants gravitated to the combination of self-explanation and worked examples of the intervention. Six of 23 (26%) participants cited the worked examples, with little to no emphasis on self-explanation, as more beneficial to learning as it relieved them of having to complete the problem individually, but rather could use the time to understand the concepts. Two participants indicated:

> The worked-out problems really helped me to understand the problem. Once I started using them, they helped me in lab when Knewton displayed a completed problem. I would say that this gave me most confidence because I've always struggled with math. (Trained Section, Participant 1, Interview)

> Although I think self-explanation helped me to learn, the most helpful was the worked example. I really liked seeing the completed problems. It helped me to figure out what I needed to do and that helped me understand when I would get another problem. Knowing that I had these in my notes with my words explaining really made a difference and made me feel good about the class and how I would do in it. (Trained Section, Participant 18, Reflection)

Negative consequence of worked examples. A benefit of a worked example is the model that it can provide students to follow during the novice state. However, one Trained participant expressed a negative consequence of using worked examples. While her mathematical knowledge was sufficient to understand the mathematics involved, the fixed nature of the worked example was challenging as it used a different approach than her prior mathematical experience or training may have indicated:

> Self-explanation is a good way to understand a math problem and it doesn't require a lot of learning how to do it. Sometimes it can confuse you though if the problem is worked out in a way that doesn't make sense to you. Because then you're trying to put a reason on a step you don't understand. This is because the way that someone works out a

> problem is not necessarily the way that you would do it and this makes me get really confused when this is the Section. (Trained Section, Participant 6, Interview)

This dilemma can be expected as not all learners use the same process when solving a mathematics problem. Therefore, alternative methods can be utilized where the learner could complete the problem using a different strategy and then self-explain that process.

Untrained Section

Participants within the Untrained section struggled for several weeks as they constructed a self-explanation while trying to understand why they should devote time to this endeavor. As they navigated the intervention, the participants were divided in terms of which components of the intervention benefitted mathematical comprehension. Twelve of the 20 (60%) participants cited the worked example portion of the intervention as being most beneficial to learning mathematics, with the remaining 40% citing both components together equally fostering mathematical meaning.

For participants who used both components together, the power of the intervention was realized. Two students expressed the thoughts of many as they said:

> It (worked example) helped me go through the steps a little bit better. It kind of, helped me remind myself of the in-between, you know, for each step. Writing it in my own words, pretty much helped me to understand what the math meant. I just wrote down for each step, pretty much what I reminded myself of as I transition from step to step. After I could see the steps then I could try to come up with an explanation for what was happening within the step. When you explain something to yourself it makes something "click." (Untrained Section, Participant 6, Interview)

> I think it really helped a lot to be able to go back and look at the problems and put it in our own words because it's easier to remember and helped me understand what we were doing. For me at least. When I explain things, I explain how it's meaningful to me. I'm able to focus in on the important things. I think being able to take the time to sit and study the problem lets me go more in depth with it. I think it made it "click" inside my brain. (Untrained Section, Participant 3, Reflection)

For one participant, the classroom environment provided opportunities for more mathematical understanding than mathematics classes previously taken. She said:

> I think it, it helped me because I like knowing each step and like explaining the details in each step, so I found it beneficial cause it helped me to understand it all better. This was actually the first class, my first math class, where I actually understood math completely. And I think it was because of self-explaining and putting things into my own words. So, I think that I would definitely use that in in future classes. (Untrained Section, Participant 2, Interview)

Several themes, consistent between both sections, emerged.

Metacognitive awareness. Similar to the Trained section, Untrained participants who struggled to understand a mathematical concept viewed the struggling as an "early alert" for a mathematical misunderstanding. A stark difference between the two sections was the Untrained participant's indication of which component facilitated the awareness. Fourteen of the 20 (70%) Untrained participants identified the use of the worked example as the primary component to recognize a mathematical gap. As participants analyzed the worked example step, the inability to understand the mathematics displayed pinpointed a breakdown in understanding, while the completed problem gave them an awareness of the correct solution's strategy. One participant's comments effectively conveyed the thoughts of those who primarily used the worked examples as the vehicle for learning, while recognizing the struggle that they had in constructing a self-explanation. The participant remarked:

> Yes. I can see the steps and understand it helps me see what math is being used. That was most helpful to me because it guided me through it. The self-explanation was hard because I really didn't know how to explain it even though I could see the math in front of me. When I didn't know what the math meant, I just talked it out with my group members. Sometimes I would write it out what we talked about but most of the time I didn't. It was too much to write. (Untrained Section, Participant 3, Interview)

Recall of prior knowledge. In addition to the worked example providing an understanding of mathematical gaps, 12 of the 20 (60%) participants indicated that analysis of the worked example and subsequent group discussions, was highly beneficial to activating prior knowledge. Participant 19 indicated in a reflection, "Seeing the problem all worked out helped me remember things that I had learned in high school. Then I could see how that helped me do the math that we were currently working on."

Unlike the Trained section, which used the worked example and self-explanation together to identify and recall prior knowledge, the analysis of the worked example and collaborative nature of the group discussions in the Untrained section allowed for an increased sharing of prior knowledge and principles. The researcher's field journal captured this in an early entry as the participants were not incorporating the knowledge into their explanations. It said:

> The participants are eagerly engaged with the worked example and seek help from the instructor or group members when the step of the worked example is misunderstood. However, after clarification or discussion, participants are not weaving this information

> into the self-explanations. Participants continue to create very brief restatements, rather than individual self-explanations, despite rich discussions of the problem. (Researcher's Journal, Week 8)

As the journal entry referenced, not all participants would incorporate the relevant prior knowledge and new knowledge together in their self-explanations. Ten of the 20 (50%) participants indicated they may not have incorporated the information from these group discussions into their self-explanations. Participant 8 indicated in an interview, "My group helped me to understand a lot of the math. We talked about the worked example and that made it clearer. But I didn't really write the explanation about all that we discussed."

Research Question Three

The third research question examined whether perceptions of the participant's mathematical attitudes were with the introduction of the self-explanation when combined with worked examples instructional strategy.

Mathematical Attitude and Perception Survey

To measure mathematical attitudes, the Mathematical Attitudes and Perception Survey was presented at the start and completion of the study. Four of the seven factors were examined: growth mindset, confidence, persistence, and mathematical interest.

Descriptive statistics (Table 16) were calculated for the Pre- and Post-MAPS surveys by section. All questions, with the exception of the filter question (Question 10) were used within the analysis. Results were based on participants who completed both surveys, which included 18 Trained Section and 16 Untrained Section participants.

The results of the survey illustrated the comparison of mathematical attitudes and perceptions between the two sections. Important differences existed in the mathematical attitudes between the two sections at the beginning of the study. The Untrained Section's Pre-MAPS survey mean composite score of 6.69 (SD = 3.30) while the Trained Section's mean was 3.72 (SD = 3.25). This indicates the Untrained Section had mathematical attitudes and perceptions more similar to those of a mathematical expert than the Trained Section. The Pre-MAPS median composite score for the Untrained Section was 7.00 as compared to the Trained Section's 2.50 composite score.

At the conclusion of the study, the Trained Section had a noteworthy gain in their MAPS score using the same survey. The Trained Section's mean score increased to 5.39 (SD = 2.59), or a gain of 1.67, compared to the Untrained Section's gain of 0.06.

Table 16

MAPS Composite Statistics by Section

	Pre-MAPS (N = 18)			**Post-MAPS (N = 16)**			
	Mean	**SD**	**Median**	**Mean**	**SD**	**Median**	**Gains**
Trained (N=18)	3.72	3.25	2.50	5.39	2.59	5.50	1.67
Untrained (N=16)	6.69	3.30	7.00	6.75	3.62	6.00	0.06

Factors

Of the four factors examined within the MAPS survey, descriptive statistics were presented in Table 17. Consistent with the overall composite score, the Pre- and Post-MAPS scores indicated that the Trained Section had lower mean factor scores than the Untrained Section on all four factors.

Each factor of the Trained Section had a gain, with the largest gains in the areas of Confidence (0.88) and Growth Mindset (0.50). For the Untrained Section, gains were found in two of the four factors, Mathematical Interest (0.25) and Growth Mindset (0.18), with losses within the Confidence (- 0.31) and Persistence (- 0.06) factors.

Table 17

MAPS Factors by Section

Category	**Section**	**Pre-MAPS**	**Post-MAPS**	**Gains/Loss**
		Mean (SD)	**Mean (SD)**	
Growth Mindset	Trained	1.28 (1.23)	1.78 (1.52)	0.50
	Untrained	2.38 (1.41)	2.56 (1.21)	0.18
Confidence	Trained	1.06 (1.26)	1.94 (1.16)	0.88
	Untrained	2.06 (1.12)	1.75 (1.18)	-0.31
Persistence	Trained	0.89 (1.02)	1.00 (0.97)	0.11
	Untrained	1.44 (0.96)	1.38 (0.89)	-0.06
Mathematical Interest	Trained	0.50 (0.79)	0.67 (0.77)	0.17
	Untrained	0.81 (0.91)	1.06 (0.93)	0.25

Qualitative Themes

Two qualitative themes emerged from participant interviews and reflections regarding the nature of the learner's perspective regarding mathematics and how their mathematical ability changed over the course of the study.

Theme: Confidence

Figure 2 illustrates similarities and differences among the two sections with regard to the Confidence theme.

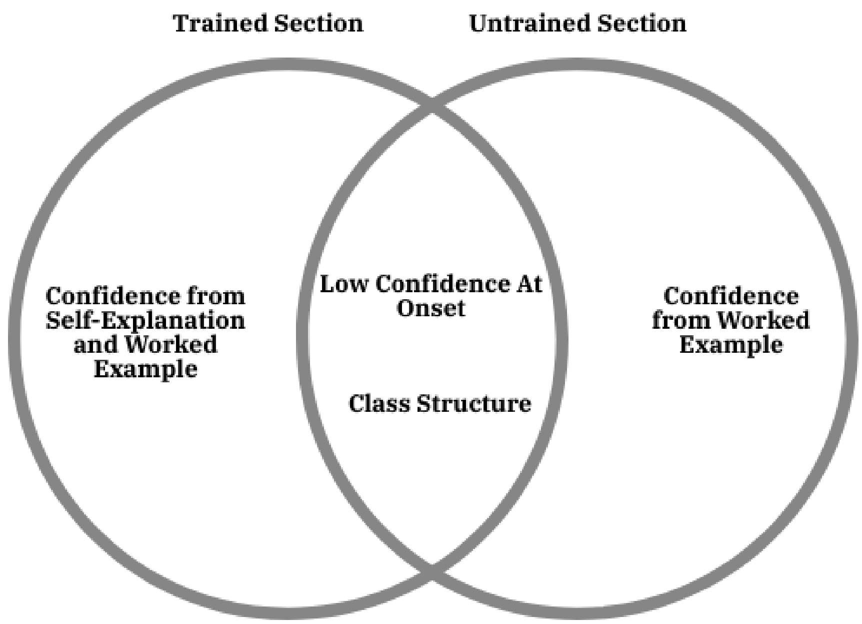

Figure 2

Confidence Theme and Subthemes by Section

Trained Section

Low confidence at onset. Analysis of participant interviews and reflections indicated that almost 70% (16 of the 23) of the Trained participants reported low mathematical confidence at the start of the intervention. Many expressed feelings such as “worried,” “nervous,” and “scared” when thinking of performing within a collegiate College Algebra class prior to beginning the semester. The researcher’s journal documented the lack of confidence as the semester began. One Week 2 journal entry noted. “Participants are scared to make a mistake, even on low-stakes in-class problems with no point value. They do not feel confident in their abilities when discussing problems and their solution.”

