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Motivation in Online Course Design: Action Research Using a Self-Determination Theory-Based Mathematics Unit to Improve Students' Autonomy, Competence, and Relatedness

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MOTIVATION IN ONLINE COURSE DESIGN: ACTION RESEARCH USING A SELF-DETERMINATION THEORY-BASED MATHEMATICS UNIT TO IMPROVE STUDENTS' AUTONOMY, COMPETENCE, AND RELATEDNESS

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DEDICATION

This dissertation is dedicated to my husband, Jonathan, and my daughter, Lily. Thank you for giving me countless days and hours to achieve this work. I could not have completed this without your support and encouragement.

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ABSTRACT

Strong mathematics achievement is lacking in the United States, with motivation waning especially among mathematics and online students. Online mathematics students, in particular, struggle with self-regulation and self-efficacy (Kim, 2012; Sun & Rueda, 2012). Ryan and Deci (2017), in their well-established and empirical self-determination theory, contended that satisfying the psychological needs of autonomy (involving self-regulation), competence (involving self-efficacy), and relatedness (involving a sense of belonging) creates a suitable environment for integrated extrinsic and intrinsic motivation to thrive. The purpose of this action research was to create and implement a self-determination theory-based online unit on factoring polynomials for mathematics students at the school in this study to improve students' motivation levels. The research questions aimed to identify changes in the levels of autonomy, competence, and relatedness of the participants as well as the effect on the factoring polynomials final assessment scores.

This action research study utilized a convergent mixed methods design. The Algebra 2 course provided a purposive sample (n = 50) for this online school in the northeastern United States. The intervention, a factoring polynomials unit built with supports for students' autonomy, competence, and relatedness needs, replaced a unit in the Algebra 2 course. A pretest-posttest motivation questionnaire, a pretest-posttest content knowledge exam, and six student interviews were used as data collection methods. Quantitative data were analyzed with descriptive and inferential statistics.

Inductive analysis was used to analyze the qualitative data and identify emergent themes. The results indicated a significant increase in competence after completing the intervention unit in both the quantitative and qualitative data. While no significant increase in autonomy or relatedness were evident in the quantitative results, the qualitative findings showed some support for improved autonomy and strong support for improved relatedness.

The results revealed that the design components for competence in the intervention unit supported participants' perceptions of self-efficacy with optimal challenge. Specifically, check buttons with correctness and informative feedback, prior knowledge information with check for understanding questions, and chunking the content with appropriate scaffolding throughout the lessons provided an environment for competence to thrive. Recommendations, implications, and limitations of the study are given.

TABLE OF CONTENTS

Dedication iii

Acknowledgements iv

Abstract v

List of Tables ix

List of Figures xi

Chapter 1 Introduction 1

National Context 1

Local Context 3

Statement of the Problem 5

Researcher Subjectivities and Positionality 7

Definition of Terms 9

Chapter 2 Literature Review 11

Motivation in Education 13

Self-Determination Theory 23

Gagne's Nine Events of Instruction 38

Chapter Summary 40

Chapter 3 Method 43

Research Design 43

Setting 45

Participants 49

Intervention 51
Data Collection Methods 66
Procedures and Timeline 74
Rigor and Trustworthiness 76
Plan for Sharing and Communicating Findings 79
Chapter 4 Analysis and Findings 81
Quantitative Findings 81
Qualitative Findings and Interpretations 85
Chapter Summary 159
Chapter 5 Discussion, Implications, and Limitations 160
Discussion 160
Implications 180
Limitations 195
Closing Thoughts 197
References 199
Appendix A: Consent Form 220
Appendix B: Samples of Algebra 2 General Lessons 223
Appendix C: Motivation Questionnaire 226
Appendix D: Content Knowledge Assessment 228
Appendix E: Interview Protocol 231
Appendix F: Interview Script and Questions 233

LIST OF TABLES

Table 3.1 Use of Gagne's Nine Events in Algebra 2 Lessons 47

Table 3.2 Demographics for Interviewees 50

Table 3.3 Intervention Objectives and Standards Alignment 54

Table 3.4 Research Questions and Data Sources Alignment.....67

Table 3.5 BPNSFS Category and Item Alignment 69

Table 3.6 Unit Objectives and Assessment Items Alignment.....70

Table 3.7 Research Question 1 Constructs and Interview Questions Alignment 73

Table 3.8 Timeline of Research Procedures 74

Table 4.1 Descriptive Statistics for the Motivation Questionnaire.....83

Table 4.2 Descriptive Statistics for the Content Knowledge Test 84

Table 4.3 Number of Codes per Classification and Subtopic 91

Table 4.4 Number of Codes for Themes and Related Categories.....95

Table 4.5 Summary of Qualitative Findings.....100

Table 4.6 Number of Categories and Codes for Themes.....102

Table 4.7 Relationship of Theme 1 Categories and SDT Needs 103

Table 4.8 Codes and Classifications for Prior Knowledge Increased Confidence 112

Table 4.9 Distribution of Classifications for Options Improved Motivation.....117

Table 4.10 Theme Two Categories and Number of Codes.....126

Table 4.11 Codes and Classifications for Grades Increased Motivation 140

Table 4.12 Theme Three Categories and Number of Codes.....143

Table 5.1 Interview Categories and Codes Aligned with SDT Needs.....162

Table 5.2 Autonomy Design Components and Associated Interview Categories.....164

Table 5.3 Competence Design Components and Associated Interview Categories.....170

Table 5.4 Relatedness Design Components and Associated Interview Categories.....177

Table A.1 Original Motivation Questionnaire Items and Changes.....226

LIST OF FIGURES

Figure 3.1 SDT Implementation Strategies and Intervention Design Components.....55

Figure 3.2 Sample of the Opening Page of an Intervention Lesson 57

Figure 3.3 Sample of the Vocabulary Section of an Intervention Lesson 58

Figure 3.4 Sample of Check Button Feedback in an Intervention Lesson.....59

Figure 3.5 Sample of an Optional Remediation Button in an Intervention Lesson.....60

Figure 3.6 Sample of an Optional Enrichment Question in an Intervention Lesson 61

Figure 3.7 Sample of a Prior Knowledge Section in an Intervention Lesson.....62

Figure 3.8 Sample of an Example in an Intervention Lesson 63

Figure 4.1 Sample of First Round of Initial Codes.....87

Figure 4.2 Sample of Second Round of Initial Codes 88

Figure 4.3 Sample of In Vivo Codes 90

Figure 4.4 Sample of Initial Codes, Refinement 1, Classifications, and Refinement 2.....92

Figure 4.5 Sample of Initial Codes, Refinements, Classifications, and Categories.....94

Figure 4.6 Sample of Forum Posts Related to Learning Support 146

Figure 4.7 Sample Forum Post of a Participant Presenting Content.....148

Figure 4.8 Sample Interactions of Participants in Forum After Content Explanation.....149

Figure 4.9 Sample of Common Struggles with Negatives in Forums 154

Figure 4.10 Sample of Common Struggles with Restrictions in Forums 155

Figure 5.1 Means and Standard Deviations of Composite Autonomy Scores.....164

Figure 5.2 Means and Standard Deviations of Composite Relatedness Scores.....176

Figure 5.3 Sample of Check Button Used in New Course 187

Figure 5.4 Sample of Prior Knowledge Used in New Course 189

Figure 5.5 Sample of Lesson Organization Used in New Course 191

Figure 5.6 Sample of Chunking and Scaffolding Used in New Course 192

Figure A.1 Sample Introduction Section of General Algebra 2 Lesson 223

Figure A.2 Sample Explanation Section of General Algebra 2 Lesson.....224

Figure A.3 Sample Example Section of General Algebra 2 Lesson.....225

Figure A.4 Sample Summary and Tabs Section of General Algebra 2 Lesson.....225

CHAPTER 1

INTRODUCTION

National Context

Mathematics achievement scores in the United States are lower than achievement scores in other advanced nations (Desilver, 2017). For example, "25 percent of American students did not reach the PISA baseline for level 2 in math proficiency…only about 10 percent of students in countries such as Canada, Korea, Shanghai, and Singapore failed to reach that benchmark" (Bidwell, 2013, para. 7). Even with the recent creation of the Common Core State Standards for Mathematics (CCSSM) with the purpose of improving mathematics education in the United States, the need is still great to improve mathematics teaching and learning (Dossey, McCrone, & Halvorsen, 2016).

This need is not only felt within the school system, but also in the lives of the students after they complete schooling and in our country's work force. In the United States, "the fastest-growing careers today are centered on math-related analytics, big data and all sorts of automation, including robotics" (Aldridge, 2017, para. 6). Improving mathematics competency in the United States education system will help better prepare students for successful careers in the high-paying and high-need areas of mathematics and engineering, and is essential for our improvement as a nation (Casey, 2012; Israel, 2017; Smith, 2016). According to Liou (2010), two "influential reports… stated that the well-being of America largely depends on mathematics and science" (p. 1).

Across the nation, students consistently score below proficient in mathematics (McFarland et al., 2018). The northeastern state where this study took place is representative of these results, ranking in the middle range for mathematics in the United States ("Pre-K - 12 rankings," 2019). This state has adopted its own version of the national CCSSM aimed at integrating the national standards with current practices and assessments in the state curriculum ("Mathematics," 2019). Even with this integration, the state still hovers at the middle of the pack for mathematics achievement of eighth grade students entering high school ("Mathematics & Reading Assessments," 2015).

The need for improving mathematics achievement is evident nationally and in this state, but the need is even greater in the subset of online education with its current rapid growth (Baturay & Yukselturk, 2015; de Barba, Kennedy, & Ainley, 2016). A key component for improving mathematics ability is motivation (Liou, 2010), but it is especially important in the online environment (Huang, Backman, Backman, Mcguire, & Moore, 2019; Xie & Huang, 2014). Issues relating to motivation, such as self-regulation and persistence, self-efficacy and goal-setting, and interpersonal relationships, have been recognized as difficult hurdles to overcome in the online environment (Evans, Baker, & Dee, 2016; Higashi, Schunn, & Flot, 2017; Martin, Kelly, & Terry, 2018).

Self-determination theory (SDT) is a widely known, empirical, practical, and relied upon theory of motivation (Huang et al., 2019; Ryan & Deci, 2017). This theory can be efficaciously applied to the online environment (Huang et al., 2019; Martens, Gulikers, & Bastiaens, 2004; Proulx, Romero, & Arnab, 2017; Tamborini, Bowman, Eden, Grizzard, & Organ, 2010). Self-determination theory is comprised of three psychological needs: autonomy, competence, and relatedness (Ryan & Deci, 2017).

When supports for these three needs are prevalent and undermining factors are limited, autonomous extrinsic and intrinsic motivation increase (Huang et al., 2019; Ryan & Deci, 2017). This increase in motivation can lead to an improvement in overall student grades and performance (Fredricks et al., 2016; Martin et al., 2018).

Local Context

The research was conducted at Peacock Cyber School (a pseudonym). References citing the school have been removed to protect the identity of the school. Peacock Cyber School is a fully online public-school in the northeastern United States serving students in Grades 6-12. There were about 2,600 students enrolled in the school at the time of the study. Students complete their schoolwork from home, while teachers work together in an office for most of their time. Students and teachers collaborate through Jigsaw, e-mail, and phone. In Jigsaw, teachers hold classes with many students at a time. Teachers also have virtual office hours where students can log into Jigsaw and receive one-on-one help. The courses are provided through the learning management system, Moodle. Students are encouraged to attend synchronous class times, called live classes, but these are not required. In general, the school runs asynchronously with quarterly deadlines students must meet.

> Peacock Cyber School is a top online school in its state. Littlefield (2017) notes:
>
> Using [middle school state test] scores, [Algebra 1 state test] scores, PSAT participation, SAT scores and other academic performance measures, [Peacock Cyber School] regularly outperforms other [state] cyber schools. [Peacock Cyber School] holds the highest score of any cyber charter on the College Ready Benchmark, which includes the SAT and ACT scores of 12th-grade students.

> [Peacock Cyber School] has also been ranked in the top 5 to 10 percent of high schools in [the state] for SAT scores. (para. 2)

Although Peacock Cyber School ranks at the top among online public schools in the state, there is still much room for improvement.

At Peacock Cyber School, mathematics achievement and improvement are continual topics of discussion, especially among the mathematics teachers. Anecdotal evidence suggests that teachers are concerned with the level of interaction students have with the lessons. Based on discussions teachers have had with students and Moodle data logs, teachers find that students hurry through or even skip lessons in order to get to graded assignments. Some teachers believe this is due to the assignments being worth points, which affects the students' overall grades, whereas lesson completion does not directly affect their overall grades. In informal discussions with some students, the students felt that earning points through quizzes and assignments was the most important part of the course to increase their grade. Lessons can be time consuming and are not worth points, so tend to be used more as reference material than as something the student works through from start to finish.

In response to this problem at Peacock Cyber School, teachers have tried various interventions to help improve the interaction of students with lessons. Teachers have tried explaining the importance of the lessons in the live classes and walking students through some of the lessons to show how to navigate them. Teachers also point to the lessons when students ask questions about how to do a certain topic or skill. Additionally, teachers often address questions in Jigsaw during their virtual office hours by directing students to the appropriate lesson. In this way, students become more comfortable

working with the lessons and finding needed information. If students struggle with this, teachers will have students share their screen so they can look at and talk about the lessons together.

In addition to the teacher interventions, developers and designers have tried more systematic interventions to address the problem of students not spending the necessary time in lessons at Peacock Cyber School. Developers and designers have made the lessons more user-friendly, easier to navigate, and easier to understand. For example, they have created clear and consistent templates for each lesson, which include a section for key information from the lesson. They have also tried improving student interaction with the lessons by implementing interactive components in some lessons, such as HTML5 Package (H5P) interactive activities. These questions are embedded within the lessons and provide immediate feedback for students, but do not affect their grade. These questions may appear in the form of drag and drop, fill in the blank, sorting images, finding a hotspot, or other question types.

Even with the continuous improvements to the lessons from teachers, developers, and designers, however, teachers still find that students are not motivated to spend enough time in the lessons to gain a solid grasp of the material.

Statement of the Problem

A lack of motivation to complete online lessons for mathematics students at Peacock Cyber School has resulted in low grades on online assessments following the lessons.

A student's level of motivation for interacting in an online course is related to the student's achievement and a student's grade can even be predicted by the level of

interaction with the online course (de Barba et al., 2016; Evans et al., 2016; Li & Baker, 2018). Based on discussions with mathematics teachers at Peacock Cyber School, this research is echoed in their experiences with mathematics students as follows: when a student is sufficiently motivated to interact with an online lesson, then he or she performs better on the assignments associated with the content of the lesson. Although many interventions have been tried in the online lessons at Peacock Cyber School, as discussed above, the use of theories of motivation in constructing a lesson had not been implemented before this study. Motivation has been shown to increase when implementing online content that facilitates the psychological needs of self-determination theory: autonomy, competence, and relatedness (Huang et al., 2019; Martin et al., 2018; Proulx et al., 2017; Ryan & Deci, 2017; Tan, 2018).

Purpose Statement

The purpose of this action research was to create and implement a self-determination theory-based online unit on factoring polynomials for mathematics students at Peacock Cyber School in order to improve students' motivation levels.

Research Questions

1. How does the implementation of a self-determination theory-based unit on factoring polynomials in an online mathematics course affect students' motivation at Peacock Cyber School?
    a. How are students' feelings of autonomy affected?
    b. How are students' feelings of competence affected?
    c. How are students' feelings of relatedness affected?

2. To what extent does the implementation of a self-determination theory-based online unit on factoring polynomials in an online mathematics course affect students' mathematics content knowledge at Peacock Cyber School?

Researcher Subjectivities and Positionality

I believe each person is capable, at some level, of participating in, understanding, and completing educational content that is presented in an appropriate way for that person. My ontological belief that only one reality exists is complemented by the pragmatic paradigm, which indicates that humans can have various approaches to or interpretations of the truth (Shook & Aboulafia, 2013). This belief strengthens my research because if one method does not work, it incites me to search for different well-researched methods, technologies, approaches, or pedagogies to reach each student.

The ontological belief that things exist and can be studied and interpreted (Thompson, Diamond, McWilliam, Snyder, & Snyder, 2005) aids my pragmatic approach to research. In this approach, practical problem solving takes center stage and my focus depends on the following pragmatic characteristics:

> Whether something is useful, whether it engages our interests, whether it helps us cope in the appropriate circumstances, whether it helps us make better sense of the world around us, and, more generally, whether…it fits in with our already secured fund of beliefs and experience. (Malachowski, 2014, p. 6)

Most of all, the pragmatic approach to the action research model employed in this study helped me work towards a solution in my sphere of influence in the most practical way possible (Creswell & Creswell, 2018).

The positionality that best described my role in this research study is the *insider in collaboration with other insiders* location on the continuum by Herr and Anderson (2005). As an employee of Peacock Cyber School, I am an insider and worked to create equitable relationships with those in my sphere of influence involved in my study. This included the following groups at Peacock Cyber School: students, mathematics teachers, instructional systems design team, and administrators. Each of those groups were involved collaboratively in the study and are insiders within Peacock Cyber School.

A collaborative and equitable positionality was beneficial to the research; however, clear boundaries were necessary during the research study. For example, other stakeholders such as my supervisor, the instructional systems design team, or the teachers involved, may have had different ideas about how to approach my research or solutions to the problem at hand. Although their ideas were carefully considered and applied to the research study accordingly, the integrity of the study was maintained.