The Trained section's participants described negative attitudes towards mathematics as students indicated that they "hated math" (Trained Section, Participant 18, Reflection) or "never have been good at math" (Trained Section, Participant 21, Reflection). Two participant's reflections indicated the heightened emotions similarly felt by others. They indicated:

> My feelings towards mathematics involve severe frustration. I try my absolute hardest and in some sections I still do not learn the material. My professional field includes a lot of math, so I want to excel in it. Math it is my weakest subject, I have always struggled with math. My other courses I seem to not have as much trouble in. (Trained Section, Participant 7, Reflection)
>
> I have never been good at math and it has always been my worst subject. I am not a fan of math and probably never will. I would feel more successful if I understood math problems. Math is my biggest struggle of classes. Compared to my other classes this is much harder and I do struggle in other classes but not as much as math. (Trained Section, Participant 23, Reflection)

Many factors can influence a learners' mathematical attitudes. The Trained section's participants cited one or more factors which attributed to their low confidence.

History of low mathematical performance. Eight of 16 (50%) participants who reported having low initial confidence indicated consistently performing at a low level in prior mathematics courses, which was at odds with their career choice. This affected their confidence in their ability to perform the mathematics required for their degree. One participant indicated:

> I have always struggled with mathematics and it's just has been a pain for me. I can barely remember equations half the time, and the other half my mind blanks in the middle

> of an equation. I don't know if I'll be able to learn what I need to learn to get my degree. (Participant, 4, Interview)

Waning mathematical performance. However, 10 of the 16 (63%) participants indicated a period within their academic history in which they excelled in mathematics. As mathematics became more challenging, their mathematical abilities and confidence declined. One participant noted:

> Math used to be my strong subject, but as time gets going, there's so much more to it than just addition, subtraction, all that. In high school, that was my strongest subject, always has been. But in college it's completely different. Like I kind of struggle with it just because there's so much you need to remember and so much steps to a problem. (Trained Section, Participant 3, Reflection)

Factors out of the learner's control. Lack of confidence can occur from reasons outside the learner's control. Six of the 16 (38%) participants cited instances within their prior mathematical experiences where they struggled to navigate differing pedagogical strategies from one teacher to another. This lack of consistency of explanations and activities caused confusion for the learner. While one participant's experience may be unusual, it indicates the hardship that can occur from changes which are out of the students control and how the experiences may affect their confidence. He indicated, "Well starting in the eighth grade, I had four different math teachers in one year. So, it was hard to learn math with all of those ways that they taught me." (Participant 1, Interview).

Higher confidence at onset. While not the majority, it is important to note that not all of the Trained participants lacked confidence at the beginning of the course. Five of the 23 (22%)

participants indicated they possessed mathematical confidence and enjoyed, understood, and felt they could perform the necessary mathematics needed for their class and degree choice.

The diversity of incoming experiences can be explained due to the variety of mathematical levels that existed within the course. Some participants had high mathematical aptitude but chose to enroll in the course due to the increased support and slower pace of the curriculum. Their mathematical experiences may have differed from someone who had continuous struggle. Participants expressed mathematical interest, “Math is one of my favorite subjects” (Trained Section, Participant 17, Reflection) or within their confidence to mathematically perform, “I am pretty confident I my math skills” (Trained Section, Participant 22, Reflection). Another participant indicated:

> I enjoy being able to perform math. But, at the same time I feel that math is a very difficult subject for some individuals to grasp. I don’t tend to worry about math so much as my other courses. I have always been somewhat good at math growing up and it transferred over into college. (Trained Section, Participant 19, Reflection)

Increased mathematical confidence at conclusion. Attitudes surrounding mathematics can be complex. While the majority of the Trained participants began with low confidence, analysis of the participant interviews and reflections indicated a dramatic change in confidence at the conclusion of the intervention. Eighteen of the 23 (78%) participants indicated increased confidence within their own mathematical learning and understanding at the conclusion of the study. The intervention, its individual components, as well as other factors were specifically cited as beneficial to increasing confidence. The participants were free to indicate as many factors as they felt contributed to their increase in confidence.

Intervention as a whole. Self-explanation gave the participants the opportunity to write words which made sense to them as they incorporated their own prior knowledge in the process of solving the problem. Of the 18 participants who indicated they felt confidence, 10 of the participants (56%) attributed the change to feelings of having less stress regarding learning mathematics and being more in control of their learning. One participant’s remarks indicated this feeling as he stated that the intervention helped them to be more confident in mathematics and approach problems with less trepidation and stress. He said:

> Now that we're almost done with the semester, I have built a confidence in mathematics. The self-explanations and the problems really helped me to understand it without pressure. I could just relax and learn. This helped me on tests because I remembered the example and remembered what I wrote. (Trained Section, Participant 7, Reflection)

The feeling of “being in control” of their own learning is an important change in attitude for underprepared learners who may not have felt this in prior mathematics learning situations. The change improved performance on exams and was a catalyst for inclusion into study skills and future learning opportunities. Participant 18 indicated in the class reflection, “Self-explanation really helped me on tests. I was in charge of writing a good explanation for me and this made me remember what I wrote. It helped me more than if I were remembering some hard-to-understand book explanation.” Another participant indicated:

> The intervention helped me feel better about math, like more in control. I feel is that I'm a very visual learner in seeing how the problem works and seeing the outcome of that problem and combining that with words, that make sense to me, helps me understand the concept more and feel confident about the process and the math. (Trained Section, Participant 2, Interview)

As control of their mathematical learning increased, participants felt confident when thinking of their performance within future mathematical or STEM classes. One participant explained the relationship that the intervention had with future learning. She indicated:

> Yes, I actually am understanding and am confident again. Um, self-explanation helped me to understand math better. I was able to write what I know about the problem, for each step. It helps to see the whole problem. That and my writing helped me understand the math in a different way. I can write about things I already know with what I'm now learning. That really helped with my confidence level. It's like I feel so much better go back on in the fall, even if we have to be online. Like I can actually use self-explanation and all those things that you taught some class how to understand topics for the fall. It helps me to figure out what I know. So I'm excited to go to another math class and not be scared. (Trained Section, Participant 2, Interview)

The scaffolding provided by the worked example allowed the underprepared learners to view a completed solution, without the need to generate the solution on their own. As the participants discussed how they studied the worked example, they referenced the need to "analyze" before "doing." Phrases such as "slowing down," "pausing," and "thinking before working" were used to illustrate this important activity. One participant expressed how the examination of the worked example allowed them to be more analytic and less reactive which in turn gave them confidence. He indicated:

> With the intervention, I feel like I have to stop and think, "What do I know?" instead of just reacting to the problem. When I understand then I put my explanation to the steps, and that helps me to break it down which is easier. I really like that I can use self-explanation for any problems. It helps to build my confidence knowing, "Oh I have

> something else that can help me get through this and these other problems and these other topics and everything". So, it really helps with all that in the confidence. (Trained Section, Participant 7, Interview)

This increased attention to the mechanics of the problem allowed gaps to be seen. Participant 17 said in a reflection, "I feel confident about math again because using self-explanation let me figure out what I was missing (in math) before the test. This helped me to keep going and get better at self-explanation because I was finally getting it."

Self-explanation. One powerful realization many learners experienced from the intervention was the awareness of how much mathematical knowledge they possessed of concepts that were previously mastered and retained. Seven of the 18 participants (39%) cited the self-explanation component of the intervention as responsible for documenting their prior knowledge in mathematics, which helped to increase confidence in their ability to perform at the college level. This was particularly empowering for the participants given the years of mathematical struggles encountered in K-12. One participant remarked that their mathematical self-worth was low prior to the intervention, but changed dramatically due to the intervention. This learner's comments echoed the thoughts of many when she indicated,

> I never felt like I knew a lot about mathematics. My confidence was really low because of how badly I have done in math. But I'm understanding things and I think that self-explanation helped me do that. What surprised me was how much math I actually know. This gave me the confidence because I was able to help others in my group. It makes me feel better about going into my next class. (Trained Section, Participant 5, Reflection)

Class Structure. Several factors regarding the class structure and environment were indicated as contributing to an increase in confidence. In addition to the intervention, 7 of the 18

(39%) participants referenced the use of collaborative groups as being helpful in relieving stress from prior classes when they had to mathematically perform in front of an entire class. The ability to solve problems as a team helped struggling learners ask questions to a smaller group than to the whole class at large. Participant 4 indicated in a reflection, “I was scared to even speak out in class but I would ask questions to my group.”

Five of the 18 indicated that classroom instruction and structure were contributing factors for increasing their mathematical confidence. Participant 18 indicated within a reflection, “In all honesty, I wasn’t that big of a math fan until I took this class. The class made math easier to me because the instruction was clear.”

One participant indicated that instruction, in addition to the learner’s own grit, can shape the learning experience. Participant 20 indicated within a reflection, “Depending on the topic or the equations, mathematics can be extremely complex and difficult to understand, but given proper instruction paired with determination, anyone can become better at math. I feel better about math now after this class.”

Decline in confidence at conclusion. It is important to note that not all participants experienced an increase in confidence. One of the 23 participants within the Trained Section indicated their confidence level decreased as the course progressed. The participant had positive feelings regarding the intervention, but their confidence waned as the mathematics became more robust. Participant 4 indicated within an interview, “It (the intervention) did help me grasp the concept of what I was doing a bit more, but in actual practice of doing the problem, I still needed help to understand the math.” While these perceptions were not directly linked to the intervention, it was important to recognize the overwhelming feelings that can occur when a learner struggles academically. Individuals who do require more educational support need interventions which scaffold and strengthen their mathematics but also support and guidance from the educator.

Untrained Section

Low confidence at onset. Fifty percent (10 of the 20) Untrained section's participants indicated they entered the course with a low level of confidence. While these attitudes may have resulted from a variety of factors, participants described their feelings with common language such as, "worried," "nervous," and "unsure."