It should be noted that in light of my personal experiences and beliefs, I cannot understand where every student is coming from. Where I hold achievement in high esteem and so am internally motivated to succeed, students may have other goals and motivations in life; where I am naturally curious about mathematics and problem solving, students may have different interests; where I cannot leave a problem until I figure it out, students may be better at compartmentalizing. The need is great to put myself in others' shoes during the research process, yet this may not always be fully possible. This reality was considered during the research, especially in conducting and analyzing the interviews, in hopes of avoiding subjectivities concerning motivation, curiosity, or determination that could have clouded the results of my research.

Definition of Terms

Assessment: A graded test that has a variety of questions and question types, graded for correctness, and counting towards the final grade in a course.

Autonomous Extrinsic Motivation: The extent to which participants internalize external motivational factors and attribute value to specific learning activities (Deci & Ryan, 1985).

Autonomy: The level at which participants rate their feelings of self-regulation, freedom, choice, volition, and enjoyment within the online lessons and activities.

Basic Psychological Needs Mini-Theory: A person's well-being as measured by the satisfaction or frustration of the three basic psychological needs: autonomy, competence, and relatedness (Ryan & Deci, 2017).

Check for Understanding Question: A question for a learner to attempt after content is presented for the first time related to the specific content that was just presented.

Competence: The level at which participants rate their feelings of self-efficacy and mastery of appropriate challenges within the online lessons and activities.

Extrinsic Motivation: The extent to which participants are affected by external influences, outcomes, punishments, or rewards.

Forum: An online space for students enrolled in a specific course to interact with each other and their teacher. Text, images, and video are permitted in the forums with text being the most common.

Intrinsic Motivation: The extent to which participants are incited to act based on their curiosity, interest, and self-determination.

Lesson: Subject-specific content presented to a learner for the first time based on learning objectives. In addition to the instructional material, lessons may include check for understanding questions and/or mixed practice questions.

Mixed Practice Questions: Questions based on the objectives of the previous lesson(s) in which the objective-specific content varies from question to question.

Motivation: In this study, motivation is defined in reference to the self-determination theory of motivation. Motivation is enhanced by the satisfaction of the three psychological needs of autonomy, competence, and relatedness and is undermined by the frustration of the three needs. This theory is discussed in detail in Chapter 2. Motivation will be measured by the levels of autonomy, competence, and relatedness of the participants.

Online Lesson/Assessment: Online content or an online test presented and completed asynchronously, on a computer, and through the learning management system, Moodle.

Relatedness: The level at which participants rate their feelings of positive social connectedness and acceptance within the online lessons and activities.

CHAPTER 2

LITERATURE REVIEW

The purpose of this action research was to create and implement a self-determination theory-based online unit on factoring polynomials for mathematics students at Peacock Cyber School in order to improve students' motivation levels. This literature review focuses on the key variables associated with the following research questions: (1) How does the implementation of a self-determination theory-based unit on factoring polynomials in an online mathematics course affect students' motivation at Peacock Cyber School? and (2) To what extent does the implementation of a self-determination theory-based online unit on factoring polynomials in an online mathematics course affect students' mathematics content knowledge at Peacock Cyber School?

Strategies to Locate Literature

Scholarly strategies aided in locating relevant literature, including the use of specific databases, keyword searches with explicit modifiers, and reference mining.

Databases. Multiple databases were used for searches for varying purposes. The *Psychology and Behavioral Sciences Collection* helped to identify key articles and authors concerning theories behind motivation and differing views on motivation. For example, searches for extrinsic and intrinsic motivation as well as self-determination theory were utilized through this database. The *Academic Search Complete*, *Education Source*, and *ERIC* databases were used for identifying many of the prior research studies

in the areas of motivation, self-determination theory, and online education, including the challenges, benefits, and lesson design of online learning. The University of South Carolina's *Find It* search tool was used as a broader search engine. This tool helped to identify more articles in the areas listed above as well as related book chapters and seminal works by specific authors. For example, general searches using key terms related to the variables in the study were used in this database as well as searches for Vygotsky, Ryan, and Deci. Finally, *Google Scholar* was used to find book chapters and locate articles by specific authors, such as Lepper, Malone, White, Vygotsky, Ryan, Deci, and Bandura.

Keyword searches. When conducting the searches using the databases described above, intentional keyword combinations and parameters were used. Samples of search terms used include self-determination theory, scaffolding, outcomes, challenges, online education, mathematics, autonomy, relatedness, competence, self-efficacy, intrinsic motivation, extrinsic motivation, motivation, engagement, instructional design, accessibility, action research, and technology. The common parameters used for these searches included recent dates, generally within the last five to seven years, English language, peer-reviewed, full-text, and academic journals. These parameters did not apply to seminal works by specific authors. The results were analyzed and sorted for those most relevant to the present study. Results that had a combination of two or more of the following characteristics were deemed to be the most applicable: mathematics, online learning, the use of self-determination theory in lesson design, and Grades 6-12.

Reference mining. The references sections of peer-reviewed articles were mined for additional sources, especially if an article was strongly related to the present study.

Many results yielded from this mining were related studies with a similar theoretical base and intervention, as well as research about online education. For example, studies using self-determination theory to affect motivation levels of students as well as challenges to online education in general were found using this method. Reference mining helped to ensure that related literature and studies were not missed using keyword and database searches.

This literature review is organized according to the following three sections: (a) a broad overview of motivation including various theories of motivation, the importance of motivation, and challenges to motivation, (b) the self-determination theory of motivation including its core components of autonomy, competence, relatedness, the continuum of motivation, and the mini-theories of self-determination theory, and (c) Gagne's nine events of instruction for use as a basic online lesson structure. These sections are meant to provide a comprehensive explanation for the background of, reasoning for, and strategies used in the implementation of the intervention in this study.

Motivation in Education

This section will include the following: (a) a definition of motivation, (b) a brief description of various theories of motivation, (c) extrinsic and intrinsic motivation (d) the importance of motivation in education, and (e) the challenges to motivation in education.

Definition of Motivation

The underlying theme in definitions of motivation is the exploration of catalysts for action or behavior. Humans are driven to interact with their environment because of feelings of satisfaction that their "behavior has an exploratory, varying, experimental character and produces changes in the stimulus field" (White, 1959, p. 329). In general

terms, motivation is "what moves people to action" (Ryan & Deci, 2017, p. 13) and "refers to those things that explain the direction, magnitude, and persistence of behaviors" (Keller, 2016, p. 4). The connections between various catalysts of action, such as self-regulation, expectations, satisfaction, persistence, self-efficacy, and environmental factors are elucidated by various theories of motivation.

Theories of Motivation

Detailed theories have come about to describe and apply motivation. Three of the more prominent of these include (a) expectancy value theory, (b) social cognitive theory, and (c) self-determination theory. Although expectancy value theory and social cognitive theory are major theories of motivation, self-determination theory was selected as the basis of this work due to the specific challenges faced in the online educational environment and specific features of self-determination theory, both reasons of which are elaborated upon later in this chapter.

Expectancy value theory. The modern form of this theory, detailed by Wigfield and Eccles (1992), has its roots in Murray's (1938) concept of human needs, and especially Atkinson's (1957) focus on the need for achievement (Wentzel & Wigfield, 2009). Expectancy value theory is based on two internal components, expectations and value attribution. A person's expectations about how he or she will perform, whether confidence or fear, affects a person's intrinsic motivation and outcomes (Hardré, 2003). In combination with these expectations, motivation and achievement are also determined by the amount of subjective value a person places on succeeding in the task (Wigfield, 1994).

Expectations and value are most affected by beliefs of self-efficacy, achievement goals, existing schemata, and intrinsic interest (Park, 2018; Wigfield, 1994). For example, Higashi, Schunn, and Flot (2017) investigated underlying motivations of 286 participants in a free online robotics course using a correlational study and Joo, Lim, and Kim (2013) investigated the predictors of learning outcomes among 897 online university students in a quantitative study. These studies found that students' prior schemata, goals, and interest predicted their persistence and achievement in online courses (Higashi, Schunn, & Flot, 2017; Joo, Lim, & Kim, 2013).

Social cognitive theory. Bandura (1989) postulated that a person's motivation to act is based on a framework of "triadic reciprocal causation" (p. 1175). This framework is comprised of personal factors, such as emotions, feelings of competence, and thought-processes; behavioral factors, such as choice, effort, and achievement; and environmental factors, such as social modeling, feedback, and rewards (Bandura, 1989; Wentzel & Wigfield, 2009).

Of prime importance among the personal factors is self-efficacy. Bandura (1989) defined *self-efficacy* as "people's beliefs about their capabilities to exercise control over events that affect their lives" (p. 1175). A high level of self-efficacy leads to improved internal thoughts and the setting of more challenging goals, which improves motivation (Bandura, 1989). Self-efficacy promotes self-regulation and is affected by the outcomes of past actions (Park, 2018; Wentzel & Wigfield, 2009). The idea of self-efficacy is similar to expectancy in expectancy value theory (Park, 2018). The use of social cognitive theory is thought to improve motivation, persistence, and achievement (Schunk & DiBenedetto, 2020). Yantraprakorn, Darasawang, and Wiriyakarun (2018) conducted

an in-depth study on self-efficacy in 6 online learners and found that a lack of self-efficacy and feedback resulted in decreased persistence. Self-efficacy is a key factor of social cognitive theory in achieving improved motivation.

Self-determination theory. Self-determination theory (SDT) is a well-recognized, empirically-based, practical, organismic theory of motivation (Deci & Ryan, 1985; Huang et al., 2019; Ryan & Deci, 2017). Its originators, (Deci & Ryan, 1985), recognized learners as taking an active role in their environment. Psychological needs' fulfillment and the satisfaction or enjoyment that comes from meeting those needs are the underlying catalysts for motivation. Among the three needs of autonomy, competence, and relatedness, competence is similar to self-efficacy in social cognitive theory and the expectations in expectancy value theory.

Of prime importance in self-determination theory are the social factors that support or undermine the three psychological needs (Ryan & Deci, 2017). In this theory, motivation varies not only in strength, but also in orientation, as described by a continuum of motivation (Park, 2018; Ryan & Deci, 2017, 2020). A full description of self-determination theory and its tenets is provided in the Self-Determination Theory section below.

Extrinsic and Intrinsic Motivation

Skinner (1953) asserted through his description of operant conditioning that external reinforcement, such as rewards, is the driving motivator behind behavioral change. Mechanistic theories of motivation tend to arise from this approach, where the learner takes a passive role and acts based on physiological needs or environmental factors (Deci & Ryan, 1985). On the other hand, White (1959) contended that humans

have an internal need to efficaciously interact with their environment. Organismic theories of motivation tend to arise from this approach, where the learner takes an active role and is responsible for willfully generating his or her own behavior (Deci & Ryan, 1985). Through these lenses, motivation in education has traditionally been separated into two distinct categories: extrinsic motivation and intrinsic motivation.

Extrinsic motivation. *Extrinsic motivation* can be defined by the extent to which external reinforcement, such as outcomes, punishments, or rewards, incite a person to act (Lambert, 2017; Lee & Martin, 2017; Leong, Tan, Lau, & Yong, 2018; Ryan & Deci, 2000; Wilkie & Sullivan, 2018). Extrinsic motivation is based on external rewards and environmental factors (Lambert, 2017; Ryan & Deci, 2000; Wilkie & Sullivan, 2018). Setting goals that deal with performance outcomes and achievement contribute to extrinsic motivation (Lee & Martin, 2017; Leong et al., 2018; Wilkie & Sullivan, 2018).

Skinner (1953) distinguished between positive reinforcement that comes from outside of the person versus that which comes from inside of the person. Interval reinforcement is provided after a certain amount of time has passed, which represents an external locus of control (Skinner, 1953). Interval reinforcement may occur after a fixed or variable amount of time has passed (Kapp, 2012; Skinner, 1953). Ratio reinforcement, on the other hand, is provided when the person completes the desired behavior after a certain number of times, giving the control back to the person regarding when he or she will receive the reward (Skinner, 1953). Similar to interval reinforcement, ratio reinforcement may occur after a fixed or variable number of successful completions (Kapp, 2012; Skinner, 1953). The *quantity* of output may increase due to extrinsic motivation, depending on the type of reinforcement schedule used, while intrinsic

motivation has a greater effect on the *quality* of output (Kapp, 2012; Wijsman, Saab, Schuitema, van Driel, & Westenberg, 2019).

Intrinsic motivation. *Intrinsic motivation* can be defined as the extent to which one's curiosity, interest, and self-determination incite a person to act (Deci & Ryan, 1985; Lambert, 2017; Lee & Martin, 2017; Ryan & Deci, 2000; Samruayruen, Enriquez, Natakuatoong, & Samruayruen, 2013). Intrinsic motivation is based on one's inner feelings, curiosity, enjoyment, and interest (Lambert, 2017; Lee & Martin, 2017; Ryan & Deci, 2000; Wilkie & Sullivan, 2018). Wilkie and Sullivan's (2018) qualitative study among 3,562 Australian middle school mathematics participants emphasized the importance of students' internal interest on motivation and engagement. Contextualization, personalization, and choice have been shown to have a strong positive effect on intrinsic motivation, resulting in an increase in the amount students learn and their felt competence (Cordova & Lepper, 1996; Malone, 1981). Self-efficacy, self-regulation, and self-determination are key indicators of intrinsic motivation (Leong et al., 2018; Ryan & Deci, 2000; Samruayruen et al., 2013).

Although the value of intrinsic motivation in education is widely accepted, the role of extrinsic motivation in combination with intrinsic motivation is more ambiguous. For example, in a study of self-regulation among 64 online university students, Cho and Shen (2013) found that intrinsic motivation had a positive effect on self-efficacy and all types of self-regulation in the study, whereas extrinsic motivation only positively affected self-efficacy. In contrast, Lambert (2017) conducted a quasi-experiment with 139 university students concerning self-regulation and found that students achieved similarly whether they were extrinsically or intrinsically motivated. Different than intrinsic

motivation playing a more valuable role (Cho & Shen, 2013) and intrinsic and extrinsic motivation playing equal roles (Lambert, 2017), Lee and Martin (2017) found that extrinsic motivation was the underlying catalyst for action in a cross-sectional study among 86 online graduate students. Although extrinsic motivation may be more prevalent among some groups (Lee & Martin, 2017) and play a postive role in achievement alongside intrinsic motivation (Cho & Shen, 2013), intrinsic motivation provides more self-efficacious and self-regulatory value (Lambert, 2017). It seems likely a combination of the types of motivation may be best.

The Importance of Motivation in Education

The history and theories of motivation in education seem to have one idea in common: motivation is a key component in positively affecting a student's experience, whether that be behaviorally, emotionally, cognitively, or environmentally. These positive effects have been characterized in many ways, including enhanced achievement and learning outcomes and improved retention and persistence.

Achievement and learning outcomes. The importance of motivation in education is often recognized through enhanced achievement and learning. For example, in a study of 24,768 eighth grade science students from the United States, England, Malaysia, and Singapore, Leong et al. (2018) found that increased motivation resulted in increased achievement. Furthermore, a quantitative analysis of a large educational database revealed that self-efficacy, a key element of motivation, is the most important predictor in mathematics achievement in students (Liou, 2010). Froiland, Davidson, and Worrell (2016) established that supporting student autonomy, another key element of motivation, significantly predicted student achievement in a study of 110 ninth grade

mathematics students. In contrast, Chen and Jang (2010) found that self-determination did not predict achievement in their study of 262 learners, however, this study had an abnormally high mean in final grades, which may have affected the prediction of achievement. Nevertheless, the importance of self-efficacy and self-determination in enhancing achievement have continued to be critical issues in analyses and frameworks of motivation (Margolis & McCabe, 2004; Schunk & DiBenedetto, 2020).

The positive relationship between motivation and achievement has been echoed in the online educational environment in multiple research studies. For example, in a study of 148 online English language students, Baturay and Yukselturk (2015) found a positive correlation between students' achievement scores and the motivational components of students' preferences and expectations. De Barba et al. (2016) also studied the online environment with 862 participants in a macroeconomics course and found that participation and motivation were strong predictors of learning outcomes. More specifically, Hsu, Wang, and Levesque-Bristol (2019) investigated the effects of applying self-determination theory in multiple online courses among 330 participants and established that increased motivation led to improved achievement and knowledge transfer. Similarly, Kim, Park, Cozart, and Lee (2015) found that self-efficacy and effort regulation separated high and low performers in a study of 100 online mathematics high school students. This finding may be supported by Yantraprakorn et al. (2018) who, as previously mentioned, determined that a lack of self-efficacy resulted in decreased achievement. As shown by these studies, the importance of motivation in learning and achievement has been widely accepted in education in general as well as in the online environment.

Persistence and retention. Persistence and retention rates have been cited as an issue in online courses. For example, Evans, Baker, and Dee (2016) conducted a large study of 44 college-level online courses to analyze the low persistence rates and found that the rates drop rapidly in the beginning of an online course. In addressing this challenge of online courses, heightened motivation in learners has been linked with improved persistence and retention. For example, in a study of self-determination theory applied to an online course of 1,007 students, Martin, Kelly, and Terry (2018) found that the application of motivational principles increased persistence and the rate of course completion. Similarly, in a mixed methods study of 965 online students enrolled in highly rated courses, Hew (2016) found that increased retention and engagement of the students was related to the core motivational constructs of autonomy, competence, and relatedness.

The development of the ARCS-V model of motivation further supports the link between persistence and motivation (Keller, 2010, 2016). In Keller's (2010) attention, relevance, confidence, and satisfaction (ARCS) model of motivation, Keller found that a key component of motivation, persistence, was not able to be accounted for. Keller (2016) added a fifth component to this widely used model, volition, making the new ARCS-V model that can now account for students' self-regulation or persistence.

From the positive effects of motivation found in these studies, it may be concluded that supporting and improving motivation is likely to bolster achievement, learning outcomes, persistence, and retention.

Challenges of Motivation for the Intervention

In considering the application of types of motivation and motivational theories to the intervention in this study, based on the importance of motivation in education, it was also necessary to examine the challenges of motivation that may have arisen during the intervention. The intervention took place in a fully online environment in the area of mathematics education. With this context in mind, two main categories arose in analyzing challenges of motivation in online settings and mathematics students, namely, self-regulatory challenges and self-efficacious challenges.

Self-regulatory challenges. A heightened focus on external rewards and punishments, in general, is likely to have a negative effect on autonomous regulation (Ryan & Deci, 2020). For example, using eight in-depth interviews as part of a large (n = 5,392) explanatory sequential mixed methods study of mathematics students, Bourgeois and Boberg (2016) found that motivation decreased from Grades 3-8, caused by a focus on grades as an extrinsically motivating factor, removing autonomy from students. Internal psychological factors, such as discounting and devaluing, can also negatively affect motivation in mathematics students (Rinfret et al., 2014). Sun and Rueda (2012) found that this lack of self-regulation, when applied to 203 online students, may result in further decreased motivation due to a lack of direct instructor encouragement and social interaction. In an online mathematics course, students may already have decreased self-regulation because of the subject matter (Bourgeois & Boberg, 2016; Rinfret et al., 2014), and this may be furthered due to the isolated environment (Sun & Rueda, 2012).

Self-efficacious challenges. In combination with these self-regulatory challenges, students in online mathematics courses may have negative academic emotions related to

self-efficacy (Kim, 2012). Two studies of motivation in middle school mathematics students found that a lack of clear expectations, support, confidence, and interesting challenge can dampen feelings of competence (Durksen et al., 2017; Wilkie & Sullivan, 2018). Inappropriate goal setting and insufficient or unhelpful feedback can result in reduced self-efficacy in online learners (Yantraprakorn, Darasawang, & Wiriyakarun, 2018). In light of these self-efficacious challenges, it is important to design supports for self-efficacy in order to remove roadblocks for motivation in online mathematics students. Improving motivational factors, through methods such as scaffolding, self-regulatory supports, and self-efficacious supports, have had positive effects on students (Ryan & Deci, 2020).

Self-Determination Theory

Made manifest by the studies previously described, lack of motivation is prevalent in mathematics and online students (Higashi et al., 2017; Kim, 2012; Sun & Rueda, 2012). When motivation is low, student learning and achievement tend to be negatively affected (Yantraprakorn et al., 2018). To address these challenges, the effects of various components of motivation on students' learning and achievement have been studied. For example, in a study of 500 Ghanaian accounting students, the researchers found that the motivational component of volition has a significant effect on achievement (Ahinful, Tauringana, Bansah, & Essuman, 2019). Similarly, in a study of 132 online college students, the motivational component of self-efficacy was strongly associated with students' learning goals and engagement (Xie & Huang, 2014). Yet another component of motivation, perceived value, was found to be a strong indicator of performance in a study of intrinsic motivation among 471 college students (Ibrahim, Baharun, Harun, &

Othman, 2017). Different components of motivation then, especially those related to intrinsic motivation, may support learning and performance in mathematics and online students.

Although multiple theories exist to address these different components of motivation, self-determination theory's encompassing and practical approach lends itself well to this study's pragmatic action research design and is applicable to the online environment. For example, the results of Hsu, Wang, and Levesque-Bristol's (2019) study of seven online courses with 330 participants indicated that self-determination theory can be efficaciously applied to the online environment. Furthermore, Huang, Backman, Backman, Mcguire, and Moore (2019) found that designing virtual learning based on self-determination theory improved motivation and learning based on their 198 participants. Similarly, Rayburn, Anderson, and Smith (2018) studied the use of self-determination theory in the design of a marketing course among 98 students and found a positive effect on students' autonomy, competence, and relatedness levels because of this design. In an exploratory study of 35 students and teachers in an online course that employed the use of self-determination theory, Jacobi (2018) found that the needs of online students align well with the needs of autonomy, competence, and relatedness. Based on these studies, self-determination theory has been shown to be applicable and effective in course design and the online environment.

In addition to its effectiveness and applicability, the three psychological needs of self-determination theory address the challenges of motivation in mathematics and online environments discussed earlier. In particular, self-determination theory supports self-regulation and reduced feelings of isolation through the satisfaction of autonomy and

relatedness. The fulfillment of competence helps overcome self-efficacious challenges. For example, in a large study of motivation among 1,037 online learners, Durksen, Chu, Ahmad, Radil, and Daniels (2016) found that feelings of isolation can be difficult to overcome in large online courses and designing for relatedness may help assuage those feelings. In a study of autonomy among 499 physical education students (Haerens, Aelterman, Vansteenkiste, Soenens, & Van Petegem, 2015) as well as a study of autonomy among 80 physical education teachers (Aelterman, Vansteenkiste, Van Keer, & Haerens, 2016), the researchers found that facilitating autonomy supportive environments has a positive effect on motivation. Finally, feelings of self-efficacy were shown to increase in a study using self-determination theory in gamification among 254 students (Tan, 2018). Self-determination theory was selected for use in this study because of its direct application to the challenges faced in the mathematics and online environments, its applicability and efficacy to these environments as shown in prior research, and its comprehensive foundations in theory.

This section will include the following: (a) an analysis of the psychological needs of self-determination theory, (b) the motivation continuum associated with self-determination theory, and (c) the mini-theories of self-determination theory.

Psychological Needs of Self-Determination Theory

Ryan and Deci (2017) defined the three psychological needs of autonomy, competence, and relatedness as the essential needs that every person must have satisfied or fulfilled to grow and live in a healthy way. If these needs are satisfied, a person's intrinsic motivation, autonomous extrinsic motivation, and social and personal well-being are improved (Ryan & Deci, 2017). For example, in applying self-determination theory to

the study of game mechanics, Proulx, Romero, and Arnab (2017) contended that supporting the psychological needs of autonomy, competence and relatedness likely results in increased enjoyment and motivation. Similarly, other researchers applied the satisfaction of the three needs to video games in an experiment involving 129 university students and found that enjoyment resulted from need fulfillment (Tamborini et al., 2010). This section will include a discussion of the three needs: (a) autonomy, (b) competence, and (c) relatedness. A definition, the factors that support, the factors that undermine, and the strategies for implementation in an educational environment will be expatiated upon for each need. The way in which the strategies for implementation of each need correspond to the design of the intervention unit is detailed in Chapter 3, including a summary of the alignment in Figure 3.1.

Autonomy. The principal need in self-determination theory is autonomy, which represents a person's self-regulation (Ryan & Deci, 2017). A person's willingness to do a task, or volition, depicts self-regulated behavior (Tamborini et al., 2010). The person who is doing this willful behavior must possess an internal acceptance of the behavior upon reflection (Tan, 2018). Additionally, the person must perceive that he or she is in control of the behavior (Ryan & Deci, 2020). In this way, the person is the center and controller of his or her behavior (Proulx et al., 2017). In sum, self-regulation requires internal volition and the person's perception and acceptance of the willful behavior.

Supporting factors. Certain internal and external factors have been shown to support the satisfaction of autonomy. Autonomy is fostered by intrinsically motivating tasks that provide choice, value, and interest (Ryan & Deci, 2020). When this choice is given with a sense of trust and empowerment and followed with positive informative

feedback, the conditions for autonomy are optimized, as demonstrated in Rayburn, Anderson, and Smith's (2018) study of self-determination theory in the design of a marketing course. Flexibility, in relation to the establishment and execution of choice, also provides a framework for the perception of autonomy to flourish, as shown in a study of 1,037 online learners (Durksen, Chu, Ahmad, Radil, & Daniels, 2016). In a study of designing virtual learning based on self-determination theory, the researchers found that an environment of positive behavior and emotions promotes a feeling of freedom, as it relates to autonomy (Huang et al., 2019).

The type of structure utilized in an environment that facilitates autonomy is important. When structure is provided through supportive means, rather than controlling means, then the feeling of freedom is enhanced (Ryan & Deci, 2020). Supportive means includes nurturing the interests of students rather than teacher prescribed directives, as shown in the study of autonomy among 499 physical education students (Haerens et al., 2015). In Hartnett's (2015) exploratory case study of undermining factors of self-determination theory among 14 participants, she found that supportive structure also includes frequent, constructive, and informational feedback. Based on these research studies, autonomy can be defined as the perception and acceptance of one's self-regulation and is supported by choice, interest, empowerment, and non-controlling structure.

Undermining factors. When particular perceptions and environmental factors are present, autonomy is undermined. This occurs when a person senses his or her actions are controlled by external forces (Ryan & Deci, 2020). For example, if a person feels the need to act due to external pressure, coercion, or regulation, then the need for autonomy

will be found wanting (Ryan & Deci, 2017). These types of external forces may be demonstrated by high stakes activities, a sizable workload, and time constraints (Hartnett, 2015). Similarly, Jaiswal's (2019) quantitative study of 26 post-high school English language learns showed that a student-centered environment improves autonomy more than a controlled teacher-centered environment. Extrinsically motivating reinforcements, such as rewards and punishments, create an unsuitable setting for autonomy (Ryan & Deci, 2020). To summarize, a teacher-centered setting with heteronomy, restrictions, and exclusively extrinsic reinforcement should be avoided or limited to create an ideal climate for autonomy to flourish.

Implementation strategies. In light of the supporting and undermining factors of autonomy, various strategies for implementation in an educational environment have been shown to satisfy this need. For example, in a study of 110 ninth grade mathematics students, Froiland, Davison, and Worrell (2016) found that positive instructor communication, including respectful words and actions, helping students benefit from their mistakes, and valuing their perspective, aid in fostering a setting that reduces heteronomy. A teacher should be available to students and willing to be used as a resource (Hew, 2016). In an action research study of 32 graduate students, Qian and Sun (2019) found that additional resources, especially in the area of vocabulary acquisition, can improve autonomy.

Beyond the teacher role and extra resources, authentic student choice should be designed into a curriculum (Martin et al., 2018). Based on a case study of two eighth social studies classrooms over a year-long period, technology integration has been found to provide more options for authentic student choice (Hilton, 2016). Alongside this

student choice should be appropriate scaffolding and clear expectations to bolster a supportive structure (Ryan & Deci, 2020). For example, in a study of 170 online eighth grade physics students, Chen (2014) found that adaptive scaffolding positively affected students' level of motivation and learning outcomes. Based on this research, implementation strategies that facilitate the perception of autonomy are likely to include teacher attitudes and communication, authentic student choice, and appropriate structure.

Competence. Ryan and Deci (2017) built their definition of competence around White's (1959) concept of effectance motivation. In essence, people are viewed as active players in their environment and seek effective interaction with it, which results in internal satisfaction from being efficacious (Deci & Ryan, 1985; Ryan & Deci, 2017; White, 1959). This innate need to interact effectively with the surrounding environment can be recognized by effort and curiosity (Ryan & Deci, 2017). Furthermore, people desire an appropriate challenge in their environment (Tamborini et al., 2010). When they interact with this appropriate challenge, they want their interaction to be effective in the way they intended it to be (Tan, 2018). In this way, competence involves both optimal challenges and the perception of effectively completing those challenges (Proulx et al., 2017). People are then able to feel a sense of ability to achieve success and growth (Ryan & Deci, 2020). In sum, competence refers to the feelings of self-efficacy and mastery of optimal challenges within the surrounding environment.

Supporting factors. The ideal conditions for competence occur when certain supporting factors are present. Positive feedback, communication, and an appropriate level of challenge enhance competence (Ryan & Deci, 2000). The feedback should not only be positive, but also informative (Ryan & Deci, 2020). For example, students

correcting their own quizzes and using the results as constructive information rather than as a grade in the course has been shown to boost competence (Deci & Ryan, 1985). Building confidence in a person by showing approval and confirmation builds a feeling of self-efficacy (Rayburn, Anderson, & Smith, 2018). Competence and autonomy are strongly dependent on one another, and so supporting autonomy also supports competence (Durksen et al., 2016). In particular, including the autonomous support of structure rather than chaos is imperative in improving competence (Ryan & Deci, 2020). In short, providing specific supports for optimal challenges, structure, and informative feedback aid in feelings of self-efficacy and the perception of competence.

Undermining factors. Competence may be undermined when certain other conditions are present in the educational setting. It has been shown that if the challenge level is too easy, self-efficacy is not improved (Huang et al., 2019). Conversely, ambiguous or extensively detailed instructions along with irrelevant resources have been shown to lead to feelings of helplessness and anxiety because the task is too difficult (Hartnett, 2015). Feedback that has a controlling significance, causing a person to feel pressured to act in a particular way, depletes feelings of competence (Ryan & Deci, 2020). High-stakes evaluations can create additional pressure and stress, undermining feelings of competence (Carr, 2020; Martin et al., 2018). Based on this research, creating tasks that are not too easy or too difficult, ensuring instructions are not too wordy or unclear, and removing sources of pressure and stress will likely remove many of the roadblocks for feelings of competence to prevail.

Implementation strategies. The strategies that have been shown to improve feelings of competence in the learner fall under the umbrella of scaffolding. According to

Vygotsky (1978), there is a zone between what students are capable of doing individually and what they are able to master with the help of others, called the zone of proximal development. Based on a study of Vygotskian pedagogy among 106 college-level students in the online environment, Harwood and Brett (2019) confirmed that progress through this zone is best facilitated by interaction between a mentor and learner with positive communication and politeness. This process of facilitation, or scaffolding, involves helping the learner focus on tasks he or she is able to complete by limiting information or activities that are initially beyond his or her capability (Kapp, 2012). Ak (2016), in a quasi-experiment of 60 online students concerning technology-based scaffolds, found the following four types of scaffolding were effective in student problem solving and eliminate many procedural issues: conceptual (scaffolding knowledge levels), metacognitive (scaffolding thinking processes), procedural (scaffolding tools and resources), and strategic (scaffolding different approaches to problems). Utilizing scaffolding in the learning environment aids in learners' self-efficacy.

Specific elements related to the curriculum, educational environment, and learner have been shown to support scaffolding. In a study applying scaffolding to 170 eighth grade online physics students, Chen (2014) found that scaffolding can be enhanced by personalization based on the prior knowledge of the learner. Informative correctness feedback from the instructor also supports scaffolding (Cho & Shen, 2013). Strongly guided instruction, such as worked out examples or worksheets demonstrating and requiring process activities, aids in reducing cognitive load and fosters competence (Kirchener, Sweller, & Clark, 2006). Optimal challenge, within the zone of proximal development, may be designed for by sharing the target and level of the course, offering

learning extensions and enrichment, and encouraging self-goal setting (Martin et al., 2018). In sum, identifying and remaining within the bounds of a learner's zone of proximal development through the use of scaffolding, with techniques such as guided instruction, enrichment, and student self-goal setting are implementation strategies that likely foster the perception of competence.

Relatedness. Relatedness is the basic need for humans to feel genuinely connected to and accepted by others (Ryan & Deci, 2017). People often attempt to secure their acceptance by identifying others' expectations and actions (Ryan & Deci, 2017). Operating in this way, a person may integrate others' values, leading to internalized extrinsic motivation, or view them as extrinsic controls, leading to controlled extrinsic motivation (Ryan & Deci, 2017). For the need of relatedness to thrive internally, a person must perceive unqualified social attachment or belongingness (Proulx et al., 2017). Although one study found that relatedness acts as a separate component in self-determination theory (Durksen et al., 2016), it is generally accepted that relatedness is interconnected with autonomy and competence (Hartnett, 2015; Ryan & Deci, 2017; Tamborini et al., 2010). This interconnectedness is due to a social setting involving the satisfaction of competence and autonomy, resulting in feelings of trust and acceptance (Hartnett, 2015). When relatedness is realized, a person's motivation to participate and apply knowledge is increased (Rayburn et al., 2018). In general, an unconditional feeling of social acceptance, which is dependent on the satisfaction of autonomy and competence, fulfills the need of relatedness and improves motivation.

Supporting factors. When certain genuine attitudes and actions are present in a social environment, the need for relatedness is supported. Relatedness is facilitated by

showing a person respect and positive emotions (Ryan & Deci, 2020). Positive interactions from the instructor, including politeness, have been shown to increase internal motivation (Harwood & Brett, 2019). More specifically, in Bourgeois and Boberg's (2016) explanatory sequential mixed methods study of high-achieving mathematics students, the researchers found that relatedness can be impacted by a perception of a positive, open, and trusting environment, as described by instructors or other school personnel. Providing a framework for student collaboration with clear expectations has been shown to increase curiosity and motivation (Huang et al., 2019). Based on these studies, an educational environment should aim for openness, respect, clarity, and collaboration to support the fulfillment of relatedness.

Undermining factors. Although collaboration and communication are essential components of relatedness, certain conditions when implementing these may precipitate the opposite effect. For example, when disagreements or conflicts arise among group members, a lack of appropriate resources to determine how to move forward can undermine relatedness and cause feelings of isolation (Hartnett, 2015). Isolated environments, such as distance learning, further compound the issue of relatedness by causing a person to feel disconnected (Durksen et al., 2016). With a large distance learning course size, relatedness has been shown to be the most difficult need to satisfy (Martin et al., 2018). In addition to isolation, feelings of rejection or only being accepted based on meeting certain conditions weakens relatedness (Ryan & Deci, 2017). Relatedness is tenuous in that isolation, insincerity, and control subvert it, so care should be taken to promote genuine positive interactions to improve internalized motivation.