An early researcher's journal entry noted differences between the two sections as students participate within whole-class discussions. The entry indicated:

> The students in the Untrained section appear to be nervous to ask a mathematical question but once the conversation begins, many join in to whole class discussions in addition to small group-based discussions. This interaction is different than the Trained section in that whole-class discussions rarely occur. (Untrained Section, Researchers Journal, Week 7)

Similar to the Trained section, participants listed one or more factors which affected their feelings of mathematical confidence at the onset of the course.

History of low mathematical performance. A learner's relationship with math may be a complex one. Six of the 10 (60%) participants indicated a multi-year history of mathematical struggle, which affected their incoming mathematical confidence. These feelings fostered a negative attitude regarding mathematics and caused a lack of confidence regarding the participants to perform the necessary mathematics needed for successful completion of the course. Participant 4 indicated within their interview, "I was a little worried at first because I never have done well in a math class. I've always struggled with math."

Prior performance can cause negative feelings regarding mathematics with fears linked to the participant's ability to pursue their desired degree. One participant indicated:

> Some math makes me nervous. I understand the need for everyone to have good basic math skills but, I worry that a math class will make me have to change my major. I worry more about math than I do with my other courses. Math doesn't come easy to me and I can't always relate how a problem fits into my real-life situations. Because, I have to think differently about it in order to understand it, it makes it harder and that makes me more uncertain about what I'm doing. (Untrained Section, Participant 1, Reflection)

Factors out of the learner's control. Similar to the Trained section, 3 of the 10 (30%) participants indicated a lack of pedagogical consistency which affected their confidence as teachers changed, sometimes during the same academic year. Participant 5 recounted their experience in high school when she said: "I don't feel confident. I had like three or four teachers that year and I don't remember a single thing from that year."

The Untrained section participants also indicated that gaps between enrolling in mathematics courses was attributed to their low confidence upon entering a collegiate mathematics course. As gaps can affect a learner's ability to remember important concepts, properties and mathematical meaning, this was a cause of concern. Four of the 10 (40%) participants indicated a gap in mathematics courses which occurred either in high school or the Fall semester of their Freshman year, caused doubt as to whether the participant would remember the prerequisite material to ensure success within College Algebra. Participant 3 indicated, "I was not confident at all because I didn't take a math class my first semester (of college)."

Longer periods of delay were also referenced by another participant within an interview. She said:

> I didn’t have a large level confidence just because I didn't take a math class this semester prior. I did take one my junior year of high school, but not my senior year so I had like a large gap in between. So, I wasn't super confident in my math skills going into it. (Untrained Section, Participant 2, Interview)

Fortunately, external factors such as illness may not affect all learner’s academic progress, however one participant shared their mathematical experience that resulted from an illness. Understanding how these external events affect the trajectory of the learner’s future, in addition to feelings of mathematical confidence, can help learners in current and future classes. The illness and the events surrounding it altered the learner’s mathematical progress and caused a change in their mathematical attitudes. One participant said:

> I was out a whole year because I got really sick. I was in the hospital and so they put me on homebound and that teacher really didn't teach me math. He put me in calculus and I was only a sophomore, so I really didn't know what to do and it really put me behind in math and I really struggle with it now and I probably will for a long time. (Untrained Section, Participant 8, Reflection)

Higher confidence at onset. Not all participants within the Untrained section indicated a lack of mathematical confidence. Ten of the 20 (50%) Untrained participants indicated they had average or high confidence at the beginning of the course and did not have negative attitudes towards mathematics. Two individuals expressed the relaxed nature of the participants, in addition to their being open to learning.

> I would describe myself as pretty neutral. Just open to what was coming, you know, just being unfamiliar with everything, just trying to absorb as much as I could. So, I was just kind of waiting to see what was going to happen. (Untrained Section, Participant 6, Interview)
>
> I think I was excited. I thought that the course would, I didn't think that I would get, like I would get an A, but I thought, okay, I can pass the class. Like I can do this. I was like excited to learn math and have like a good teacher. (Untrained Section, Participant 5, Interview)

Increased mathematical confidence at conclusion. While 50% of the participants began the study reporting with low confidence, analysis of the interviews and reflections indicated that mathematical attitudes increased upon the conclusion of the study. Twelve of the 20 (60%) participants reported an increase in confidence based on the intervention, its components, or other factors. The participants were free to indicate as many factors that pertained to their learning and attitudes.

Intervention as a whole. The self-explanation component allowed students to express mathematical meaning using their own words. Yet, even with the lack of training, five of the 12 (42%) participants indicated both components of the intervention as beneficial to increasing confidence in their learning and understanding of mathematics. In an interview, Participant 2 summarized the thoughts of others when she indicated her confidence increased from being "able to look at the example and explain it to myself and someone else."

While this number of students is fewer when compared to the Trained Section, the intervention increased their confidence by providing insight to the mathematical gaps they possessed. The comment of one participant illustrated how mathematical attitudes improved as self-explanation in conjunction with worked examples helped the learners to gain confidence.

> My confidence has increased. With a better understanding of the material that we've been going over. Everything, especially self-explanation and trying to understand what the problem is doing and the class has helped me a lot. Learning to self-explain was useful in helping me to relax a little. It made me feel more positive about math. (Untrained Section, Participant 1, Interview)

Given the range of mathematical abilities, the intervention did not remediate and eliminate gaps immediately. The participants, nonetheless, felt increased confidence in their ability to work with the mathematical concepts.

> I feel like my math ability has increased. I still don't think that I could just like look at a problem and fully be able to do it by myself. But I think that studying the problems and then writing down what the steps mean has helped me get through a problem easier. This has helped my overall confidence in math. (Untrained Section, Participant 16, Reflection)

> Learning to explain math problems to myself has taught me how to understand them better, because seeing the problem already completed was nice because I just have to understand each step. I can then look at the math properties within the steps. Seeing with solutions really helped me learn because I was just examining the answer that had already been completed. (Untrained Section, Participant 18, Reflection)

Worked example. Seven of the 12 (58%) Untrained participants who expressed an increase in confidence cited the examination and use of the worked example as the component which resulted in this new feeling. The completed solution allowed the participants to relax and learn without stress as they would “worry about understanding it rather than just completing it”

(Untrained Section, Participant 5, Interview). The participants felt more likely to engage with the completed solution because they were released from the stigma if they could not solve it from start to finish.

> I feel better about math now. I guess when I see the problems worked out it lets me see how it should be worked. I'm not stressed out to immediately solve it. I can figure out the parts that I know and ask questions about the other parts. I liked that part of it. (Untrained Section, Participant 14, Reflection)

> Just being able to look at the problem, study it, and then write out the math helped me. I could get away from having to know the properties or names of things, like rules, and just explain things in my own words. It helped me to not feel as pressured about remembering things, but just to concentrate on understanding them which gave me confidence. I didn't feel bad when I didn't understand it because I was supposed to just try to understand it. (Untrained Section, Participant 3, Reflection)

Given that the problem was previously solved, the participant's role was to examine it for understanding. This examination revealed areas of mathematical misunderstandings. However, the participant's perception was that the identification of these gaps did not negatively affect their mathematical attitudes, but helped to form positive attitudes as they were able to seek help from work that was not of their own creation. One participant indicated:

> To me looking at the problems was great. I could see how it was solved and if it was an incorrect worked example, I just had to spot the mistake. Those were almost like a game. It wasn't my mistake so I knew I was learning from someone else's mistake. (Untrained Section, Participant 6, Reflection)

Class structure. Each class period, the participants had the opportunity to work together collaboratively. In addition to the intervention, participants cited the ability to share mathematical ideas and discussions as contributions to their positive mathematical attitudes. Seven of the 12 indicated the community and support felt by their group and class structure helped to improve mathematical attitudes.

Each group became a community as they supported each other. One participant discussed how the classroom environment was different from that of high school in that each student was on a similar path to a STEM degree. This helped each individual support the group as a whole. He remarked:

> Yes, my math skills and confidence have increased. I feel like I understand more math now. Um, I think the atmosphere, like the people in the class were wanting to learn and we were there for a major – all for the same purpose. Especially in my group. I'd look at the examples and explain it and then we would share what we wrote. Sometime, they had better explanations than me, so that helped. I liked that we got to really look at problems and talk about them and it just wasn't straight lecture for the entire semester. There were times when I was the one who understood it and I got to share it with others. That felt good. (Untrained Section, Participant 6, Interview)

Both groups of participants noted the positive feelings that they experienced while sharing their knowledge with others. For many, this was a new feeling to be able to share mathematical knowledge among a group of students. The give and take among the group offered each a voice and helped them feel needed by their group members.

In addition to the collaboration, five of the 12 (42%) participants indicated that course structure and teacher support assisted with the increase of positive attitudes during the study.

> I have better understanding of how the math works. It's a new feeling. My confidence has increased. I understand a lot more about math now after this course. In class when we looked at the problems and writing down what the line in the problem is doing, that really helped me to figure things out. You helped me to feel comfortable and to feel like you cared, which meant a lot. (Untrained Section, Participant 9, Reflection)

> I definitely feel so much better about going into my next math class now and I don't worry as much about how I'll do in that next class. Your teaching and studying the examples and the self-explanation really helped me. Having a teacher who cared also helped me to want to learn. Like I could tell that you wanted to help us or that really helped. (Untrained Section, Participant 4, Interview)

The external factors, together with the intervention, gave students the confidence to attempt solutions and feel supported within their learning. The improved attitudes helped students as they looked towards their next class within the sequence needed for their degree.

CHAPTER VI

DISCUSSIONS AND CONCLUSIONS

This chapter examines the effect training a learner in self-explanation, a generative learning practice, has on the quality of the explanation produced in addition to how the introduction affected mathematical attitudes. Training the learner on the intervention was the condition which separated the two sections of College Algebra. The results of the study provided valuable insights into the perceptions of the participants within the two sections regarding the method that the intervention was introduced, the obstacles faced, benefit to learning mathematics, and how the intervention affected student attitudes on mathematics.

Training, or lack thereof, affected the intervention in many ways and across each research question. In this study, the participants were provided a brief training or merely told it was a useful strategy. The participant's response to the manner in which the intervention was introduced affected the manner in which they engaged, valued, and used the components of the intervention. This response provided situations which aligned the two sections as well as highlighted stark differences between the two.

The discussion begins with the effects on the intervention as a result of the training condition. As each section navigated the uncertainty of the new intervention, the participants reacted in different ways to the manner in which the intervention was introduced. Next, the discussion will address how the training conditions affected the self-explanation quality produced. Finally, the discussion will analyze the importance of the intervention's relationship with mathematical attitudes and the ability for students to continue, even though the path may be challenging, as they pursue their STEM degree.

Effect of the Training Condition on Intervention

Establishing an environment for learning helps students make necessary connections between prior knowledge and new knowledge (Wittrock, 1974a). However, the establishment of this environment is usually left up to the teacher's own methods. As the study provided varied training conditions, it was interesting to note that both sections, despite the training condition, faced challenges as they implemented the intervention. Each section had an initial resistance to the intervention, exhibited by learners of all mathematical levels. Lower mathematical ability learners feared continual mathematical misunderstandings and setbacks similar to what they had previously experienced in K-12 while those who had higher mathematical ability resisted for fear that it would damage their fragile mathematical understanding (Hodgen & Marks, 2009).

The Trained group was informed of the structure of the self-explanation, which should contain prior and new knowledge, and the relevancy of each component to the benefit of learning mathematics. The training modeled a level of instruction known as Informed Training (Brown et al., 1981) in which the participants are provided knowledge of the significance of the intervention and its components. As the Trained section began to implement the formal knowledge learned within the training, they immediately were resistant due to the perceived increase of time and effort necessary to create the set of "personal instructions." However, this was short lived as the opportunity to explain and reference material and information from beyond the boundaries of the given problem allowed them to flourish (Rittle-Johnson et al., 2017).

The Trained participants were pleasantly surprised with the amount of knowledge that they had amassed, a new feeling for the underprepared learners. The participants used the analysis of the worked example to understand the mathematical principles which in turn, helped them generate the explanation which included their personal understanding (Chi et al., 1989).

Most participants appreciated the ability to personalize the self-explanation by including words which would help them to remember why or when the principle should be applied. The perception of the Trained learners indicated that the ability to write the *why* and *how* helped with recall on tests and open-ended problems.

However, without training, the two sections viewed the worked example component with different importance. The Trained section viewed it as a valuable learning tool which facilitated the creation of the self-explanation, whereas the Untrained section's participants relied more so on the worked example for their learning.

The Untrained participants were provided incomplete instruction as to how the instruction was to be performed, its significance, and relevancy to the learning of mathematics. Given this lack of information, the Untrained participants managed the intervention and its' resources in unexpected ways. While some learners can infer the significance to learning that the intervention holds, not all do. Brown et al. (1981) refers to instruction which does not inform the learner of why they perform the activities that they do as "blind instruction" which leaves the learners blind to its significance. The current study utilized this approach as the self-explanation was unknown in terms of structure and content.

Like the Trained section, the Untrained participants initially viewed the self-explanation intervention through the lens of time and effort to compose. They perceived the worked example as less work and less to manage (Kalyuga, 2011) than the creation of the self-explanation. As they identified the worked example component as the primary method of learning within the intervention, the self-explanation was relegated as a secondary or less important component.

Group collaboration. Each section was able to participate in group collaborations, a component of the class structure. Participants from both sections individually examined the worked example and completed their self-explanations. Subsequent open-ended problems with similar and dissimilar factors were then completed. All group compositions were different due to the various academic levels that existed within the class and groups. Due to this, the potential range of mathematical ideas in some groups may have been more robust than other groups.

The collaborative review of the worked examples featured discussion which at times, identified prior knowledge from a group member which helped to bridge the gap between prerequisite and new knowledge. The group members were free to write as much information within the self-explanation as deemed necessary and could include the information learned within the group discussions. The group collaboration aspect of the course was well-received for both sections as it helped to build a community which facilitated support and positive attitudes.

Wittrock's research indicates that an effective type of elaboration is explaining the material to another (Wittrock, 1986). However, not all verbal explanations were of the same quality. To this end, researchers have shown that individual learning is superior to group collaborations when using worked examples (Retnowati, Ayres, & Sweller, 2017). When lower-level learners worked together, their prior knowledge often contained many gaps which led themselves or others to difficulty in creating a robust self-explanation. Differences in how the two sections engaged with their peers was noticed and validated through interviews and reflections.

For the Trained section, the collaboration was viewed as a support but was not necessary to perform the intervention. The construction of the self-explanation was viewed as a *personal* construction of the learner. As the Trained section concentrated more on the generation of their self-explanation rather than the worked example, their knowledge was broadened as bridges connected to disparate information together. Their individual generations proved to be what the students remembered as they examined future problems more so than the examination of the worked example (Mullins, Rummel, & Spada, 2011).

For the Untrained section, the group collaboration was important as they navigated the uncertainty of utilizing an intervention with scant performance information provided. A possible reason that group collaborations were so effective within the Untrained section was their shared group goal, allowing each member to share in the responsibility to help create meaning and understanding (Slavin, 1988). Each group member had responsibility to help create stability given the lack of information provided at the intervention's onset. The Untrained section participants searched for support and organically found it within an existing course structure, group collaborations. Upon completion of the analysis and creation of the self-explanation, they would discuss the steps of the worked example, what each step meant, as well as prior knowledge which affected the mathematics being displayed.

Often, the Untrained participants would not include the knowledge learned from their group's interactions or teacher assistance into their self-explanation which negated their ability to form relationships and build schema (Chi et al., 1989). While the conversations of the group may have included information that would be helpful to bridge between prior and new knowledge within a self-explanation, the participants did not know to include these within their constructions.

A negative side effect of group collaborations occurred as these conversations fostered the spread of brief restatements of worked example steps within the Untrained section. The restatement of the worked example provided a description of the *action* but not its *meaning*. The collaboration also encouraged revision of self-explanations as dissimilar explanations were considered incorrect. For these reasons, most participants within the Untrained section composed similar, but succinct, restatements of the worked example step with no inclusion of individual knowledge from either their background or the background of a group member.

Benefits of intervention. The benefits of the intervention to learning mathematics were seen across each section. For both sections, the study of worked examples provided a model that the participants could examine and learn (Atkinson et al., 2000). This knowledge assisted the participants when performing subsequent open-ended problems which were attempted after the self-explanation was constructed (Glogger-Frey et al., 2015). By studying this completed solution, the learners could then apply this knowledge to new open-ended problems (VanLehn, 1996).

Review of the initial worked example analyzed gave the learners the opportunity to explore an efficient solution strategy and enabled them to discuss areas of mathematical trouble, which normally would have been misunderstood (Atkinson et. al, 2000; Renkl, 2014; Sweller & Cooper, 1985; Zhu & Simon, 1987). For one participant, the structure of the solution was limiting as she would have solved the problem using a different tactic. But an overwhelming majority appreciated the worked example for the solution that it provided.

Participants from both sections perceived an increase in their own knowledge monitoring through the identification of mathematical gaps (Chebbini et al., 2019). Yet even though both sections perceived these metacognitive benefits, they were derived from different factors. The Trained section used *both* components, the worked example and the self-explanation, to support knowledge acquisition (Renkl et al., 1998). The identification of gaps was achieved either through the failure to understand the worked example step or when their mathematical knowledge prohibited the construction of a self-explanation. Once the gap was identified, it provided an opportunity for the participant to seek assistance. Therefore, each component assisted the learner in highlighting mathematical misunderstandings.

The participants within the Untrained section primarily used the worked example to identify missing information within their mathematical knowledge. While the examination of the worked example was effective for learning mathematics (Sweller & Cooper, 1985; Zhu & Simon, 1987), the self-explanations produced were poor and may not have helped form the connections between content as was perceived by the Trained section.

In Chi et al.'s (1989) seminal study, "successful" learners were classified as those who devoted more time and attention to the worked example. Within the current study, the Untrained section did analyze the worked example to a higher degree than the Trained section. However, the increased review did not produce the same results as in Chi et al.'s study as the Untrained participants were not instructed how to self-explain. This lack of awareness of how to construct yielded a less than robust effort on their part in which their explanations did not relate the steps back to the broader mathematical content being discussed.

This study did not measure mathematical performance. Both groups were given the opportunity to complete open-ended problems after the examination of the worked example and construction of the self-explanation. While both groups struggled as the mathematics became more challenging, they were each able to solve these problems which were related to the worked example with minimal effort. This was consistent with findings of both Sweller and Cooper (1985) and Renkl et al. (1998).

The perception of the participants showed that the conversations within the groups expanded their understanding as the interplay of ideas, examination of procedures, and experiences were explored (Rittle-Johnson, 2006). As both groups explored the procedural aspects of the worked example, this knowledge helped to inform and create a foundation for mathematical understanding.

Exam scores provided anecdotal evidence of the progression of learning between the two sections which used the same exams on the same content. While the exam scores were similar for the first exam, the Trained section outperformed the Untrained section for each subsequent exam. This progression of learning, when comparing the two sections, does support Jonassen's (2004) assertion that the learner's ability to transfer knowledge to later problems is predicted from the quality of the self-explanations produced.

Quality of Self-Explanation was Affected by the Training Condition

In congruence with the Ozuru et al. (2010) study, the present study found that training improved the quality of self-explanations for underprepared learners. Using an adapted form of the rating scale developed by McNamara et al. (2007), the 5-point coding system allowed the reviewers to indicate the perceived level of internal and external information referenced within the participant's self-explanation. While the rating was subjective, it was conducted by three skilled mathematics instructors who had years of experience with underprepared collegiate mathematical learners.

An unexpected result occurred within the first artifact as the mean quality scores for both sections were similar, despite training of how to construct a self-explanation provided to only one section. A possible explanation for this was mentioned within participant interviews and reflections. The participants shared that the mathematical material covered on the first artifact was very familiar and well-understood from prior mathematical instruction. However, by the second artifact, a marked difference could be seen between the mean quality scores as the Trained section scored at a much higher level than the Untrained section.

To further investigate differences between the two sections, a mean score per step was calculated to compare the two artifacts. Only the Trained section displayed a gain from Artifact 1 to Artifact 2. This showed that only the Trained section was able to increase the quality of their self-explanations, both overall and when examining them at the step-level, as the mathematical content of the second artifact represented the most challenging material of the course.

A surprising result was found when investigating the two artifact's scores by ACT category (Remedial - ACT < 17, Underprepared – ACT 17 - 20, and College-level – ACT > 20). In all but one category (Underprepared - ACT 17 – 20 on Artifact 1), the Trained section received higher quality scores than the Untrained section, regardless of ACT category. In many cases, the difference in scores was marked when comparing the two sections. The most dramatic finding was within the Trained section within the Remedial category. In this category, the participants produced a higher quality score than both Underprepared and College-level learners within either section.

This was significant as researchers have shown that self-explanation is not dependent on prior knowledge (Chi & Vanlehn, 1991; Renkl, 1997). However, quality within this study was determined by the learner's ability to include information, either internal and external to the worked example, into their self-explanation. Therefore, the awareness of these concepts was a key determination of quality.

One possible explanation for this result may be explained by the recent mathematical classroom experiences of participants within the two sections. Students of both sections who entered with an ACT less than 17 were required to take a remedial course prior to enrolling in College Algebra. The Trained section had a larger percentage of its population considered

Remedial than did the Untrained section. That recent exposure to prerequisite mathematical information may have assisted them in developing self-explanations with references to prior knowledge more than participants who did not have this experience.