Implementation strategies. To create a supportive educational setting for relatedness to thrive, certain design components and types of communication can be built into a course. It is important to include student with student and student with instructor interactions (Hew, 2016). Clear expectations with communication is important, such as warm and friendly instructor feedback (Martin et al., 2018). Based on a mixed methods study of 152 online instructors, it is likely that forums may provide a means of connecting students and personalizing the experience (Bonk et al., 2018). Creating these opportunities for discussions as well as collaborative brainstorming sessions help with relatedness (Sun & Rueda, 2012). Scaffolding, although a strategy for competence, has also been shown to improve interactions among students and teachers in an online course (Cho & Cho, 2016). Relatedness can be improved in mathematics when teachers respond positively to students seeking help, which may include appropriate scaffolding (Durksen et al., 2017). To summarize, key strategies to promote relatedness in an online course include forums or discussion boards, clear parameters for positive communication, and friendly and informative communication from the instructor.

Motivation Continuum

Ryan and Deci (2000, 2017) proposed a continuum of controlled to autonomous regulation that describes the type of motivation present within a person (Deci & Ryan, 1985). Depending on whether the social factors present in the environment facilitate or thwart the three needs, a person's motivation may be absent, more controlled, more autonomous, or intrinsic (Ryan & Deci, 2017). At one end of the continuum is amotivation, the absence of an intention to do something (Ryan & Deci, 2000). At the other end is intrinsic motivation (Ryan & Deci, 2000), which is comprised of a person's

inner feelings of interest or enjoyment about a task (Lambert, 2017; Lee & Martin, 2017). These actions are regulated by the self (Samruayruen et al., 2013).

In between amotivation and intrinsic motivation rest the following four degrees of extrinsic motivation: (a) external (controlled), (b) introjected (somewhat controlled), (c) identified (somewhat autonomous), and (d) integrated (autonomous; Gagne & Deci, 2005; Ryan & Deci, 2000). When extrinsic forces, such as rewards, punishments, or pressure, are viewed as controlling or manipulative, the actions are devalued by the learner and external extrinsic motivation is produced (Lambert, 2017; Ryan & Deci, 2017). If a learner feels this pressure internally, such as through feelings of guilt or shame for completing an action, the motivation moves from external to introjected (Carr, 2020; Ryan & Deci, 2017). Identified extrinsic motivation arises if the learner accepts or places value on these extrinsic forces (Ryan & Deci, 2020). Finally, if extrinsic forces incite internal feelings of competence or value attribution and these feelings are integrated into one's belief system, then integrated extrinsic motivation is produced (Gagne & Deci, 2005; Ryan & Deci, 2017).

The transition from more controlled extrinsic motivation to more autonomous extrinsic motivation can be facilitated by the existence of certain internal, environmental, and social factors. In general, the satisfaction of the three needs of autonomy, competence, and relatedness facilitates the transition from controlled to autonomous motivation (Ryan & Deci, 2017). More particularly, when instructors help learners improve self-consciousness and initiative, autonomous motivation has been shown to increase (Qian & Sun, 2019). Informative feedback heightens autonomous motivation whereas evaluative feedback leads to discounting and heightened controlled motivation

(Rinfret et al., 2014). In a similar sense, when a learner places value on environmental or social factors, such as informative rather than evaluative feedback, then the learner internalizes these external events (Gagne & Deci, 2005). A supportive environment with a teacher who is autonomously motivated and provides structure with efficacy-based feedback, cognitive scaffolds, and choice facilitates the movement toward more autonomous extrinsic motivation (Ryan & Deci, 2020). This movement arises from the fulfillment of autonomy, competence, and relatedness in the learner (Ryan & Deci, 2020).

In sum, the most beneficial forms of motivation involve the least controlling influences acting on a person because this allows for the most self-regulated behavior to take place (Carr, 2020; Ryan & Deci, 2017; Samruayruen et al., 2013). These beneficial types of motivation include the internalization of external factors through value attribution (i.e., autonomous extrinsic motivation) and inherent interest, curiosity, or enjoyment in a task (i.e., intrinsic motivation; Deci & Ryan, 1985; Gagne & Deci, 2005; Ryan & Deci, 2000, 2017).

Mini-Theories of Self-Determination Theory

Through continued studies and research, Ryan and Deci (2017) formed six mini-theories to describe different aspects of motivation in self-determination theory. The following list identifies the mini-theories and includes a brief description of each: (a) *cognitive evaluation theory* delineates how intrinsic motivation is affected by social environments, (b) *organismic integration theory* provides support for the continuum bringing controlled extrinsic motivation to autonomous extrinsic motivation, (c) *causality orientations theory* details differences in personality and how they are affected by the social environment, (d) *basic psychological needs theory* reveals the ways that health and

well-being are affected by the level of need satisfaction, (e) *goal contents theory* considers people's intrinsic and extrinsic goals, and (f) *relationships motivation theory* identifies how relatedness and autonomy are connected through interpersonal relationships (Ryan & Deci, 2017). Through these mini-theories, Ryan and Deci (2017) further explained and examined the interconnectedness between the various components of self-determination theory.

Among the mini-theories, the basic psychological needs mini-theory has special significance in this study. In this theory, Ryan and Deci (2017) moved beyond motivation into a broader interpretation of human well-being. A person who is appropriately motivated, characterized by autonomous extrinsic and intrinsic motivation through the satisfaction of autonomy, competence, and relatedness, will experience wellness and vitality. A person's well-being, therefore, is dependent on the satisfaction of the three psychological needs, while the frustration of these three needs causes a person's ill-being (Ryan & Deci, 2017). The satisfaction (i.e., fulfillment) or frustration (i.e., thwarting) of the three needs varies between people and over time and occurs whether or not a person is aware of these needs (Ryan & Deci, 2017).

Well-being is understood "in terms of thriving or being fully functioning rather than merely by the presence of positive and absence of negative feelings" (Ryan & Deci, 2017, p. 241). This thriving is grounded in efficaciously undertaking worthwhile endeavors (Ryan & Deci, 2017). When a person succeeds in what he or she considers valuable activities and interactions, his or her basic needs of self-regulation or autonomy, self-efficacy or competence, and social connectedness or relatedness are met, resulting in wellness and increased motivation.

The basic psychological needs mini-theory was important in this study because one of the data collection methods, the motivation questionnaire (see Chapter 3), was based on this theory. The extent to which the intervention design components for autonomy, competence, and relatedness (see Chapter 3) affected motivation levels was, in part, measured by this motivation questionnaire. This motivation scale measures the levels of satisfaction and frustration of the three basic psychological needs (Chen et al., 2015).

Gagne's Nine Events of Instruction

The basic structure of the lessons in the Algebra 2 course at Peacock Cyber School generally follows Gagne's nine events of instruction. The layout of the lessons in the intervention unit continued to follow this format, with modifications made based on the implementation strategies of self-determination theory. In order to help differentiate items implemented in the intervention using self-determination theory from the basic structure of existing lessons, which will be delineated further in Chapter 3, this section includes an overview of Gagne's nine events of instruction.

Gagne, Briggs, and Wager (1992) contended that external events of instruction are able to support the internal processes that cause learning. These internal processes include reception, selective perception, rehearsal, and semantic encoding (Gagne et al., 1992). The various external events that activate the four internal processes are necessary because there are different types of learning that take place (Gagne, 1985). The following nine events support the activation of the internal processes: (a) gaining attention, (b) informing learners of objectives, (c) stimulating recall of prior knowledge, (d) presenting the content, (e) providing learning guidance, (f) eliciting performance, (g) providing

feedback about correctness, (h) assessing performance, and (i) enhancing retention and transfer (Gagne, 1985; Gagne et al., 1992).

Unlike broader models of instructional design, Gagne's nine events of instruction can provide an effective layout for a specific lesson. For example, Polat and Oz (2017) used Gagne's nine events of instruction as the basis for creating a specific lesson plan for 23 eighth grade students in informational technology because of its usefulness in facilitating learning. In a comparative quantitative study of Gagne's nine events of instruction used in a postgraduate armed forces institute, Ullah, Rehman, and Bibi (2015) found its implementation as a framework for lessons improved student satisfaction, performance, and retention. Similarly, Jaiswal's (2019) use of Gagne's nine events as a student-centered approach among 26 English language learners enhanced retention and transfer. In another study utilizing Gagne's events to design pharmacy curriculum, this model improved meaningful knowledge acquisition, retention, and the use of knowledge in novel situations (Davies, Pon, & Garavalia, 2018). Gagne's nine events of instruction have been also been recognized and developed as a framework for online lesson design (Jeffery & Ahmad, 2018).

Although other instructional design models have also been effective in course design, mathematics lessons at Peacock Cyber School have been organically created in a way that aligns with Gagne's nine events of instruction. Because of this preexisting close alignment, the format of the lessons in the Algebra 2 course has been further updated and redeveloped over time to correspond to Gagne's model. The specific features of the lessons in the current study, as they relate to Gagne's nine events of instruction and self-determination theory, will be fully explicated in Chapter 3.

Chapter Summary

Motivation in education has been defined by the basic underpinnings of extrinsic motivation, characterized by external punishments, rewards, and outcomes; and intrinsic motivation, characterized by internal interest, curiosity, and volition (Lambert, 2017; Lee & Martin, 2017; Leong et al., 2018; Ryan & Deci, 2000). Several theories have been developed to expatiate upon the underlying causes and attributes of motivation, including expectancy value theory, social cognitive theory, and self-determination theory. Through these theories, the way in which the environment, including social interaction, modeling, and reinforcement factors, affects the internal workings of volition, interest, self-efficacy, expectations, and value attribution, is brought to light (Bandura, 1989; Deci & Ryan, 1985; Ryan & Deci, 2017; Wigfield, 1994).

Motivation is important in online learning because it has been linked to improved learning outcomes, achievement, persistence, and retention (Froiland et al., 2016; Hew, 2016; Hsu et al., 2019; Kim et al., 2015; Martin et al., 2018). Motivation has been shown to be lacking in online mathematics students as a result of various self-regulatory and self-efficacious challenges that hinder the cultivation of motivation in these students (Durksen et al., 2017; Kim, 2012; Wilkie & Sullivan, 2018; Yantraprakorn et al., 2018).

Self-determination theory is a well-established theory of motivation that attributes the level and type of motivation to the extent to which internal needs are satisfied, specifically, autonomy, competence, and relatedness (Deci & Ryan, 1985; Proulx et al., 2017; Ryan & Deci, 2017). Autonomy is related to a learner's self-regulation, competence depends on a learner's self-efficacy, and relatedness revolves around a learner's feelings of social acceptance (Ryan & Deci, 2017). The satisfaction of the three

needs is interconnected and dependent upon the fulfillment of each one (Hartnett, 2015; Ryan & Deci, 2017; Tamborini et al., 2010). These psychological needs have specific characteristics that can be designed for in online lessons using distinct strategies (Durksen et al., 2016; Huang et al., 2019; Rayburn et al., 2018; Ryan & Deci, 2000, 2020).

In self-determination theory, motivation is defined on a continuum starting with amotivation, moving to varying degrees of controlled and autonomous extrinsic motivation, and ending with intrinsic motivation (Gagne & Deci, 2005; Ryan & Deci, 2000, 2020). The positive effects of extrinsic motivation may be temporal, while internalized extrinsic motivation and intrinsic motivation are best for the learner (Cho & Shen, 2013; Kapp, 2012; Ryan & Deci, 2000, 2020). The fulfillment of autonomy, competence, and relatedness is the foundation for internalized extrinsic and intrinsic motivation in self-determination theory (Gagne & Deci, 2005; Ryan & Deci, 2000, 2020).

Gagne's nine events of instruction provide a solid structure for lesson design (Jaiswal, 2019; Jeffery & Ahmad, 2018; Polat & Oz, 2017; Ullah et al., 2015). This structure forms the basic lesson template upon which the intervention in this study was built using implementation strategies from self-determination theory.

Two key conclusions from this review are that motivation is lacking in many online mathematics students and when intrinsic and autonomous extrinsic motivation are maximized, student learning outcomes will likely improve (Bourgeois & Boberg, 2016; Cho & Shen, 2013; Kim, 2012; Rinfret et al., 2014; Ryan & Deci, 2000, 2020; Sun & Rueda, 2012; Yantraprakorn et al., 2018). The implication for this study emerges from these conclusions. Designing a lesson adhering to the structure of Gagne's nine events of

instruction, with supports for the fulfillment of autonomy, competence, and relatedness, as described by self-determination theory, is likely to improve the intrinsic and autonomous extrinsic motivation of online mathematics students, resulting in improved learning outcomes.

CHAPTER 3

METHOD

The purpose of this study, to create and implement a self-determination theory-based online unit on factoring polynomials for mathematics students at Peacock Cyber School in order to improve students' motivation levels, was examined through the two research questions: (1) How does the implementation of a self-determination theory-based unit on factoring polynomials in an online mathematics course affect students' motivation at Peacock Cyber School? and (2) To what extent does the implementation of a self-determination theory-based online unit on factoring polynomials in an online mathematics course affect students' mathematics content knowledge at Peacock Cyber School?

Research Design

The general purposes of action research, such as connecting theory with action, school improvement, and personal growth (Mertler, 2017; Sagor, 2000) align with the goals of the current study. First, the research connects the *theory* that self-determination theory-based online lessons provide more motivation to students with the *action* of creating Algebra 2 lessons at Peacock Cyber School based on this theory. Second, one of the reasons for pursuing this research topic is to aid in school improvement by increasing student learning and math assessment results. Finally, this research helps my own professional growth as an online content developer and designer by furthering my understanding of effective methods to create online curriculum.

Action research differs from traditional research in various ways and these differences make it more fitting for the current research project. Action research, conducted by the researcher, has the purpose of improving an aspect of the researcher's sphere of influence as opposed to an outside actor conducting scientific inquiry (Buss & Zambo, 2014; Sagor, 2000). An important goal is to improve a problem for the local participants (Belzer & Ryan, 2013; Sagor, 2000). A lack of motivation among students to complete mathematics lessons was identified in my local context and this study was conducted with the goal of improving that problem. This study also applied the intended benefit to all participants, rather than limiting the intervention to only certain participants (Creswell & Creswell, 2018). Finally, action research is meant to be an iterative process, where changes are made as necessary based on initial results (Adelman, 2006; Hine, 2013). Since my aim was to address the lack of motivation in mathematics students at Peacock Cyber School, it may be beneficial to make changes based on my results for future improvements.

The study followed a convergent mixed methods design. Since the purpose of this study was to determine the effects of a self-determination theory-based online mathematics unit on students' motivation levels, a mixed methods approach provided a more thorough and holistic understanding of the situation. Using both qualitative and quantitative data on motivation levels and assessment results helped improve the validity and completeness of the results (Adami, 2005; Cope, 2014). The use of a triangulation of data for assignment results and motivation levels pertaining to autonomy, competence, and relatedness, provided the best means for gathering the data in the local context, as

discussed in more detail in the Rigor and Trustworthiness section under the subheading Methodological Triangulation (Casey & Murphy, 2009).

Setting

The action research study took place at Peacock Cyber School, which is a public online school of choice located in the northeast region of the United States for students in Grades 6-12. As described in more detail in the Local Context section of Chapter 1, collaboration between students and teachers takes place using Jigsaw, e-mail, and phone, while coursework takes place in the learning management system, Moodle. Students work entirely online, remotely, and asynchronously, with optional and highly recommended synchronous class meeting times. Students are considered behind if they do not complete the work assigned for a week by the following Monday, however, they have until the end of each quarter to finish all assigned work for that quarter.

The Algebra 2 course contains lessons that are consistent in their function, layout, and technical specifications. This section will provide a description of (a) the function of lessons in Algebra 2, (b) the general lesson layout based on Gagne's nine events of instruction, and (c) the technical specifications of the lessons in Algebra 2.

General Lesson Function

The lessons in Algebra 2 are intended to enable learners to comprehend and internalize the information, formulas, procedures, and thought processes necessary to be successful on the assessments that follow the lessons. A quiz or assignment follows each lesson to assess student understanding of the preceding lesson. The quizzes are computer graded multiple-choice assessments. Students have two attempts on quizzes but do not receive teacher feedback about their submissions. The assignments are open ended

homework type activities where students show their work and receive feedback from a teacher for improvement. Larger tests and projects throughout the course require students to apply, synthesize, and transfer the knowledge they have gained in the lessons. Tests are normally computer graded while projects are normally teacher graded. The assessments stand apart from the lessons and constitute the graded material in the course that count toward the students' final grades. In contrast to the lessons designed for the intervention, the general lessons in Algebra 2 are not graded. The impetus for students to complete them lies in the value of gaining the essential knowledge and skills needed to be successful in the course.

General Lesson Layout

The layout of the lessons in the Algebra 2 course generally adheres to Gagne's nine events of instruction, described in Chapter 2. This layout provides consistency of design throughout the course. Learners start at the top of the lesson webpage and scroll down as they read, listen, watch, and/or interact with the material on the page. The presentation of the lesson sections may take the form of text, images, audio, video, and/or interactives. The content and presentation of Gagne's nine events in the general Algebra 2 lessons is displayed in Table 3.1. See Appendix B for samples of the different lesson sections.