Within the interviews and reflections, the participants shared perceptions of their mathematical attitudes which surrounded the construction of both artifacts. The Trained section indicated an increased confidence within their constructions as the course progressed and the intervention's ability to assist them in understanding mathematics. Their reliance on the intervention increased as the College Algebra content became more difficult. Participants recognized the ability to monitor their own learning (Atkinson et al., 2000) and comprehension as they navigated the unfamiliar mathematical topics (Otero & Graesser, 2001). They perceived their mathematical understanding was strengthened as they were able to identify necessary prerequisite information needed to solve the problem and construct explanations which personally told them how the prerequisite and new material were related. Several of the participants began using the intervention within other aspects of the course to increase their learning. One individual also began using the intervention within a course they were also enrolled in as the self-explanation assisted them in creating mathematical meaning when they struggled to understand the concepts being discussed.

The Untrained section participant's perception of their ability to gain mathematical knowledge from both components of the intervention was mixed. The participants did not feel confident in their constructions in terms of what information should be included and what format the self-explanations should take. Given the lack of training, the majority indicated an increased reliance on the worked example and a decrease in effort expended on the generation of the self-explanation. While the reliance to the worked example allowed learning and mathematical understanding to occur, the lack of the inclusion of knowledge learned from collaboration was a factor in the decreased rating of quality. For the Untrained participants that did continue to add mathematical knowledge, personal to them, they discussed the intervention's benefit to helping the material "click" as old and new knowledge was linked.

Verbal readiness data was collected to understand if verbal ability would influence the quality of the self-explanations created. Foreman-Murray and Fuchs (2019) conducted a study which examined the necessary verbal ability of school age children to construct a quality self-explanation. They found that students with lower verbal ability may be ill-equipped to construct self-explanations of high-quality. However, the results of this study do not support those findings as the Trained section had lower incoming verbal standardized test scores and yet were able to construct elaborations of higher quality than those not trained. This suggests that the training was able to scaffold the learners even when their verbal abilities were low.

Mathematical Attitudes, Confidence, and Engagement

Development of positive mathematical attitudes is an important component of an underprepared student's journey towards earning their college degree. The development of these attitudes will sustain them in their efforts (Bailey et al., 2010). When an intervention addresses both academic needs and supports positive changes in attitudes, this support will increase the likelihood of success within their STEM classes (Tobias, 1993).

Mathematical attitudes were evaluated using the Code et al.'s (2016) Mathematics Attitudes and Perceptions Survey. The pre- and post-MAPS survey studied Confidence, Persistence, Growth Mindset, and Mathematical Interest factors. Student perceptions was also examined. A surprising result, between the two surveys, was the amount of gain experienced by the Trained section compared to the Untrained. The Trained section had a gain of 1.67 as compared to 0.06. Participant reflections and interviews validated these results and shed light on the differences between the two sections' perceptions.

Despite both sections' initial resistance to the intervention, both groups immediately recognized the benefit the worked example provided the participants. They used the model to understand mathematics properties and relationships without generating the complete solution on their own (Renkl, 1999). This immediately put the participants across both training conditions at ease.

Due to the training, the Trained section was able to work through their initial hesitations and accept the intervention, once benefits were seen. As the Trained section progressed through the course, they increased their confidence within the intervention and themselves. Individuals would express positive mathematical emotions and pride in their ability to understand and explain a difficult concept. This was empowering to the underprepared learners who had very little, self-admitted confidence, coming into the course.

While the Untrained section participants came into the course with a higher amount of initial confidence, some expressed thoughts of being nervous and unsure. The introduction of the intervention brought doubts regarding time and effort involved in performing the intervention over open-ended problem-solving techniques. However, both groups initially became more confident from the worked example component of the intervention which was helpful to facilitate an understanding of mathematical principles. This made that component of the intervention more utile.

Lack of confidence was present as the participants engaged with the self-explanation. Both sections struggled at the intervention's onset with construction of self-explanations. For the Trained section, it was a matter of putting into practice what the training had referenced.

However, the Untrained section's doubts were also rooted in lack of information on the intervention which was provided to the other learners. The Untrained section participants struggled knowing how to construct a self-explanation, what information should be included, and how specific the information should be. While the Untrained section did reach a level of comfort with the environment, it was due to the relegation of the self-explanation to the background. Restatement provided an easy way to self-explain. The learners were able to write down the mathematical operations involved within the step, which was viewed as supportive to learning.

At the completion of the study, the MAPS survey indicated that both sections experienced an increase in overall mathematical attitudes when comparing the pre- and post-MAPS surveys. In a surprising turn, the Trained section not only increased their mathematical attitudes dramatically, but also had increases on all four mathematical attitude factors, with the highest increase in the Confidence factor.

The Trained section was found to be more engaged with both components of the intervention. Each component had a positive effect on their increase in confidence. The increase in confidence was a result of their improved understanding regarding their own mathematical knowledge. Perceptions indicated the intervention facilitated mathematical awareness which in turn allowed them to feel confident expressing themselves mathematically. This new experience allowed the participants to feel comfortable within the class and more dedicated to mastery of the material (Kargar et al., 2010).

The Untrained section increased only slightly with the results indicating a consistency of mathematical attitudes during the study. Even though the mathematical attitudes were high at the onset, the participants cited primarily the use of the worked example as a contributing factor to their increase in their own mathematical confidence. In general, for the Untrained section, the lack of specificity surrounding the intervention was not indicated by the participants as increasing, nor decreasing, their overall mathematical attitudes. However, the participants did lack confidence in how to construct self-explanations.

In addition to Confidence, the Trained Section had increases within the Growth Mindset, Persistence, and Mathematical Interest with the Untrained Section increasing slightly in Growth Mindset and Mathematical Interest.

Conclusion

Underprepared learners struggle with mathematical deficiencies in addition to damaged attitudes surrounding mathematical learning. While their aptitude may seem at odds with the mathematics necessary to earn the degree, many underprepared learners have the dream of a STEM career whose earnings may change their life situation. As these learners enter college, successful completion of the initial gateway mathematics course is required to "unlock" additional mathematics and STEM courses necessary for their degree plan. While this puts a formidable amount of pressure on the learner, the corequisite course structure allows these underprepared mathematical learners to navigate the same curriculum as those who have higher math preparedness, with support.

To help underprepared learners reach their goals, interventions are developed and put into place to remediate efficiently to keep on pace with their degree plan. Support can also be provided to the whole student, to offset any negative attitudes surrounding mathematics as they affect mathematical attitudes and decisions that the student makes daily.

Creating instruction for underprepared collegiate learners involves providing an environment in which mathematical exploration, reason, reflection, and communication is possible. Within corequisite educational courses, a variety of academic levels can exist within the same classroom making a one size fits all instruction virtually impossible. All students have mathematical gaps. As the gaps are uncovered, the classroom culture scaffolds the learner and provides assistance to help them persist (Sullivan et al., 2013).

Self-explanation when combined with worked examples provides the ability to assist learners of all academic levels by individualizing their generations. For learners who have lower mathematical knowledge, the worked example provides scaffolding as they master the concepts. For those with higher mathematical knowledge, self-explanations can be generated with the provided worked example or as they come up with a different solution strategy.

One of the most important aspects of self-explanation is the monitoring of one's own learning. As students explore intellectually challenging mathematical topics and identify gaps within their knowledge, the classroom environment should provide support and encouragement during remediation (Pajares, 2000). As students feel more comfortable with their own generations, they may explore its use within other aspects of the course and in other STEM disciplines. By gaining confidence in a strategy which can be applied to a myriad of mediums, the learner has a powerful, proven effective tool to gain understanding of complex topics. This consistency will help the learner master their ability to explain worked examples found in a variety of other educational materials. This promising low-cost and approachable intervention can be useful for all academic and socio-economic levels as no materials are needed other than the writing materials.

To minimize resistance, educators should include, as an aspect of the training, the increased time and attention that will be required of the learner as they construct the self-explanation. This advance knowledge can assist the learner as they set up expectations for the intervention and to alleviate negative attitudes that may be expressed by the student. Educators can also provide expectations for discussion and sharing of explanations within a small group as the learners gain confidence. This provides opportunities for rich and fruitful discussions of mathematical strategies and prior knowledge. These discussions can be incorporated into additional open-ended problems which feature similar problems to the worked example and some with slight mathematical differences to bring up the discussions of technique.

Generative learning strategies allow the learner to construct a resource which is meaningful to themselves. Viewing mathematics through words, which they themselves construct, allows them to mathematically connect topics which may seem separate. While students were encouraged to self-explain using mathematical terms, they were free to describe the concept in words that they chose. Explaining the principle *to* themselves *for* themselves was a powerful and motivating way to learn mathematics. The learners did not feel the pressure to immediately solve the problem but rather concentrated on understanding the idea being presented within the worked example. This lack of pressure opened up new feelings of confidence as they were able to reduce the anxiety and insecurities previously experienced.

Quality of self-explanations varies with individuals and over time. As learners make mathematical connections, self-explanations can mature. Self-explanation is a skill that must be taught so that each learner has the ability to construct a self-explanation of the highest quality possible. Training to understand the mechanics of the intervention, its relevancy to learning, and mathematical benefit, is necessary. Both sections, regardless of training, were able to find a way to increase their mathematical knowledge and awareness. This in turn helped mathematical self-concept as confidence increased for each section. However, those participants which were trained created self-explanations of a higher quality and increased attitudinal gain than those who were not.

Self-explanation when combined with worked examples was a useful strategy to employ with underprepared learners within this study. For learners that utilized both components, it helped them to understand the mathematical concepts and their own learning. The worked example provided a model, while the self-explanation a way to individualize the learning. The advantage of the intervention was that each learner, regardless of prior knowledge, could construct a self-explanation that they understand.

Implications

To understand the implications, it is important to understand the genesis for the study – the continual efforts of my state, by educators like myself, to maximize the underprepared learner's mathematical efforts and learning experience as they pursue a STEM degree. I chose to examine how training affects the quality of the self-explanation constructed when training is applied or withheld. Training, the sometimes-overlooked aspect of an intervention, can determine the learner's understanding and ability to produce a quality representation of their work. The findings from this study lead to implications which focus on three main areas: incorporation of training to produce a higher quality self-explanation, metacognitive benefit, and mathematical attitudes.

Underprepared learners generate higher quality self-explanations with training. A necessary component to consider at the start of any intervention is the manner in which it will be introduced to the learner. Instruction must focus student attention to relevant material and teach the appropriate methods necessary to learn and achieve mastery (Wittrock, 1987). In addition to informing the learner of how to perform the task, the instruction must also communicate its relevancy to learning (Martin & Navarro-Zavala, 2006).

Wittrock's (1974a, 1987) research indicates that learners must be instructed how the intervention should be performed. This practice creates a supportive classroom community. By providing guidance to the learner regarding the intervention's mathematical goals, a better overall educational environment is created. Understanding the role that the educational environment, which surrounds the study, its effect on learning, quality produced, and attitudes was at the heart of the study.

Much of the body of research regarding self-explanation rests on the theoretical foundation on Chi et al.'s (1989) "Self-Explanation Effect". However, by looking to Wittrock's (1974a, 1974b) generative learning theory, the individual's construction can form bridges to existing knowledge. By examining the learner's own knowledge, the intervention adds to their existing proficiencies, in addition to filling in mathematical gaps (Anthony & Walshaw, 2009).

In this study, quality of the underprepared learner's generations was examined in terms of the amount of knowledge referenced both internal and external to the worked example step. Quality of self-explanation is a predictor of the learner's ability to transfer the concept to future problems (Jonassen, 2004). As the Trained section's participants became proficient with the intervention, their quality of self-explanations improved (Foreman-Murray & Fuchs, 2019; McNamara, 2004; Qzuru et al., 2010). Learners who had low incoming mathematical standardized scores were able to create self-explanations of a higher quality than peers who entered the course with higher mathematical scores (McNamara, 2004).

The intervention was utilized by learners with various levels of mathematical knowledge. Therefore, two learners were each able to write an individual self-explanation based on their own understanding and prerequisite knowledge. This adaptive aspect of the intervention worked for both high and low-scoring mathematical learners as they are each able to construct a self-explanation which has meaning.

This provides a significant learning opportunity for educators who design instruction for underprepared learners. The intervention met the learner where their own mathematical knowledge resided. The learner produced a generation which documented their ability to connect information internal, or within, the worked example, or external to the problem. External connections are a result from learning which occurred within the current or prior course or from support materials such as the textbook or the computerized learning platform. A higher-quality score goes beyond the worked example step and references what occurred in previous steps or to concepts outside of the worked example.

These connections allowed the learner to see that mathematical concepts are not discrete, but link together to form the tapestry of mathematical knowledge. While the underprepared learner may have gaps within that knowledge, the connections which they identify allows them to increase the quality of their generation. The opportunity to make increased mathematical connections allowed them to close those gaps. By filling in the gaps, they will continue to make progress within future mathematics or STEM courses necessary for their degree.

Training supported the metacognitive benefits of both components to be realized. Learning is messy. It involves the pursuit of activities and interventions which give the learner the opportunity to construct new knowledge, with respect to prior knowledge (Wittrock, 1974a). As learners construct this new knowledge, the educational environment must support the learner as they navigate the uncertainty of the intervention (Sullivan et al., 2013). The environment helps all learners, but particularly underprepared learners who have a fragile learning history and require support and scaffolding to overcome prior educational experiences.

Learners can make mathematical mistakes for a variety of reasons. Some occur due to careless mathematical practices such as being hurried when working on a problem. However, other mistakes are due to lack of knowledge regarding the mathematical concept. These errors are the most difficult for an educator to identify as a typical classroom may suffer from a myriad of mathematical concept gaps. Understanding their own learning is important as the learner may not be able to pinpoint where their mathematical misunderstandings reside.

Therefore, mathematical educators, as they devise instruction, must always create a learner-centric environment whose interventions and opportunities work to advance knowledge and allow one to learn from errors. The training instructed the learners how the two components of the intervention worked together to create mathematical meaning. Without the training, the learners took unexpected actions as they determined their own system of value and relevance of the interventions' components. These choices also allowed them to establish their own criteria to determine if the intervention was being performed correctly.

The study demonstrated that both sections utilized the intervention to identify missing mathematical knowledge. Self-explanation is an intervention which strengthens knowledge gaps (Nathan et al., 1994) through self-monitoring their own knowledge more so than problem solving along (Atkinson et al., 2000; Pirolli & Recker, 1994; Renkl, 1999).

The Trained Section used both self-explanation and the worked example to identify missing knowledge, whereas the Untrained Section primarily used the worked example. While both components can assist with metacognitions, the educator has the obligation to provide information to the learner how both components are relevant to learning (Martin & Navarro-Zavala, 2006), so that the maximum learning and effect of the intervention is achieved. Without training, the learners are left to determine their own ideas of relevancy, which may be different than what was originally intended by the educator.

Students create positive mathematical attitudes when using an intervention that builds on existing proficiencies. Underprepared learners may enter a classroom with preconceived expectations of their own failure. These expectations may be the result of exposure to less than successful instruction (Jones, Wilson, & Bhojwani, 1997). Student attitudes can affect persistence (Bailey et al., 2010), which can affect the likelihood of success (Tobias, 1993).

The self-explanation of worked example intervention provided two components which facilitated the identification of mathematical knowledge gaps. This is particularly helpful for underprepared learners who may have partial knowledge regarding the solution but may not be able to complete the problem in its entirety. With examination of a worked example, the learner transitions from an action mode to analysis mode, which helped the learner in a variety of ways. The examination of the worked example focused on the learner's recognition of similarities, differences, and changes as they moved from one step to another. The learner could view the mathematical concepts used as the solution progressed from beginning to end (Renkl, 2014). The intervention also allowed the learners to understand not only the individual steps but the goal of the problem as a whole.

Yet, as underprepared learners navigate through a mathematics class, they may bring those negative attitudes with them. An important aspect of the intervention for the underprepared learners within the study is that they did not feel an "ownership" of the problem, as they were merely analyzing a solution that they did not themselves create. Therefore, the learner was able to view the worked example steps objectively with their focus on understanding the solution, rather than creation of the solution.

This stepping back, or analysis of the problem, let the learner understand portions of the existing solutions and was preferred over solving open-ended problems (Sweller & Cooper, 1985). While they may not have been able to provide a solution from beginning to end, they could understand *components* of the problem. Realization of how much mathematical learning they actually possessed was a powerful turning point for both sections. Whether the participants used both components of the intervention together or primarily the worked example, the identification of mathematical knowledge retained from prior learning buoyed many insecure learners.

The increase in confidence helped to develop students' mathematical identities and self-concept. In addition, the increased confidence helped them to persist within the intervention and their degree to further their mathematical proficiencies. The analysis allowed them to identify misunderstandings within their mathematical knowledge prior to an assessment, which also helped to strengthen confidence. As students experience these positive attitudes, it can alter the course of their learning (Aiken, 1976; Singh et al., 2002).

Limitations

There are several limitations identified within this study. The participants had the ability to enroll into any MTH 127 College Algebra Expanded section offered within the university. It is unknown whether the sample represents the underprepared mathematical learners' population in general. Corequisite mathematical courses have a wide variety of academic and attitudinal levels. Participants enter these courses with strong negative emotions about mathematics and their ability to perform mathematics. Since the cases were created from two sections of College

Algebra at the same university, the results may not be generalizable to all corequisite courses or classes which teach underprepared learners. However, an important aspect of case studies is to examine a population within their “lived reality” (Hodkinson & Hodkinson, 2001, p. 3) to determine the “people, activities, policies, strengths, problems, or relationships” (Stake, 2006, p. vi) in detail. As these cases were examined and compared, the results have value and may apply to other contexts and populations to provide insight as to how other learners will be influenced by the inclusion or exclusion of training of an intervention in terms of the generations produced and surrounding attitudes.

Second, as the global COVID-19 Pandemic affected the world, it affected the current study. All university classes closed one week prior to the university’s scheduled Spring Break, which removed one week of instruction. The altering of the academic calendar followed by the change to virtual instruction changed the scope of the semester in ways that may not be understood. The stressful environment may have affected attitudinal data as the learners grappled with challenging mathematical topics while away from normal classroom supports. The lack of access affected the ability to interview a greater number of the participants as they were removed from the instructional environment and may not have had the ability to connect virtually.

Future research should fine tune the aspects of training needed when introducing self-explanation of worked example to diverse mathematical ability groups that may exist within the same class. This includes the examination of variations, duration, and intensity of training to determine the impact on the quality of self-explanations and performance. This type of research would help educators recognize whether a specific training works for all learners of if the needs of the underprepared learner population demand more personalization and time to understanding the mechanics and benefit of the intervention in order to maximize success.

As this study examined training in two proven interventions, self-explanations and worked examples, future research can isolate the effects of the two with regard to performance. The research can investigate how self-explanations, worked examples, a combination of both interventions, and a control affect performance and mathematical attitudes. Proposed research questions could include: (1) How do the treatments (self-explanations, worked examples, and mixed) impact mathematical performance, and (2) How do treatments (self-explanation, worked examples, and mixed) impact attitudes towards mathematical strategies?

The limitations can also be reduced by replicating the study within other educational contexts. Incorporating the study into courses which do not offer such broad mathematical academic ranges could help to understand how the intervention links mathematical concepts for the learner. For higher ability learners, alternative solutions to the worked example could be constructed and learners could self-explain their solution strategies.

The different sample may provide additional attitudinal perspectives from learners who have less negative emotional connections to mathematics and are more open to initially working with a new intervention as they spend the time and effort to master the active learning methods.

Another focus of future research would be to alter the methodology to examine the research questions as an experimental study context to determine how performance is affected by the inclusion or exclusion of training. Lastly, the current study utilized primarily freshman college-level mathematics students. Examining how age, gender, and first-generation learners play a role into the effect of training would enable researchers to customize learning opportunities for different segments of the population.

Scaffolding the learner is of vital importance to underprepared mathematical learners. The current study allowed the participants to self-explain the worked example in words that they chose. However, for learners who have low prior knowledge, the use of prompts and support from intelligent tutors may assist in the creation of a quality self-explanation. This narrow focus may be beneficial to point out pivotal mathematically important steps. Research can examine the effect that intelligent tutors have on learners who lack prior knowledge as they are scaffolded through the use of adaptive metacognitive feedback and fading.

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APPENDIX A

PRE-INTERVENTION SURVEY

This is a survey of your attitudes and perceptions about math; these statements all have the response choices Strongly Agree, Agree, Neither Agree nor Disagree, Disagree and Strongly Disagree, and should take less than 10 minutes. Please choose the response that matches your opinion.

Q1. Enter your Participant Code.