The motivational components of the intervention, created using the implementation strategies of self-determination theory, are distinct from the general lesson content described in Table 3.1 and will be explicated in more detail in the Intervention section of this chapter.

Table 3.1 *Use of Gagne's Nine Events in Algebra 2 Lessons*

Gagne's Nine Events	Algebra 2 Lesson Content	Content Display
Gaining attention	Interesting content that relates to the lesson in some way, such as a real-world application or a metaphor, is displayed.	Video or image with text
Informing learners of objectives	The goal of the lesson is provided at the beginning in clear, large font.	Text
Stimulating recall of prior knowledge	Each lesson provides a sentence or very brief paragraph identifying prior information or knowledge that is necessary for the lesson.	Text
Presenting the content	Vocabulary words and definitions are presented on the right side of the webpage in a vertical bar and an explanation section provides an overview of the basic math principles for that lesson. This may include procedural steps or formulas, if applicable.	Text (vocabulary) and video, image, and/or audio (explanation)
Providing learning guidance	Two to four examples provide specific details on the ways in which the content may be applied to various situations, such as different equation setups, negatives, or fractions.	Image, text, and audio
Eliciting performance	Interactive content items are embedded within the example section of some of the lessons. These items may include matching text or image, fill-in-the blank, drag and drop text or image, sequencing, or multiple choice. A question is provided that closely aligns to the example given and, when these are present, students are asked to attempt this question after the example.	HTML5 Package (H5P) website (h5p.org)
Providing feedback about correctness	Immediate feedback is a built-in feature of the interactive items. Students can see if they were correct, choose to attempt the question again, or choose to view the solution to the problem.	HTML5 Package (H5P) website (h5p.org)
Assessing performance	At the end of the lesson itself, mixed practice problems are presented for students to self-assess. The mixed practice is normally comprised	Text

	of four to six questions representing the content of the lesson. Answers are provided on a separate tab for students to check their work.	
Enhancing retention and transfer	At the end of each lesson, a summary is provided to identify the key concepts that should be understood by the learner at this point. Additional resources are also provided for students to explore the concepts in more depth and have the opportunity for additional practice. However, more importantly to retention and transfer are the cumulative reviews, projects, and exams built into the larger course.	Image and text

General Lesson Technical Specifications

The Algebra 2 course, as with the other courses at Peacock Cyber School, is housed in a learning management system, Moodle. Students log into Moodle, navigate to their course, complete the lessons and assignments, and view their grades in the Moodle course gradebook. The three sections of Algebra 2, as described in the Participants section below, are split into three separate shells in Moodle. This means that the students enrolled in the career, college-prep, and honors sections each access a different course in Moodle and teachers access a different course for grading purposes. The career shell has added explanations in some lessons and more fact-based and procedural practice in some assignments, while the honors shell has added advanced topics in some lessons and additional higher order thinking questions in some assignments. Together, the three Algebra 2 shells in Moodle contain all the students enrolled in the full-year Algebra 2 course at Peacock Cyber School.

While Moodle houses all the coursework and students may advance through it independently, Jigsaw provides a meeting place for students and teachers. On an as needed basis, students may log into Jigsaw during certain hours to ask for help. A

separate Jigsaw session is provided for each subject area. In the case of Algebra 2, students log into the high school math session and may ask for help from any high school math teacher. Additionally, the Algebra 2 teachers hold a one-hour live class each week in Jigsaw and strongly encourage students to attend. These classes provide direct instruction and practice on the lesson content of the week. All the courses at Peacock Cyber School utilize Moodle as the learning management system and Jigsaw for synchronous meeting purposes.

Participants

The Algebra 2 course has many students enrolled each year with a variety of student ages, academic histories, and academic goals. There were approximately 200 students enrolled in the Algebra 2 course at Peacock Cyber School at the time of the study, of which 54 elected to participate in the study, and 50 fully completed the study. All the participants have proper assent and consent on file (see Appendix A).

Students enrolled in the Algebra 2 course ranged from Grade 7 to Grade 12 and were split into three sections: career, college-prep, and honors, based on their academic histories and teacher recommendations. In general, those in the career section struggled with mathematics and had possibly already retaken algebra courses. Additionally, these students do not generally pursue higher mathematics courses after this course. The college-prep section normally represents the largest number of students. These students had likely demonstrated sufficient mathematics ability in past courses and generally continue in higher mathematics courses after this course, such as Algebra 3 or Precalculus. Students in the honors section likely had demonstrated advanced

mathematics ability in past courses and generally continue in advanced mathematics courses after Algebra 2, such as honors Precalculus, AP Calculus and/or AP Statistics.

Every student enrolled in each of the three sections of this Algebra 2 course at the time of the study was given the option to participate in the intervention. Of the students that agreed to participate the study, 12 were enrolled in the career section, 24 were enrolled in the college-prep section, and 18 were enrolled in the honors section. An equal number of participants from each of the three sections of the course were randomly selected to take part in the interviews for the study. Six of these participants agreed to participate in the interviews. Table 3.2 shows additional demographic information collected for these six participants, along with the pseudonyms used for these participants. This includes each participant's age, gender, grade level, Algebra 2 section, and grade earned for Quarter 1 (Q1) and Quarter 2 (Q2) of Algebra 2.

Table 3.2 *Demographics for Interviewees*

Pseudonym	Age	Gender	Grade	Section	Q1 Grade %	Q2 Grade %
Ava	15	Female	8	College-prep	94	94
Blake	16	Female	10	College-prep	89	71
Cameron	16	Female	11	College-prep	99	99
Devin	15	Female	8	Honors	95	97
Eddie	14	Male	9	Honors	97	99
Finley	15	Male	10	Honors	97	100

The Algebra 2 course was chosen as a purposive sample among the courses of Peacock Cyber School so that the same intervention with the same teachers could be

given to all of the participants (Creswell & Creswell, 2018). This course is prototypical of the mathematics content at Peacock Cyber School and is considered a mid-level course in terms of its content difficulty. Since Algebra 2 tends to be the largest math course and serves as a bridge course between required and elective courses, it provides a likely representative sampling of the students at Peacock Cyber School.

Intervention

Using theories of motivation, including self-determination theory, has been shown to increase motivation and achievement in both traditional brick-and-mortar settings and online environments (Ak, 2016; Chen, 2014; Kim, 2012; Theado & Wan, 2012; Valencia-Vallejo, López-Vargas, & Sanabria-Rodríguez, 2018). The intervention in this study was an online mathematics unit based on Deci and Ryan's (1985) self-determination theory of motivation. As such, the unit exhibited characteristics that facilitate the psychological needs of self-determination theory, namely, autonomy, competence, and relatedness. The intervention unit was built from an Algebra 2 unit and retains its core structure, as described above.

During the intervention, two teachers were assigned to the Algebra 2 course and took an active part in grading and helping the students in all sections. The students were not assigned to a specific teacher. As the mathematics instructional developer at Peacock Cyber School, I created the course content and specific intervention to be used in Moodle. As such, I was available for fixing and/or modifying the intervention in Moodle, whether through teacher request or my initiative.

The intervention lessons continued to have the same function, follow the same structure of Gagne’s nine events of instruction, and have the same technical

specifications as the other lessons in Algebra 2. In this way, students were accustomed to the procedures for accessing the lessons, familiar with their general structure, and acquainted with the avenues for seeking help on the lessons. Unique to the intervention lessons were the specific objectives as well as the strategies designed to facilitate the psychological needs of self-determination theory. This section will contain the following: (a) the intervention unit objectives with associated standards and (b) the design components added to the intervention unit based on supporting the three needs of self-determination theory.

Intervention Unit Objectives

The self-determination theory-based online mathematics unit used for the intervention in this study fully contained the content, practice, and graded material required for the students to learn about and demonstrate their understanding of the topic of study: factoring polynomials. This topic was chosen because it is representative of the type of concepts normally encountered in an Algebra 2 course in the content type, degree of difficulty, and level of abstraction. The topic was also presented at a favorable time for the intervention, occurring midway through the third quarter and before course reviews and state testing.

The objectives were created based on the following Algebra 2 state test eligible content standards:

- "A2.1.2.2.1: Factor algebraic expressions, including difference of squares and trinomials. Note: Trinomials limited to the form $ax^2 + bx + c$ where a is not equal to 0" ("Keystone exams: Algebra II," 2014, p. 13).

- "A2.1.2.2.2: Simplify rational algebraic expressions" ("Keystone exams: Algebra II," 2014, p. 13).

The following prerequisite Algebra 1 state test eligible content standard was also built into this unit:

- "A1.1.1.2.1: Find the greatest common factor (GCF) and/or the least common multiple (LCM) for sets of monomials" ("Keystone exams: Algebra I," 2014, p.4).

Finally, these objectives and standards are aligned with the following high school Common Core State Standards for this area of study:

- "CC.2.2.HS.D.2: Write expressions in equivalent forms to solve problems" ("Common Core State Standards," 2010, Algebra).
- "CC.2.2.HS.D.3: Extend the knowledge of arithmetic operations and apply to polynomials" ("Common Core State Standards," 2010, Algebra).
- "CC.2.1.HS.F.2: Apply properties of rational and irrational numbers to solve real-world or mathematical problems" ("Common Core State Standards," 2010, Number and Quantity).

The intervention objectives, based on the standards described above, were addressed in the six lessons in the intervention unit, with the Algebra 1 prerequisite standards addressed in the first two lessons of the unit. Table 3.3 shows the relationship between the six intervention lessons, their objectives, the state test eligible content standards, and the Common Core State Standards. The factoring polynomials unit is the 10th unit in the course, which is made up of 16 total units.

Table 3.3 *Intervention Objectives and Standards Alignment*

Intervention Lessons	Intervention Objectives [Unit #. Lesson #. Objective #]	Eligible Content[a]	Common Core Standards[b]
Greatest Common Factor (GCF) Lesson	[10.1.1]: Students will be able to find the greatest common factor (GCF) given a set of monomials 80% of the time.	A1.1.1.2.1	CC.2.1.HS.F.2 CC.2.2.HS.D.3
	[10.1.2]: Students will be able to factor out the greatest common factor (GCF) given a polynomial expression 80% of the time.	A1.1.1.2.1	CC.2.2.HS.D.2
Least Common Multiple (LCM) Lesson	[10.2.1]: Students will be able to find the least common multiple (LCM) given a set of monomials 80% of the time.	A2.1.2.2.1	CC.2.1.HS.F.2 CC.2.2.HS.D.2 CC.2.2.HS.D.3
Factor Trinomials Lesson	[10.3.1]: Students will be able to factor a trinomial with a leading coefficient of 1 when given a factorable trinomial with a leading coefficient of 1 80% of the time.	A2.1.2.2.1	CC.2.2.HS.D.2
Factor Binomials Lesson	[10.4.1]: Students will be able to factor a difference of squares binomial expression given a difference of squares binomial expression 80% of the time.	A2.1.2.2.1	CC.2.2.HS.D.2
Factor by Grouping Lesson	[10.5.1]: Students will be able to factor a trinomial expression by grouping when given a factorable trinomial expression with an integer leading coefficient that does not equal 0 or 1 80% of the time.	A2.1.2.2.1	CC.2.2.HS.D.2
Simplify Rational Expressions Lesson	[10.6.1]: Students will be able to use factoring techniques to simplify rational algebraic expressions when given a reduceable expression 80% of the time.	A2.1.2.2.2	CC.2.2.HS.D.2

Note. [a]Abbreviations in this column include Algebra 1 (A1) and Algebra 2 (A2). [b]Abbreviations in this column include Common Core (CC), High School (HS), Algebra (D), and Number and Quantity (F).

Design Components Based on Self-Determination Theory

The intervention unit had specific design components based on the implementation strategies of the psychological needs of self-determination theory described in Chapter 2. These features aimed to support the fulfillment of the three needs in order to enhance internalized extrinsic and intrinsic motivation as opposed to controlled extrinsic motivation or amotivation. A summary of the design components in the intervention unit based on various implementation strategies of autonomy, competence, and relatedness illuminated in Chapter 2 is provided in Figure 3.1.

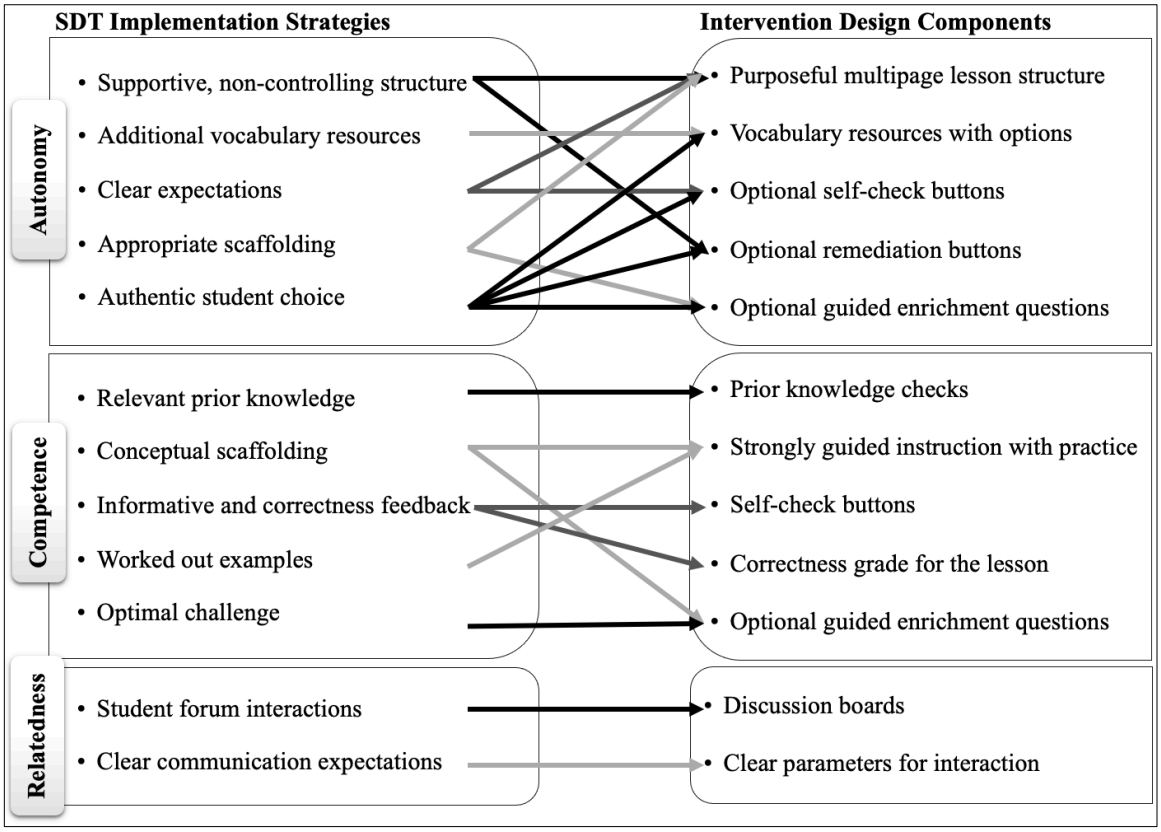

Figure 3.1. SDT Implementation Strategies and Intervention Design Components

This section will detail the design components for (a) autonomy, (b) competence, and (c) relatedness.

Autonomy components. The following features were built into the factoring polynomials unit to support autonomy: (a) purposeful multipage structure within the lessons, (b) additional vocabulary resources with built-in optional features, (c) optional self-check buttons, (d) optional remediation buttons, and (e) optional guided enrichment questions.

As described above, general lessons in the Algebra 2 course are displayed on one webpage where students scroll down to see all the content and there are no graded elements. In order to provide more appropriate structure in the facilitation of autonomy (Ryan & Deci, 2020), the intervention lessons were changed to a multipage format with graded elements. In total, students viewed the following five distinct pages when interacting with a lesson: the opening page, the introductory information page, two lesson example pages, and the summary with practice problems page.

When a lesson link was first clicked, participants viewed the opening page of the lesson. On this page, the objectives were provided in text under the title "Learning Targets." A lesson introduction to gain students' attention was provided under the title "Lesson Introduction." This introduction normally consisted of a video that provided a visual for the lesson or connected the lesson content to interesting information. The directions for completing the lesson, lesson standards, and any citations for the lesson were provided in tabs below those items. Students could view this information and, when ready, click to enter the lesson pages. See Figure 3.2 for a sample of this opening page lesson structure.

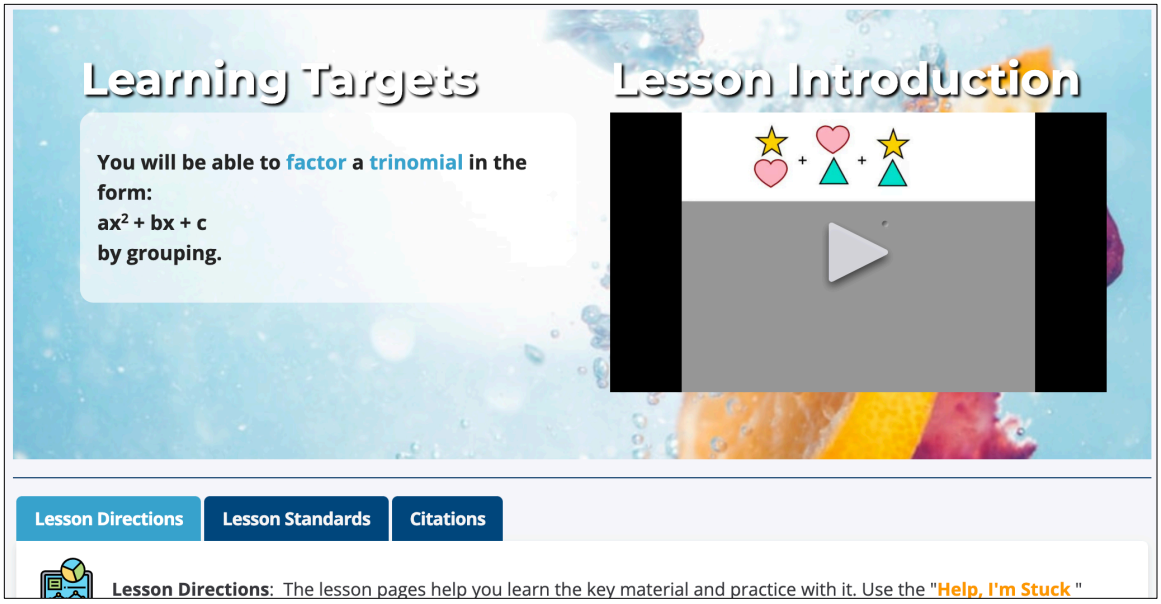

Figure 3.2. Sample of the Opening Page of an Intervention Lesson. From "Algebra 2: Factor by Grouping Lesson." Reprinted with permission.

After this opening page, students were taken to a screen where they could view each page of the lesson separately and click a next button to continue to the next page. The first lesson page contained the prior knowledge, vocabulary information, and explanation for the lesson. The next two pages were dedicated to the core examples for the lesson. Each of these lesson pages contained a check for understanding question in addition to any interactive activities on the page. The final page in the lesson included the summary and practice problems aligned with the lesson content. This supportive structure was meant to help in the reduction of cognitive load and support the scaffolding within the lesson, which is discussed in more detail in the Competence Components section below.

On the vocabulary page, a video explanation of the words with visual connections was added to the list of vocabulary words already provided. Students had the choice to read the vocabulary words, watch the video, or both. This increased support with the

flexibility of interaction options was meant to provide non-controlling structure and enhance autonomy for the learner (Qian & Sun, 2019). A sample of the vocabulary designed for the intervention with a video inside of a button and the list of words inside a button is shown in Figure 3.3.

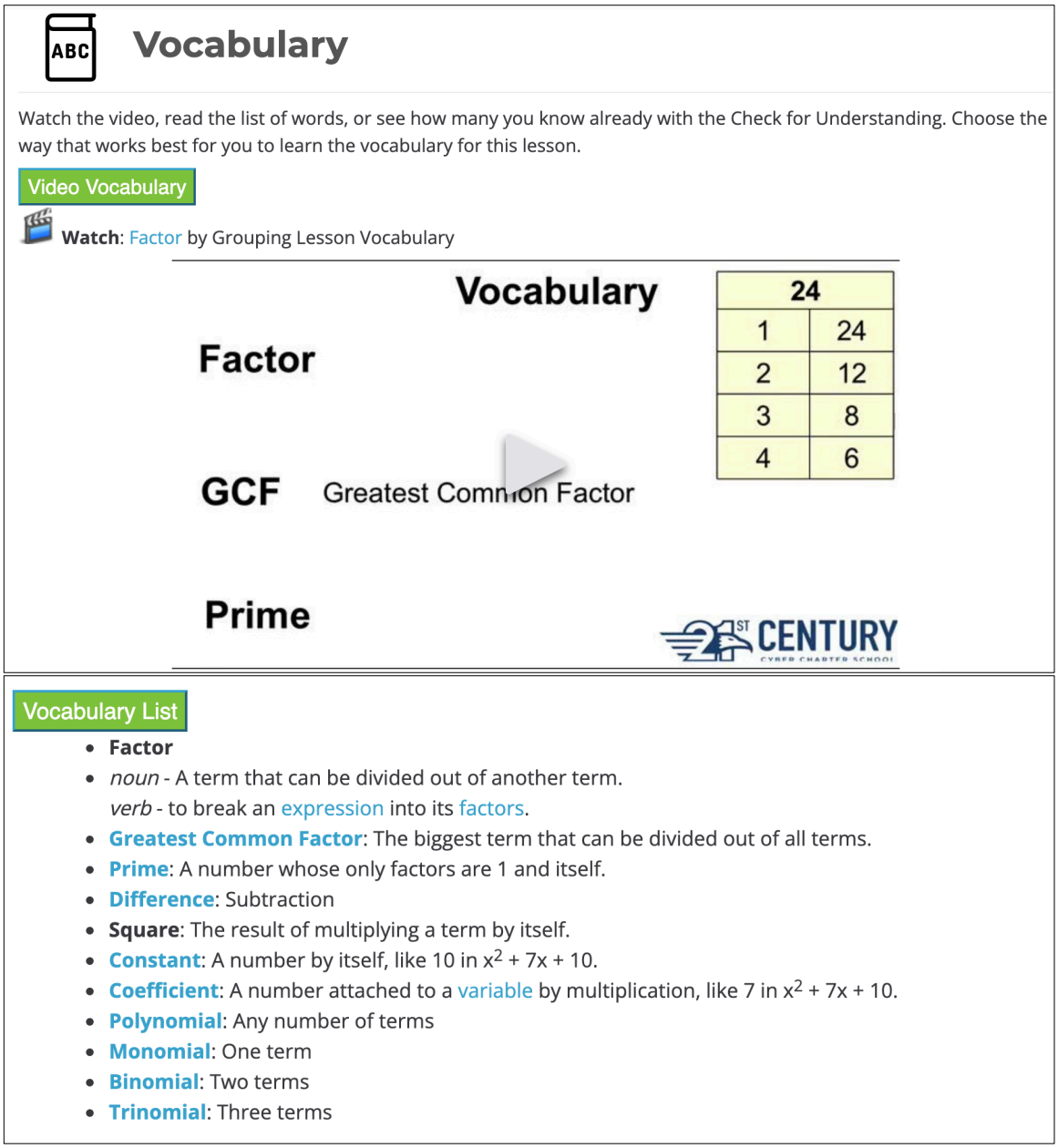

Figure 3.3. Sample of the Vocabulary Section of an Intervention Lesson. From "Algebra 2: Factor by Grouping Lesson." Reprinted with permission.

Along with the enhanced structure and vocabulary support, check buttons appeared after each check for understanding question and each practice question within the lessons. Upon pressing the check button, the students received immediate feedback and tips to help them try the problem again along with feedback about the correctness of their response. The informative and correctness feedback helped to provide clear expectations about the content for the students. Since the check buttons were optional, this feature also provided authentic student choice and promoted self-regulation. After pressing a check button, students could then press the try again button to try the problem a second time. A sample of the correctness and informative feedback provided after pressing a check button is shown in Figure 3.4.

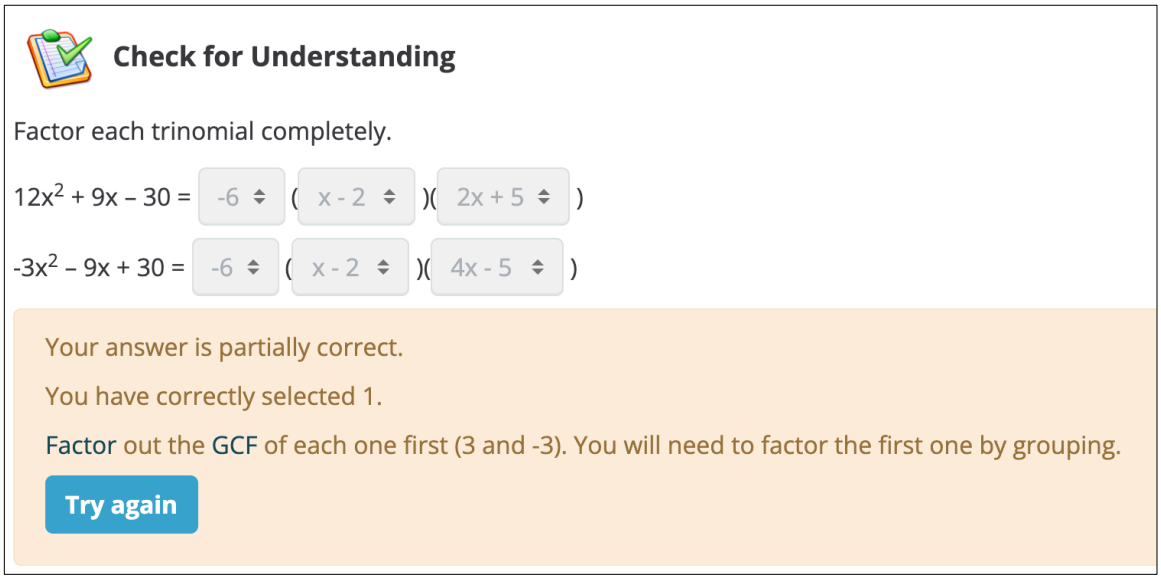

Figure 3.4. Sample of Check Button Feedback in an Intervention Lesson. From "Algebra 2: Factor by Grouping Lesson." Reprinted with permission.

Finally, additional authentic student choice was built into the lessons through optional remediation buttons and guided enrichment questions. Students had the choice to click on help buttons to see extra tips or information before attempting some questions or if they become stuck while attempting the question. Containing the extra information

within a button supported the reduction of cognitive load, as discussed in more detail in the Competence Components section. A sample of the optional remediation buttons, with one that has been opened to reveal the content and one that has not been opened, is shown in Figure 3.5.

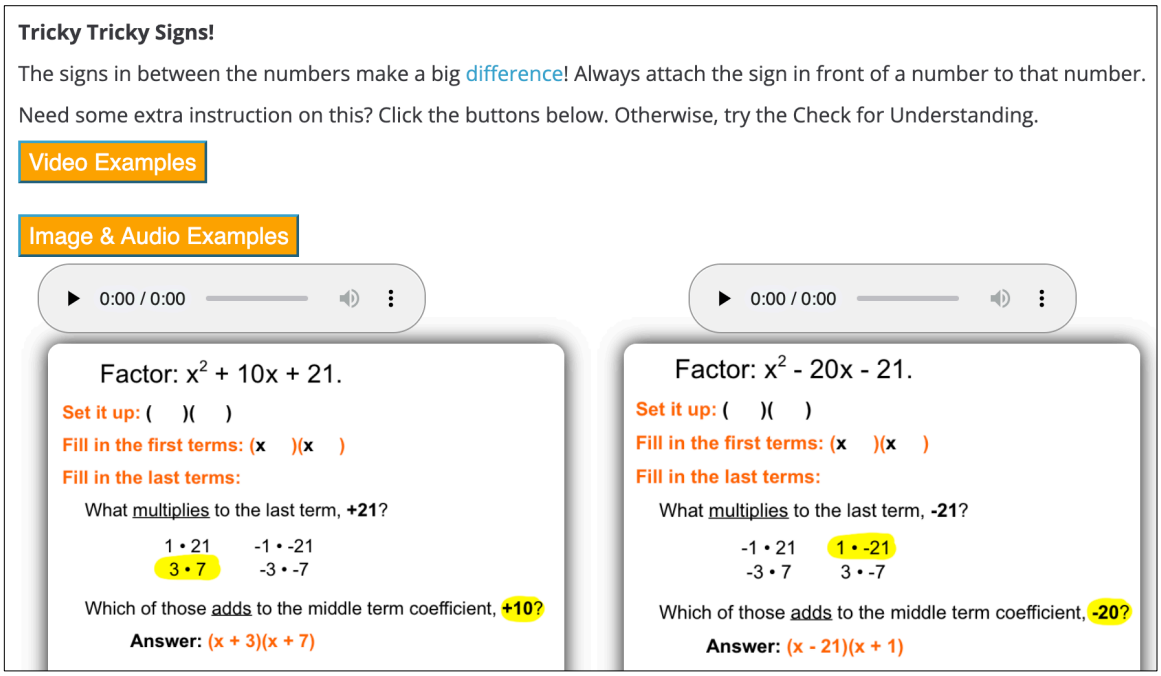

Figure 3.5. Sample of an Optional Remediation Button in an Intervention Lesson. From "Algebra 2: Factor Trinomials Lesson." Reprinted with permission.

In addition to the optional remediation, students could also attempt guided enrichment questions to extend their learning beyond the scope of the objectives in the lesson. The remediation offered extra support for learners that were struggling with the content while the enrichment added extra challenge for learners who felt they were ready for more difficult problems associated with the content. The enrichment questions did not negatively affect students' overall score if skipped. A sample of an enrichment question is shown in Figure 3.6. These remediation and enrichment options were meant to reduce

pressure and increase self-regulation by means of authentic student choice (Martin et al., 2018).

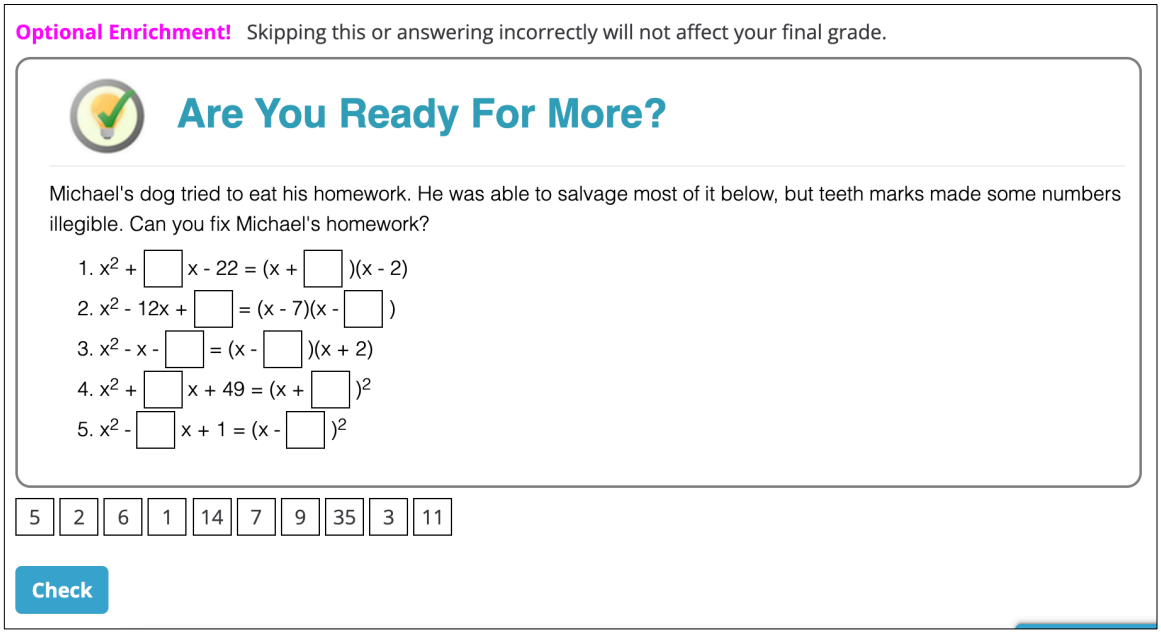

Figure 3.6. Sample of an Optional Enrichment Question in an Intervention Lesson. From "Algebra 2: Factor Trinomials Lesson." Reprinted with permission.

Competence components. The following features were built into the factoring polynomials lessons to support competence: (a) prior knowledge checks, (b) strongly guided instruction with practice, (c) self-check buttons, (d) a grade for the lesson, and (e) optional guided enrichment questions.

On the first page of each lesson, prior knowledge was presented. The prior knowledge section included a description of the prior knowledge students should have before beginning the lesson, guided instruction, and a check for understanding. Informative feedback appeared for the students if they clicked the check button after completing the check for understanding question. Students could then attempt the question again, if needed. These supports for student acquisition of relevant prior knowledge before beginning the lesson content were meant to bolster the perception of

competence (Chen, 2014). A sample of a prior knowledge section of an intervention lesson is displayed in Figure 3.7.