Q2. After I study a topic in math and feel that I understand it, I have difficulty solving problems on the same topic. (Disagree) [Confidence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q3. Math ability is something about a person that cannot be changed very much. (Disagree) [Growth Mindset]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q4. Nearly everyone is capable of understanding math if they work at it. (Agree) [Growth Mindset]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q5. If I am stuck on a math problem for more than ten minutes, I give up or get help from someone else. (Disagree) [Persistence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q6. If I don't remember a particular formula needed to solve a problem on a math exam, there's nothing much I can do to come up with it. (Disagree) [Persistence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q7. I enjoy solving math problems. (Agree) [Interest]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q8. I often have difficulty organizing my thoughts during a math test. (Disagree) [Confidence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q9. No matter how much I prepare, I am still not confident when taking math tests. (Disagree) [Confidence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q10. Please select Agree (not Strongly Agree) for this question. [Filter]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q11. I can usually figure out a way to solve math problems. (Agree) [Confidence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q12. Being good at math requires natural (i.e., innate, inborn) intelligence in math. (Disagree) [Growth Mindset]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q13. If I get stuck on a math problem, there is no chance that I will figure it out on my own. (Disagree) [Persistence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q14. I avoid solving math problems when possible. (Disagree) [Interest]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q15. I get upset easily when I am stuck on a math problem. (Disagree) [Persistence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q16. For each person, there are math concepts that they would never be able to understand, even if they tried. (Disagree) [Growth Mindset]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

APPENDIX B

POST-INTERVENTION SURVEY

This is a survey of your attitudes and perceptions about math; these statements all have the response choices Strongly Agree, Agree, Neither Agree nor Disagree, Disagree and Strongly Disagree, and should take less than 10 minutes. Please choose the response that matches your opinion.

Q1. Enter your Participant Code.

Q2. After I study a topic in math and feel that I understand it, I have difficulty solving problems on the same topic. (Disagree) [Confidence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q3. Math ability is something about a person that cannot be changed very much. (Disagree) [Growth Mindset]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q4. Nearly everyone is capable of understanding math if they work at it. (Agree) [Growth Mindset]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q5. If I am stuck on a math problem for more than ten minutes, I give up or get help from someone else. (Disagree) [Persistence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q6. If I don't remember a particular formula needed to solve a problem on a math exam, there's nothing much I can do to come up with it. (Disagree) [Persistence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q7. I enjoy solving math problems. (Agree) [Interest]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q8. I often have difficulty organizing my thoughts during a math test. (Disagree) [Confidence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q9. No matter how much I prepare, I am still not confident when taking math tests. (Disagree) [Confidence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q10. Please select Agree (not Strongly Agree) for this question. [Filler]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q11. I can usually figure out a way to solve math problems. (Agree) [Confidence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q12. Being good at math requires natural (i.e., innate, inborn) intelligence in math. (Disagree) [Growth Mindset]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q13. If I get stuck on a math problem, there is no chance that I will figure it out on my own. (Disagree) [Persistence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q14. I avoid solving math problems when possible. (Disagree) [Interest]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q15. I get upset easily when I am stuck on a math problem. (Disagree) [Persistence]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

Q16. For each person, there are math concepts that they would never be able to understand, even if they tried. (Disagree) [Growth Mindset]
Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

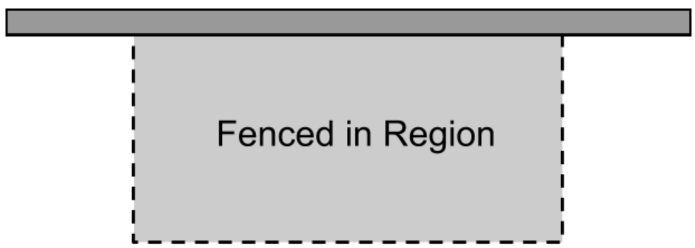
APPENDIX C

SELF-EXPLANATION ARTIFACT 1

Assignment #1
Below is a student's incorrect solution to the word problem. There is one mistake that affects the step where it appears and is carried forward in the student's following step(s). Please correct the mistake where it appears and each step(s) which follows. *Note, if you can't find the mistake, just explain each step of the solution.

Problem:
You have 244 feet of fencing that you have purchased to fence in a rectangular garden that borders a wall.

a) Find the quadratic function that models the area of the garden in terms of the width x of the garden.
b) What are the dimensions?



Their Solution:
a)
$Width = x$
$Length = 244 - 2x$
$Area = width * length$
$Area = x * (244 - 2x)$
$Area = 244x - 2x^2$
The quadratic function is $f(x) = 244x - 2x^2$
b) $h = -\frac{b}{2a}$
$a = -2 \quad and\ b = 244$
$h = -\frac{244}{2(-2)} = 61$ feet is the width

$Length = 244 - x$
$Length = 244 - 61$
$Length = 183$
The width is 61 feet and the length is 183 feet.

Correct the error, and self-explain the following steps performed.

Step	Corrections, if necessary	Explanation
Width = x		

Length = 244 – 2x		
$Area = x * (244 - 2x)$		
$h = -\frac{b}{2a}$		
$a = -2 \quad b = 244$		
$h = -\frac{244}{2(-2)}$		
$Length = 244 - x$		
$Length = 244 - 61$		
The width is 61 feet and the length is 183 feet.		

APPENDIX D

SELF-EXPLANATION ARTIFACT 2

Assignment #2
Below is a student's incorrect solution to the word problem. There is one mistake that affects the step where it appears and is carried forward in the student's following step(s). Please correct the mistake where it appears and each step(s) which follow. *Note, if you can't find the mistake, just explain each step of the solution.

Problem: If $5,000 is borrowed with an interest of 12% compounded semi-annually, what is the total amount of money needed to pay it back in 5 years? Round your answer to the nearest dollar. Do not round at any other point in the solving process; only round your answer.

Step	Corrections, if necessary	Explanation
Use $A = P\left(1+\frac{r}{n}\right)^{nt}$ Let P=5000 r=.12 t=5		
$A = 5000\left(1+\frac{.12}{2}\right)^{2\cdot 5}$		
$A = 5000(1+.06)^{2\cdot 5}$		
$A = 5000(1.06)^{2\cdot 5}$		
$A = 5000(1.06)^{7}$		

$A = 5000(1.503630258)$		
$A = \$7518.15$		

APPENDIX E

SELF-EXPLANATION CODING SHEET

Participant ID:___ _____________

Reviewer:____ ________________

Artifact #: 1 2

Codes	Description
0 = Blank	Participant leaves the explanation blank for the step or prompt.
1 = Vague or Irrelevant	No relevant mathematical content expressed when explaining the step or prompt.
2 = Step-focused	Participant restates or paraphrases the step or prompt without explanation of concepts presented. No new information is described by the participant.
3 = Local-focused	Participant uses concepts from previous steps within the explanation.
4 = Global-focused	Participant uses prior knowledge or information from a lecture, Knewton, or real-world, when explaining the step.

	Code	Field Notes
Step 1		
Step 2		
Step 3		
Step 4		
Step 5		
Step 6		
Step 7		
Step 8		

Total Score:___ _____________

APPENDIX F

SEMI-STRUCTURED INTERVIEW

Thank the participant for taking the time to participate in the interview. Explain that the interview will be recorded with their permission. The interview will be anonymous.

Demographic

1. What is your age?
2. What is your major?
3. What is your student classification?
4. Are you a full or part-time student?

Self-Explanation

5. What aspects of the course helped you learn how to self-explain worked examples?
6. We've used self-explanation of completed problems for most of the semester. To what extent did the experience impact your learning of mathematics. Does a particular moment or part of the intervention stand out?
7. In what ways might you be inclined to use self-explanation of a completed problem in future classes that you might take? If so, why?
8. We used the intervention in our lecture portion of the class. Were there other times that you used the intervention in our class?

Mathematical Attitudes

9. Describe your level of mathematical confidence at the beginning of the course?
10. Has your mathematical confidence level changed since the beginning of the course? If so, what precipitated the change?

Mathematical Background

11. Everyone has a mathematical story of how they got to where they currently are. What's yours? What were your experiences in previous mathematics classes prior to ours?

Conclude by thanking the participant for their time and responses. Mention you will send a transcript of the interview to them for member checking, and encourage them to provide any additional insights or corrections via email.

APPENDIX G

REFLECTION JOURNAL ENTRY ASSIGNMENT

Reflection: Reflect upon the use of self-explanations, when combined with worked examples that was used within the class.

1. What helped you learn how to self-explain? Would you recommend someone to learn how to self-explain in this way?

2. Describe your impression of self-explanation of a completed math problem.

3. Did you use it outside of our lecture class?

4. In what ways did self-explanation of a completed problem affect your learning of mathematics?

5. Describe your thoughts and feelings about mathematics.

6. What were your attitudes about the course before beginning? Have your attitudes changed now that the course is almost over? If they have changed, what do you feel initiated the change?

APPENDIX H

SELF-EXPLANATION TRAINING HANDOUT

Self-Explanation Training for College Algebra

The “self-explanation” strategy has been found to be very effective to enhance problem solving and understanding of mathematics related topics. It can help you to understand the topics that we will cover during this class.

How to Self-Explain

To improve your understanding of a mathematics related topic, there are a series of techniques that you should apply when using worked examples.

After viewing the worked example:

- Write a brief overview of the goal of the problem. What are we trying to accomplish by the end of the problem?

After reading each line:

- After reading each line of the worked example, try to identify and elaborate the main ideas of the step.
- Attempt to explain each step of the worked example in terms of previous ideas. These may be
  - Ideas from the problem’s introductory information
  - Information you have learned from the lectures or previous problems
  - Ideas that you have learned in lab, from Desmos or Knewton.
  - Your own prior knowledge of the topic
- Consider any questions that arise if the new information contradicts your current understanding and write these questions down.

Before proceeding to the next line of the worked example, you should ask yourself the following:

- Do I understand the ideas used within that step?
- Do I understand why those ideas have been used?
- How do these ideas link to other problem, previous topics discussed, or prior knowledge that I may have?
- Does the self-explanation that I have generated answer the questions that I am asking?

Self-explanation is not the same as paraphrasing or monitoring. Paraphrasing will not help you learn to the same extent as self-explanation.

Let’s look at a first line of a worked example:

$$\frac{x^2-4}{3}\cdot\frac{6z}{2x+4}=\frac{(x+2)(x-2)}{3}\cdot\frac{6z}{2(x+2)}$$

Paraphrasing:

"$x^2 - 4$ was rewritten as $(x+2)(x-2)$ and $2x+4$ was rewritten as $2(x+2)$"

There is no self-explanation in this statement. No additional information is added or linked. The reader merely uses different words to describe what is already represented by the worked example. You should avoid paraphrasing during worked examples as it will not help your understanding as much as self-explanation.

Restatement:

“Ok, I understand that "$x^2 - 4$ can be factored.”

This statement simply shows the reader’s thought process. It is not the same as self-explanation because the student does not relate the sentence to additional information in the text, lecture, or prior knowledge. Please concentrate on self-explanation rather than monitoring.

Self-Explanation:

“To multiply fractions, I learned a rule where we multiply numerator times numerator and then denominator times denominator. But, in class we learned that it’s easier to cancel out common terms before we do this. To see what’s common, I need to factor any parts that I can. I can use Difference of Squares to factor $x^2 - 4$ and GCF to factor $2x + 4$. This will help me see that $(x+2)$ is common and can be canceled. Also, the 3 can be canceled with the 3 in the 6 because they are common terms too.”

Tip:

This may seem like a lot of writing, but the benefits are worth it!