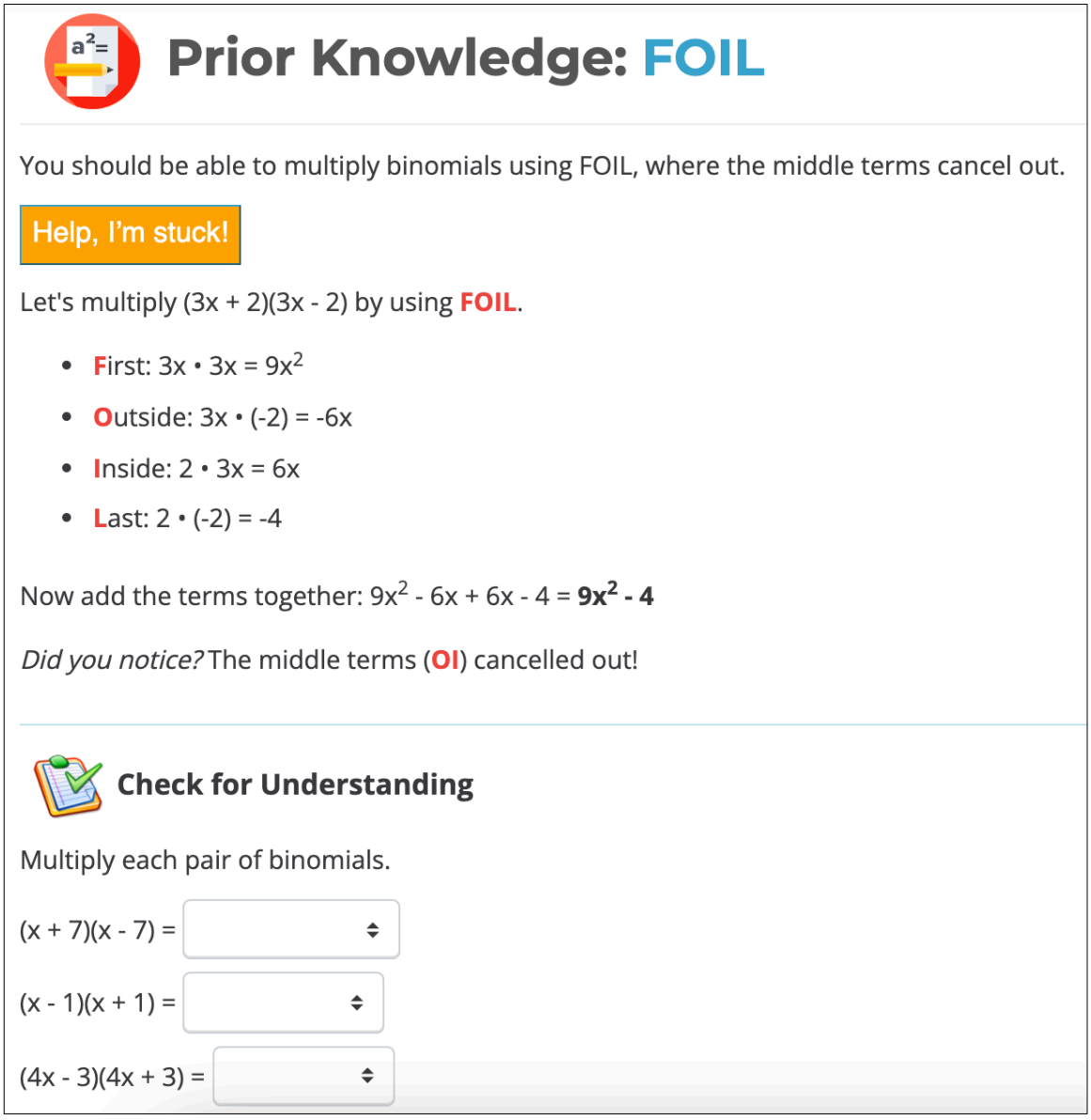

Figure 3.7. Sample of a Prior Knowledge Section in an Intervention Lesson. From "Algebra 2: Factor Binomials Lesson." Reprinted with permission.

Conceptual scaffolding was built into each example in the lesson to further support competence (Ak, 2016). Each example was separated onto its own page and strongly guided instruction was provided. At the end of the example, a check for

understanding question displayed a similar problem with the same procedures. For example, in the factoring binomials lesson, the first part of an example provided a video on how to factor a difference of squares binomial using a pattern with step-by-step examples. The next part of this example, shown in Figure 3.8, extended this thinking to more challenging difference of squares problems worked out for students to follow. The guided instruction with step-by-step processes and worked out examples was meant to aid in conceptual scaffolding and reducing cognitive load (Kirchener et al., 2006).

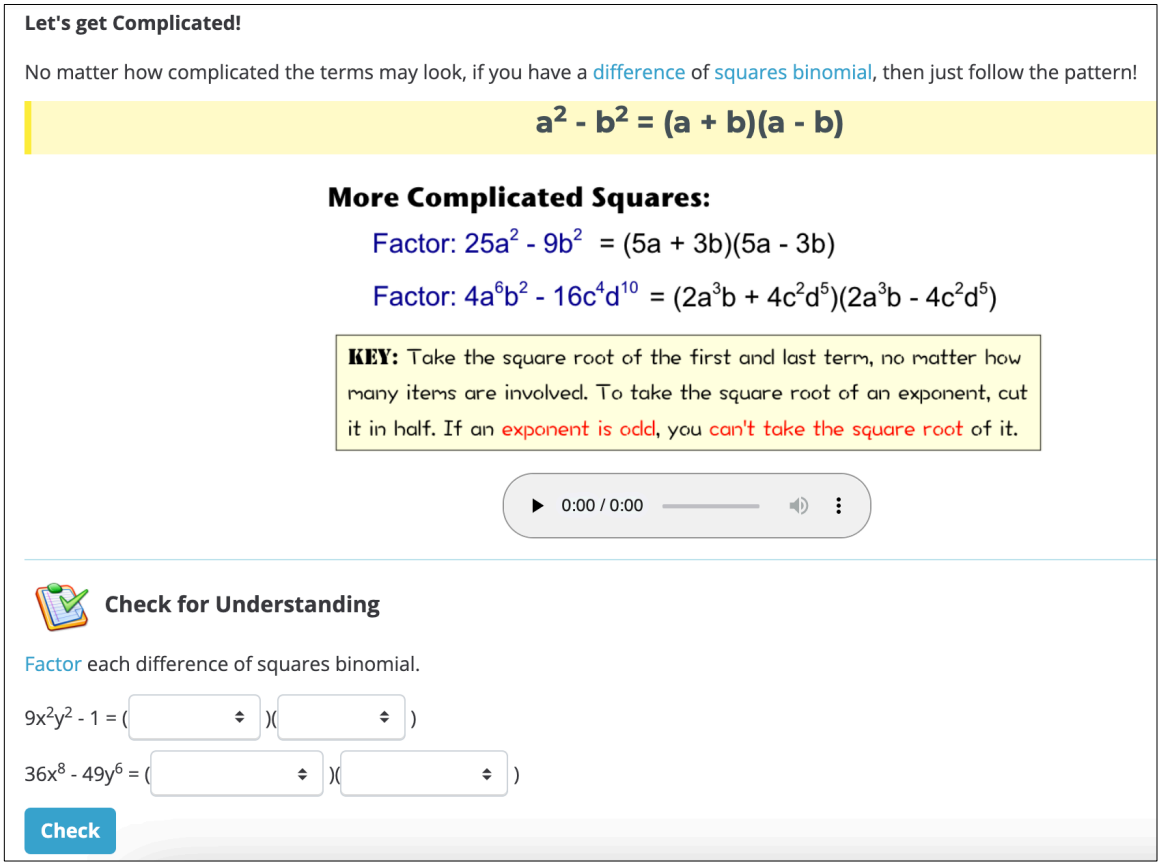

Figure 3.8. Sample of an Example in an Intervention Lesson. From "Algebra 2: Factor Binomials Lesson." Reprinted with permission.

Students had the opportunity to check each problem for correctness using the check button and receive informative feedback if the answer was incorrect, as discussed in the Autonomy Components section and shown in Figure 3.4. If incorrect, students

could attempt the problem again. By successfully completing the check for understanding question in each example, students may feel efficacious and confident to move onto the next lesson page. If unsuccessful on both attempts, students had the opportunity to learn from their mistakes through the informative feedback. The facilitation of competence may have been supported by providing both correctness and informative feedback (Cho & Shen, 2013).

The optional enrichment questions, like the check buttons, also provided an opportunity for the facilitation of both autonomy and competence. These enrichment questions, as shown in Figure 3.6, were meant to offer optimal challenge for students. The objectives for the lesson were fully explained with practice without the use of the enrichment questions. The enrichment questions went beyond the scope of the objectives, pushing students to apply their knowledge to a similar area or connect it to other mathematical content. These questions were clearly marked optional, and students were not penalized for skipping them. In this way, students may have been given choice and appropriate challenge with feelings of pressure, stress, and incompetence minimized (Martin et al., 2018).

Once each lesson was completed and submitted by the student, the student received a grade for the lesson based on the correctness of their final answers. The grade was meant to reflect the growth in the student's learning so that he or she may internalize and place value on the grade in association with self-efficacy. Receiving a grade for the lesson may have caused students to be more motivated to use the check features and supports built into the lesson. The goal with this part of the intervention was to promote

internalized extrinsic motivation along with supporting the psychological need for competence.

Relatedness components. Finally, the following features were built into the factoring polynomials unit to support relatedness: (a) discussion boards and (b) clear communication parameters for interaction in the discussion boards.

The goal of the discussion boards was to allow students to have a safe space to interact with other students and the teacher directly in Moodle. In this area, students could seek and offer help asynchronously. The discussion boards were available to students to share struggles, ask questions, and respond to other students' questions about the factoring polynomials unit. Samples of student posts in the discussion boards are provided in Chapter 4. The teachers were instructed to allow space for student-to-student interaction but also facilitate the discussions and questions. Teachers were encouraged to respond positively to students seeking extra help throughout the discussion boards.

Clear communication and structured interaction parameters were provided to the students concerning the discussion boards (Milman, 2017). For example, students were instructed to use positive and friendly communication and to show respect to other students. Students were required to post three quality discussion posts throughout each week of the factoring polynomials unit (Thompson, Leonard, & Bridier, 2019). Instructions indicated that these quality posts should not all occur on the same day. The posts had to be substantive, including items like questioning, references to the lessons, constructive tips and feedback, or short lesson summaries (Wang, 2019). Interactions involving tips for working in the lessons of the week, questions about how to complete a specific section of the lessons, and responses to a question providing informative

feedback for another student were encouraged (Thompson et al., 2019; Wang, 2019). Students were instructed that posts such as "I agree" or "that makes sense" would not be considered quality posts and an assessment rubric was provided to clearly depict varying levels of responses (Thompson et al., 2019).

The discussion boards were meant to provide an avenue for positive teacher and student interaction and appropriate student-to-student interactions (Bonk et al., 2018; Hew, 2016). As a result, the psychological need for relatedness, depicted by the perception of genuine social acceptance and the feeling of being a contributing member of a community, may have been supported and fulfilled (Ryan & Deci, 2020).

Data Collection Methods

Three data sources were used to determine the effects of implementing a self-determination theory-based online unit on the motivation levels of mathematics students at Peacock Cyber School in the Algebra 2 course. The data sources included a pretest-posttest motivation questionnaire, a pretest-posttest content knowledge exam, and student interviews. These three data sources were selected in order to contribute to a more holistic understanding of the study through both qualitative and quantitative data collection methods (Casey & Murphy, 2009; Mertler, 2017). Gathering data pertaining to participants' levels of autonomy, competence, and relatedness based on the motivation questionnaire and interviews in conjunction with data pertaining to their achievement in the unit based on the content knowledge exam helped triangulate the data. Additionally, analyzing changes in autonomy, competence, and relatedness using both quantitative and qualitative data provided a better understanding of the situation. Table 3.4 provides a

summary of the data sources that were collected and to which research question they applied.

Table 3.4 *Research Questions and Data Sources Alignment*

Research Questions (RQs)	Data Sources
RQ1: How does the implementation of a self-determination theory-based unit on factoring polynomials in an online mathematics course affect students' motivation at Peacock Cyber School?	• Pretest-posttest motivation questionnaire • Student interviews
RQ2: To what extent does the implementation of a self-determination theory-based online unit on factoring polynomials in an online mathematics course affect students' mathematics content knowledge at Peacock Cyber School?	• Pretest-posttest content knowledge exam

Motivation Questionnaire

I chose to use a motivation questionnaire with a Likert-scale to gather data concerning the participants' motivation levels for many reasons. The primary reason is that a specific motivation questionnaire, the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS), has been previously established for measuring the autonomy, competence, and relatedness levels of participants, as discussed below. In addition, valid and reliable closed-ended questionnaires can effectively measure attitudes among participants, provide consistency in a large group setting, provide easier data analysis over other types of data, allow the researcher to gather a variety and a large amount of data quickly, and provide perceived anonymity for the participants (Mertler, 2017; Rowley, 2012; Tashakkori & Teddlie, 2003). Yet even with these benefits, a

questionnaire was not sufficient to analyze how participants' perceptions of motivation were affected, so interviews were also used (Tashakkori & Teddlie, 2003).

The Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS) is a questionnaire that has been established to align with the basic psychological needs mini-theory within self-determination theory, expatiated upon in Chapter 2 (Chen et al., 2015). The BPNSFS has been validated using exploratory factor analysis, confirmatory factor analysis, and descriptive statistics (Chen et al., 2015). This scale has also been shown to be reliable in a group of 525 participants, with the internal consistencies among the items ranging from 0.64 to 0.89 (Chen et al., 2015). Applications of this scale have been used with secondary students in the areas of physical education (Haerens et al., 2015) and parenting (Cordeiro, Paixao, & Lens, 2015). The original BPNSFS along with any changes made for use in this study is provided in Appendix C.

The BPNSFS tests for both need satisfaction and need frustration of autonomy, competence, and relatedness in self-determination theory. The BPNSFS consists of 24 items, with four items corresponding to each of the six categories, as shown in Table 3.5 (Chen et al., 2015). Each item may receive a score of 1 to 5, based on a 5-point Likert scale. The score range for each of the six subscales is 4 to 20.

The motivation questionnaire was given as a pretest and posttest to every participant in the study. The pretest questionnaire was given before the intervention took place to identify a baseline for the perceived autonomy, competence, and relatedness levels of the participants. After the intervention was complete, the questionnaire was given again as a posttest.

Table 3.5 *BPNSFS Category and Item Alignment*

BPNSFS Categories	BPNSFS Items
Autonomy satisfaction	1, 8, 13, 19
Competence satisfaction	4, 10, 17, 24
Relatedness satisfaction	3, 6, 12, 21
Autonomy frustration	2, 11, 20, 23
Competence frustration	7, 14, 15, 18
Relatedness frustration	5, 9, 16, 22

Content Knowledge Exam

The content knowledge exam assessed students' content knowledge on the factoring polynomials unit. The exam was given as a pretest before the intervention and as a posttest after the intervention using the same questions. A change in scores from the pretest to posttest, used in conjunction with the other data in the study, may provide a more complete picture of the situation.

I created the exam questions based on the objectives of the factoring polynomials unit to reflect the content knowledge that should be gained from the self-determination theory-based online lessons. The eight objectives of the factoring polynomials unit were derived from the Algebra 1 and Algebra 2 state test eligible content standards and aligned to the Common Core State Standards, as described in the Intervention section. The dissertation committee validated this assessment from an educational research and psychological perspective and two subject matter experts in the mathematics department at Peacock Cyber School validated it from a content perspective.

The content knowledge exam contained 16 multiple-choice assessment items, two items for each of the eight objectives in the unit, as shown in Table 3.6. The full content knowledge exam is provided in Appendix D. Each item had a value of 1 point, for a total of 16 points.

Table 3.6 *Unit Objectives and Assessment Items Alignment*

Unit Objectives [Unit #. Lesson #. Objective #]: Objective	Assessment Items
[10.1.1]: Students will be able to find the greatest common factor (GCF) given a set of monomials 80% of the time.	4, 12
[10.1.2]: Students will be able to find the least common multiple (LCM) given a set of monomials 80% of the time.	8, 11
[10.1.3]: Students will be able to factor out the greatest common factor (GCF) given a polynomial expression 80% of the time.	14, 15
[10.2.1]: Students will be able to factor a trinomial with a leading coefficient of 1 when given a factorable trinomial with a leading coefficient of 1 80% of the time.	7, 16
[10.3.1]: Students will be able to factor a difference of squares binomial expression given a difference of squares binomial expression 80% of the time.	2, 6
[10.4.1]: Students will be able to factor a trinomial expression by grouping when given a factorable trinomial expression with an integer leading coefficient that does not equal 0 or 1 80% of the time.	9, 10
[10.5.1]: Students will be able to determine the appropriate factoring technique for a given polynomial expression in order to factor that expression using a GCF, difference of squares binomial technique, trinomial technique, or factoring by grouping 80% of the time.	1, 13
[10.6.1]: Students will be able to use factoring techniques to simplify rational algebraic expressions when given a reduceable expression 80% of the time.	3, 5

Student Interviews

I chose to use interviews in this study because they allow for in-depth participant responses, are flexible, and give the researcher the opportunity to probe and ask follow-up questions of the participants, which is not possible in the other types of data collection methods used in this study (Mertler, 2017; Tashakkori & Teddlie, 2003). The interviews gave the participants an opportunity to provide insight or opinions that were not gathered in the other closed-ended data collection methods. These benefits helped give a complete picture of how participants' motivation levels were affected by the intervention, specifically as those levels relate to the psychological needs of autonomy, competence, and relatedness.

The interviews in this study followed a semi-structured format with preplanned questions as well as follow-up probing questions (Mertler, 2017; Myers & Newman, 2007). Since interviews are more time consuming than other data collection methods and are better suited for a small number of participants (Alshenqeeti, 2014; Tashakkori & Teddlie, 2003), six participants were selected for the interviews using purposive and random sampling. Purposive sampling was used to seek a selection of participants from the career, college prep, and honors sections. Within those three levels, random sampling was used to request participation in the interviews. Using purposive and random sampling in this way could have allowed feedback to be gathered from students enrolled in all levels of the course, however, none of the students enrolled in the career section of the course that were randomly selected for the interviews agreed to participate. Instead, three participants from the college-prep section and three participants from the honors section completed the interviews. The demographic information for these six

interviewees was provided in the Participants section of Chapter 3 in Table 3.2. The interviews were intended to last approximately 30 to 60 minutes each, but actually lasted for about 10 to 20 minutes each based on the length of participant responses. The interviews were audio recorded and transcribed.

The interview questions are aligned to the three components of the first research question and include the following examples: (1) Describe a time when you used an optional help button or completed an optional challenge question if you did. *Follow up*: How did having the option to use these make you feel? (2) Give me an example of how your confidence level changed as you worked through a lesson. *Follow up*: What parts of the lesson, in particular, affected your confidence? (3) Describe the level of connectedness you felt to other students through the forums. (4) If you recall, 10% of the grade you received for the lesson came from the check for understanding questions throughout the lesson and 90% of the grade came from the practice questions on the final page of the lesson. How did receiving a grade for the lessons like this make you feel? and (5) If you completed an optional challenge question, how did the level of challenge make you feel? If you did not, why did you choose to skip these questions?