Prompts

Sometimes, you will receive prompts within a worked example, which directs your attention to a specific part of the example. These are mathematically important areas that sometimes people may miss. By self-explaining these areas in a way that’s meaningful to you, you increase your ability to understand and remember these topics on homework and tests.

For example:

Solve:

$$\begin{array}{lcl} 3x - 5y = 2 & \longrightarrow & 2(3x - 5y = 2) \\ & \longrightarrow & \\ 2x - 3y = 1 & & -3(2x - 3y = 1) \end{array}$$

Prompt: Why did the student multiply the first equation by 2 and the second equation by 3?

A possible self-explanation could be:

"In Knewton, I saw that if I want to cancel out one of the variables, I need to make the variables add up to 0. A number that goes into 2 and 3 is 6. By multiplying the first equation by 2 and the second equation by -3, we get 6x and -6x which adds up to 0.

Example: Below you will see a fictitious student's work. The two parts will be self-explained for you as an example.
Question: Evaluate the function when a) x = 1 and b) x = 3.

$$f(x) = \begin{pmatrix} \frac{x}{2} + 1, & x \leq 1 \\ \\ 3x + 2, & x > 1 \end{pmatrix}$$

Student's Work	Student's Self-Explanation:
a) $f(1) = \ \frac{1}{2} + 1 = \ 1\frac{1}{2} \ = \ \frac{3}{2}$	In class, we were told to look at the x and determine which part of the function we need to use. Because x = 1 is less than or equal to 1, you use the first part of the function. I plugged in 1 for x on the right side of the equation. Our teacher said to not write things as a mixed number unless it's a word problem, so I converted it to an improper fraction.
$b)\ \ f(3) = 3(3) + 2 = 9 + 2$ $= 11$	Because x = 3 is greater than 1, you use the second part of the function. I plugged in 3 in for x and then did the operations. You would begin by multiplying 3 times 3 since multiplication comes before addition in the order operations.

Your Turn

Self-explain the first and second step of the worked example in class today. Focus on why the step was performed, not restating how it was done.

Find the inverse of the following function: $f(x) = \sqrt{3x} - 2$

Student's Work	Student's Self-Explanation:
$y = \sqrt{3x} - 2$	
$x = \sqrt{3y} - 2$	
$x + 2 = \sqrt{3y} - 2 + 2$	
$(x+2)^2 = \left(\sqrt{3y}\right)^2$	
$(x+2)^2 = 3y$	
$\frac{(x+2)^2}{3} = \frac{3y}{3}$	
$\frac{(x+2)^2}{3} = y$	

$f^{-1}(x) = \dfrac{(x+2)^2}{3}$	

APPENDIX I

UNTRAINED SELF-EXPLANATION TRAINING ASSIGNMENT

Name: ______________________________

As your assignment for tomorrow, self-explain each of the steps in the worked example. Self-explanation is a useful strategy which can help you learn mathematics.

Bring the completed self-explanations to lab tomorrow for submission. You will be given feedback regarding the mathematics behind this topic.

Student's Work	**Student's Self-Explanation:**
$y = \sqrt{3x} - 2$	
$x = \sqrt{3y} - 2$	
$x + 2 = \sqrt{3y} - 2 + 2$	
$(x + 2)^2 = \left(\sqrt{3y}\right)^2$	
$(x + 2)^2 = 3y$	

$\frac{(x+2)^2}{3} = \frac{3y}{3}$	
$\frac{(x+2)^2}{3} = y$	
$f^{-1}(x) = \frac{(x+2)^2}{3}$	

APPENDIX J

PARTICIPANT INFORMED CONSENT FORM

Informed Consent to Participate in a Research Study

A Multi-Case Examination of Training when Self-Explanation is Combined with Worked Examples

Laura Stapleton, MS, Principal Investigator
John Baaki, PhD, Co-Investigator

Introduction

You are invited to be in a research study. Research studies are designed to gain scientific knowledge that may help other people in the future. You may or may not receive any benefit from being part of the study. Your participation is voluntary. Please take your time to make your decision and ask your research investigator or research staff to explain any words or information that you do not understand.

Why Is This Study Being Done?

The purpose of this study is to examine three aspects as the generative strategy is embedded within the course. The research questions are as follows:

This study will examine:

1. How did the training condition influence the instructional strategy of self-explanation when combined with worked examples?
2. What were the corequisite students' perceptions of self-explanation when combined with worked examples as an instructional strategy?
3. How have students' mathematical attitudes changed by learning a new instructional strategy?

Please initial your response to the statement below.
You agree to have the interview recorded. Yes: _____ No: _____

How Many People Will Take Part In The Study?

Approximately 25 people will take part in this study. A total of 48 subjects are the most that would be able to enter the study.

What Is Involved In This Research Study?

If you decide to participate, then you will join a study involving research of how training impacts the use of self-explanation of worked examples in a corequisite College Algebra course. The research will also examine how that strategy shapes your perceptions of your mathematical ability. You will complete a pre- and post- Mathematics Attitude Survey, create three artifacts, and provide a reflection based on your experiences with the instructional strategy and mathematical attitudes. You may be selected to participate in an interview to provide feedback. The interview should last no longer than 30 minutes to complete. The interview will be recorded. Once transcribed, the recordings will be deleted. You will have an opportunity to check the transcript for accuracy.

How Long Will You Be In The Study?

You will be in the study for about 9 weeks during the Spring semester. You can decide to stop participating at any time. If you decide to stop participating in the study, we encourage you to talk to the study investigator or study staff as soon as possible.

The study investigator may stop you from taking part in this study at any time if he/she believes it is in your best interest; if you do not follow the study rules; or if the study is stopped.

What Are The Risks Of The Study?

There are no known risks to those who take part in this study. There may also be other side effects that we cannot predict. You should tell the researchers if any of these risks bother or worry you.

Are There Benefits To Taking Part In The Study?

If you agree to take part in this study, you will receive 5 pts. extra credit on your lowest in-class exam. If you choose not to participate will have an opportunity to perform an alternative assignment to earn the extra credit. Other benefits are not as direct as we hope the information learned from this study will benefit other people in the future. The benefits of participating in this study may be to help future corequisite teachers and students with the inclusion of the generative learning strategy to create more mathematical meaning with the content.

What About Confidentiality?

We will do our best to make sure that your personal information is kept confidential. However, we cannot guarantee absolute confidentiality. Federal law says we must keep your study records private. Nevertheless, under unforeseen and rare circumstances, we may be required by law to allow certain agencies to view your records. Those agencies would include the Marshall University IRB, Office of Research Integrity (ORI) and the federal Office of Human Research Protection (OHRP). This is to make sure that we are protecting your rights and your safety. If we publish the information we learn from this study, you will not be identified by name or in any other way. All data and electronic files will be deleted upon completion of the study.

What Are The Costs Of Taking Part In This Study?

There are no costs to you for taking part in this study. All the study costs, including any study tests, supplies and procedures related directly to the study, will be paid for by the study.

Will You Be Paid For Participating?

You will receive no payment or other compensation for taking part in this study.

What Are Your Rights As A Research Study Participant?

Taking part in this study is voluntary. You may choose not to take part or you may leave the study at any time. Refusing to participate or leaving the study will not result in any penalty or loss of benefits to which you are entitled. If you decide to stop participating in the study, we encourage you to talk to the investigators or study staff first.

Whom Do You Call If You Have Questions Or Problems?

For questions about the study or in the event of a research-related injury, contact the study investigator, Laura Stapleton at 304-696-4334 or Dr. John Baaki at 757-683-5491. You should also call the investigator if you have a concern or complaint about the research.

For questions about your rights as a research participant, contact the Marshall University IRB#2 Chairman Dr. Christopher LeGrow or ORI at (304) 696-4303. You may also call this number if:

- You have concerns or complaints about the research.
- The research staff cannot be reached.
- You want to talk to someone other than the research staff.

You will be given a signed and dated copy of this consent form.

SIGNATURES

You agree to take part in this study and confirm that you are 18 years of age or older. You have had a chance to ask questions about being in this study and have had those questions answered. By signing this consent form you are not giving up any legal rights to which you are entitled.

____

Subject Name (Printed)

____ _______________

Subject Signature Date

____

Person Obtaining Consent (Printed)

____ _______________

Person Obtaining Consent Signature Date

VITA

Laura Leveridge Stapleton
Department of STEM & Professional Studies
Old Dominion University, Norfolk, VA

EDUCATIONAL BACKGROUND

- **Ph.D. Instructional Design & Technology,** Old Dominion University, degree expected May 2021.
- **Master of Science,** Marshall University, Huntington, WV, 1989.
- **Bachelor of Science in Mathematics and Physics**, Marshall University, Huntington, WV, 1984.

PROFESSIONAL EXPERIENCE

- Instructor, Marshall University, Huntington, WV, 1998 to Present
- Director, Tennessee State University, Academic Computing, Nashville, TN, 1994 to 1997

PUBLISHED BOOKS, MONOGRAPHS, BOOK REVIEWS, AND PAPERS

1. **Stapleton, L.** (2020). *Flipping the Mathematics Classroom*. In Walker, Z., Tan, D. & Ng Koh. (Eds.) Flipped Classrooms: An International Perspective with Diverse Learners. Singapore: Springer.
2. ***Stapleton, L.** & Stefaniak, J. (2019). Cognitive constructivism: Revisiting Jerome Bruner's influence on instructional design practices. TechTrends, 63, 4-5. https://doi.org/10.1007/s11528-018-0356-8
3. *Stefaniak, J. E., Baaki, J., Hoard, B. & **Stapleton. L.** (2018). The influence of perceived constraints during needs assessment on design conjecture. *Journal of Computing in Higher Education*, *30*, 55-71. https://doi.org/10.1007/s12528-018-9173-5. The *Journal of Computing in Higher Education* is indexed by Cabell's and uses blind peer review process. It has an impact factor of 1.44 and an acceptance rate of 10-12%. It is indexed by InCities Journal Citation reports and has a journal impact factor of 1.44. It is indexed by Ulrichs. It is published three times a year by Springer. Its launch date was 1989

PRESENTATIONS

- ***Stapleton, L**. & Baaki, J. *A Multi-Case Examination of Training of Self-Explanation when Combined with Worked Examples.* Paper presented at the 2020 Association for Educational Communication and Technology Convention, November 6, 2020.
- ***Stapleton, L.,** Epps, B., Redstone, A., & Baaki, J. *Using Selfies as an External Representation Tool to Increase Social Presence Within a Community of Inquiry*. Paper presented at the 2019 Association for Educational Communication and Technology Convention, Las Vegas, NV, October 22, 2019
- **Stapleton, L**. *Using Instructional Strategies and Adaptive Software in a Corequisite College Algebra Pilot*. Paper presented at the 2019 Association for Educational Communication and Technology Convention, Las Vegas, NV, October 23, 2019