Since the interviews probed into how the intervention affected participants' perceptions of autonomy, competence, and relatedness, interpreting the responses in conjunction with the motivation questionnaire subscales was meant to provide a triangulation of the data. As such, Table 3.7 shows the alignment between the constructs of the first research question and the interview questions. The full interview protocol is provided in Appendix E and the full interview script with questions is provided in Appendix F.

Table 3.7 *Research Question 1 Constructs and Interview Questions Alignment*

RQ1: How does the implementation of a self-determination theory-based unit on factoring polynomials in an online mathematics course affect students' motivation at Peacock Cyber School?
a) How are students' feelings of autonomy affected?
b) How are students' feelings of competence affected?
c) How are students' feelings of relatedness affected?

Research Question 1 (RQ1) Constructs	Interview Questions
Autonomy	• How did you interact with the options for learning the vocabulary: the video, the list of words, and the check for understanding? *Follow up*: How did these options affect your learning? • How did the multipage structure of the lessons make you feel, with the prior knowledge and vocabulary on the first pages, examples on the following pages, and summary with graded practice on the last page? • Describe a time when you used an optional help button or completed an optional challenge question if you did. *Follow up*: How did having the option to use these make you feel?
Competence	• Describe how you felt after completing the prior knowledge checks on the first page of the lesson. • If you completed an optional challenge question, how did the level of challenge make you feel? If you did not, why did you choose to skip these questions? • Tell me about a time when you used the check buttons that appeared after each question in the lesson and provided feedback if you used one. *Follow up*: How did the check buttons help guide your thought processes? • Give me an example of how your confidence level changed as you worked through a lesson. *Follow up*: What parts of the lesson, in particular, affected your confidence? • If you recall, 10% of the grade you received for the lesson came from the check for understanding questions throughout the lesson and 90% of the grade came from the practice questions on the final page of the lesson. How did receiving a grade for the lessons like this make you feel?

Relatedness	• Tell me about an interaction you had in one of the forums. • Describe the feelings you had when using the forums. • Describe the level of connectedness you felt to other students through the forums.

Procedures and Timeline

The procedures for this research were organized into four phases. The actions and timeframe for each phase are outlined in Table 3.8 and described in detail following the table. Students progressed through the coursework independently, so the timeframe and start dates differed. The timeframes shown are on an average per student basis.

Table 3.8 *Timeline of Research Procedures*

Phase	Actions	Timeframe
Phase 1	• Obtained participant assent and guardian consent • Identified participants • Participants completed motivation pretest • Participants completed content knowledge pretest	2 weeks
Phase 2	• Participants completed intervention unit	3-4 weeks
Phase 3	• Participants completed content knowledge posttest • Participants completed motivation posttest • Conducted interviews with selected participants	6-8 weeks
Phase 4	• Analyzed pretest-posttest content knowledge exam results • Analyzed pretest-posttest motivation questionnaire responses • Analyzed interview responses • Conducted member checking	8-12 weeks

The first phase consisted of the introductory actions that needed to occur before the intervention and took approximately two weeks. I obtained assent from the willing students in the Algebra 2 course along with their guardian's consent. From this action, I identified my participant list. Each participant completed the motivation pretest and the content knowledge pretest for the study. Upon completion of these two pretests, the intervention unit was unlocked.

The second phase consisted of the intervention itself and took approximately three to four weeks. In this phase, the participants completed and submitted the intervention lessons and assignments in Moodle. During each week of the intervention, participants needed to complete two lessons, a quiz, and one discussion forum by posting or responding three separate times.

The third phase consisted of multiple data collection methods and took about six to eight weeks. After the participants completed the intervention unit, they completed the content knowledge posttest based on the factoring polynomials objectives and the motivation posttest concerning their levels of autonomy, competence, and relatedness. Finally, six participants completed the semi-structured interviews.

The fourth phase consisted of the analysis of the collected data and took approximately eight to twelve weeks. The pretest-posttest content knowledge exam, pretest-posttest motivation questionnaire, and interviews were analyzed according to the analysis techniques described in the Data Analysis section above. The interview transcriptions and inductive analysis occurred after all the interviews were complete. Member checking, including sharing the interview transcriptions and themes, helped to ensure the accuracy of the data analysis.

Rigor and Trustworthiness

Shenton (2004) posited that "over the last twenty years, much has been achieved by advocates of qualitative inquiry in demonstrating the rigour and trustworthiness of their favoured form of research" (p. 72-73). In this research study, rigor and trustworthiness were accomplished through a variety of forms. These forms included a statement of the researcher subjectivities and positionality, as described in detail in Chapter 1, thick and rich description, methodological triangulation, member checking, and peer debriefing (Creswell & Creswell, 2018; Houghton, Casey, Shaw, & Murphy, 2013; Mertler, 2017; Thomas, 2006).

Thick and Rich Description

Thick and rich description provided a full and detailed picture of the research setting and participants so that the reader could intricately understand the setting, feelings, and actions that occurred (Creswell & Creswell, 2018). I included a variety of details, such as the Moodle course setup, a detailed description of the general lessons and intervention lessons, and a description of the participants including demographic information (Amankwaa, 2016). Thick and rich description was achieved in this study specifically surrounding the setting, intervention, and interview process. Multiple examples of participant responses are included in Chapter 4 and supported by examples of discussion board posts. This type of thick and rich description was meant to give readers a sense of how the participants felt and reacted to the intervention. In this way, readers may be able to understand more fully the rationale for the emergent themes and assertions from the interviews.

Methodological Triangulation

According to Cope (2014), "with methods triangulation, the researcher uses multiple methods of data collection in an attempt to gain an articulate, comprehensive view of the phenomenon" (p. 90). Using multiple data collection methods in a research study adds credibility by both confirming the outcomes and providing a complete picture of the data (Casey & Murphy, 2009; Houghton et al., 2013). Analyzing and measuring a particular intervention in various ways helps corroborate the findings of the study while also providing a deeper and richer explanation of the phenomenon being studied (Adami, 2005).

In this study, methodological triangulation involved gathering both qualitative and quantitative data sources. These included the pretest-posttest motivation questionnaire, the pretest-posttest content knowledge exam, and the interviews. The reliability and validity of the quantitative measures was described in more detail in the Data Collection Methods section. Using these various quantitative and qualitative methods helped give a more complete picture of the participants' feelings, attitudes, and achievement as it related to their motivation levels in the intervention unit.

As part of the discussion of the methodological triangulation analysis in Chapter 5, salient discrepant findings were reported. Identifying this type of contradictory information that arose during the study was intended to add validity to the reporting of the results (Creswell & Creswell, 2018).

Member Checking

Member checking involves asking the participants to review and comment on parts of the final report and even some of the data gathered along the way (Creswell &

Creswell, 2018; Harper & Cole, 2012; Thomas, 2006). By doing this, "the rigor of the research is enhanced…by allowing participants to verify that various aspects of the research process adequately and accurately represent their beliefs, perspectives, and experiences" (Mertler, 2017, p. 27). Amankwaa (2016) gave suggestions for conducting member checks, including having each interviewee read his or her interview transcript and having a discussion with participants after important data analysis has occurred.

In this study, multiple forms of member checks occurred to ensure the accuracy of the data collected. Interviewees were provided with the transcript of the interview and asked to review it and provide feedback on it. A document containing a table summarizing the themes and categories identified from the interviews, along with a written description was also created and shared. The interviewees were asked to review and give input on the document provided.

Peer Debriefing

Peer debriefing is the process of allowing another professional to consider and analyze the research project and give input and suggestions (Creswell & Creswell, 2018; Houghton et al., 2013). This process can allow for better clarity or new perspectives about the way in which a research project was conducted and requires a high level of trust (Shenton, 2004; Spall, 1998).

In this study, my research advisor and dissertation committee at the University of South Carolina was consulted and critiqued various parts of the research study. These individuals were made aware of the research design, methods of data collection and analysis, findings, and other relevant information needed for a comprehensive

understanding of the study (Cope, 2014). Feedback was given for improvements before, during, and after the data collection and analysis phase.

Plan for Sharing and Communicating Findings

The findings of this action research study were shared with the participants of the study, certain stakeholders at the local level, and may possibly be shared with interested parties at the regional or national level.

In order to show a form of reciprocity with the participants of the study, a one page, easy to read and understand explanation of my findings and recommendations based on those findings was created (Creswell & Creswell, 2018). The document included the purpose of the study, the psychological needs that were analyzed, a summary of the quantitative and qualitative results in a simple table, and a brief explanation of the recommendations based on the findings. This document was e-mailed to the participants of the study. The communication encouraged participants to respond with any thoughts, questions, or suggestions.

At the local level, I conducted a meeting with the following stakeholders: the instructional systems design leader, the mathematics department head, the high school principal, and the director of curriculum. During this semi-formal meeting, I presented my findings from the research and my recommendations for future mathematics course design at Peacock Cyber School based on my findings (Mertler, 2017).

Finally, I will also consider the option of sharing my findings at a regional or national conference, such as the Future of Education Technology Conference (FETC), the Association for Educational Communications and Technology (AECT), or the International Society for Technology in Education (ISTE). In presenting at this level, as

with other levels, the confidentiality of my participants will be maintained. A pseudonym will be used for the school's name and its location will be described as the northeast region of the United States. A pseudonym will be used for each participant if sharing a specific participant response.

CHAPTER 4

ANALYSIS AND FINDINGS

The purpose of this action research was to create and implement a self-determination theory-based online unit on factoring polynomials for mathematics students at Peacock Cyber School in order to improve students' motivation levels. Data collection methods for this study included a motivation questionnaire, content knowledge test, and interviews in order to answer the following research questions: (1) How does the implementation of a self-determination theory-based unit on factoring polynomials in an online mathematics course affect students' motivation at Peacock Cyber School? and (2) To what extent does the implementation of a self-determination theory-based online unit on factoring polynomials in an online mathematics course affect students' mathematics content knowledge at Peacock Cyber School?

This chapter will begin with a presentation of the quantitative data as it relates to the motivation questionnaire and content knowledge test. This will be followed by a thorough explanation of the qualitative data collection and analysis process of the interviews as well as evidence for the themes identified.

Quantitative Findings

Quantitative data was collected in this study through the following two methods: (a) the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS) given as a pretest and posttest motivation questionnaire and (b) the content knowledge exam given

as a pretest and posttest. The results of these tests were analyzed using the open-source statistical analysis program, JASP (Version 0.16, 2021).

Motivation Questionnaire

As described in detail in Chapter 3, the motivation questionnaire (Appendix C) was adapted from the BPNSFS, which has been shown to be valid and reliable (Chen et al., 2015). The questionnaire has six subscales: autonomy satisfaction, autonomy frustration, competence satisfaction, competence frustration, relatedness satisfaction, and relatedness frustration. Each of the subscales has four questions associated with it using a 5-point Likert scale, for a range of 4 – 20 points for each subscale. A composite score was calculated for autonomy, competence, and relatedness using the satisfaction score and reversed frustration score for each need (Chen et al., 2015), resulting in a range of 8 – 40 points for each composite score. A mean composite score was calculated for each need for each participant, and these values were loaded into the JASP software. A total of 50 participants, who completed both the pretest and posttest for the motivation questionnaire, were included in the data analysis. Four participants did not complete the posttest and so were excluded from the data set. As a measure of internal consistency, Cronbach's alpha was calculated for the motivation pretest, accounting for the reverse scaled items. Cronbach's alpha value for the pretest was .88, which is an acceptable level of reliability (Taber, 2018).

Descriptive statistics. The mean and standard deviation were calculated for each subscale: autonomy, competence, and relatedness. The means ranged from 3.23 to 3.91, all of which are between the Likert scale options (3) "sometimes true / sometimes not true" and (4) "rather true", with the autonomy pretest being closest to (3) "sometimes true

/ sometimes not true" and the competence posttest being closest to (4) "rather true". The means for each of the subscales increased slightly between the pretest and posttest. The variance ranged from 0.51 to 0.79. The descriptive statistics are displayed in Table 4.1.

Table 4.1 *Descriptive Statistics for the Motivation Questionnaire*

Subscale	Pre			Post		
	Mdn	*M*	*SD*	*Mdn*	*M*	*SD*
Autonomy	3.25	3.23	0.51	3.31	3.42	0.65
Competence	3.63	3.65	0.79	4.00	3.91	0.76
Relatedness	3.63	3.52	0.66	3.69	3.66	0.76

Note: $n = 50$. Each subscale is based on a composite score from the satisfaction and reversed frustration score of that need.

Inferential statistics. Since the motivation questionnaire consisted of three subscales, the standard alpha value of .05 was divided by three to get .017 using the Bonferroni correction. Results from the Shapiro-Wilk normality test suggested that one of the subscales, competence, deviated from normality ($p < .001$). The autonomy subscale had a p value of .029 and the relatedness subscale had a p value of .174, which were not significant. Since one of the subscales deviated from normality, it was determined that the nonparametric Wilcoxon signed-rank test would be better suited for the data.

A Wilcoxon signed-rank test was conducted for each of the subscales in JASP to determine whether participants had an increase in the fulfillment of autonomy, competence, and relatedness. The results indicated that there was no significant difference from the autonomy subscale pretest ($Mdn = 3.25$) to posttest ($Mdn = 3.31$, $W = 423.50$, $p = .092$) and the relatedness subscale pretest ($Mdn = 3.63$) to posttest ($Mdn = 3.69$, $W = 368.00$, $p = .038$). The competence subscale, however, suggested a significant

difference from the pretest (*Mdn* = 3.63) to posttest (*Mdn* = 4.00, *W* = 233.00, *p* = .001). Overall, these results suggest that the participants (*n* = 50) increased in competence from the pretest to posttest, while no reliable changes were indicated for autonomy or relatedness.

Content Knowledge Test

The content knowledge test, described in detail in Chapter 3, consisted of 16 content knowledge questions based on the objectives in the unit and was validated by subject matter experts and the dissertation committee. Each question was worth one point for a range of scores of 0 – 16. The same test was used for the pretest and posttest. The pretest and posttest scores were converted into a decimal out of the total of 16 for each participant (*n* = 50) and was loaded into JASP for analysis. Four participants were excluded from these results because they did not complete the posttest. As a measure of internal consistency, Cronbach's alpha was calculated for the content knowledge pretest. Cronbach's alpha value for the pretest was .71, which is an acceptable level of reliability (Taber, 2018).

Descriptive statistics. The mean and standard deviation were calculated for the pretest and posttest. The mean score increased from 64.7% on the pretest to 92.0% on the posttest. The standard deviations ranged from 0.12 to 0.20. Table 4.2 displays these results.

Table 4.2 *Descriptive Statistics for the Content Knowledge Test*

	M	SD
Pretest	0.65	0.20
Posttest	0.92	0.12

Inferential statistics. After checking for normality of the data, a paired samples t-test was conducted to evaluate whether participants' scores increased. There was a significant difference in the scores for the content knowledge pretest ($M = 0.65$, $SD = 0.20$) and the content knowledge posttest ($M = 0.92$, $SD = 0.12$); $t(50) = 9.88$, $p < .001$.

Qualitative Findings and Interpretations

Qualitative data collection included semi-structured interviews with six participants after the completion of the factoring polynomials unit. Selection of the six interviews is described in Chapter 3 with their demographic information in Table 3.2. The interviews were recorded, transcribed, and organized into Microsoft Word and Excel for analysis.

The interviews were analyzed using inductive analysis to identify emerging themes based on the participants' perceptions (Mertler, 2017; Strauss, 1987). Specifically, eclectic coding was used to identify initial codes based on participant responses, including in vivo terms (Creswell & Creswell, 2018; Thomas, 2006). This process continued with refining the codes, applying classifications to the codes, and identifying categories for the codes in order to ascertain emergent themes from the interviews (Strauss, 1987; Wiebe, Durepos, & Mills, 2010). The process of eclectic coding, coding refinements, classifications, categories, identification of emergent themes, and creation of assertions resulted in 376 codes, 4 classifications, 19 categories, 3 themes, and 3 assertions. Peer debriefing occurred with my dissertation advisor after the initial coding, classifications, categories, and theme identification. My advisor reviewed my codes, categories, and themes and provided feedback along the way for improvements. Salient feedback is provided within the section that follows. The following section will

include a comprehensive description of the qualitative analysis process as well as an in-depth presentation of the emergent themes.

Analysis of Qualitative Data

The six participant interviews were conducted over the computer, with the audio recorded, and then transcribed. An initial transcription document was created from the audio files using Adobe Premier Pro. I listened to the audio files in their entirety while fixing and editing the transcription document word-by-word and line-by-line to ensure the accuracy of the transcriptions. The final transcription Word document with the six participant interviews was 23 pages long and contained a total of 10,903 words.

First cycle coding. With the transcription document ready, I began the first cycle of coding with eclectic coding. Eclectic coding can serve "as an initial, exploratory technique with qualitative data" (Saldana, 2021, p. 223). This exploratory stage included analytic memo writing and initial codes, a refinement of the codes, classifications, and a second refinement of the codes.

Analytic memos. I created a Word document with three columns: analytic memos, the transcription text, and initial codes. The analytic memos included my observations and comments about participants' inflections or intended meaning (Saldana, 2021). For example, one participant seemed to have trouble recalling the lessons in the study at first, evidenced by a hesitant tone of voice, but gained a more confident tone of voice as memories seemed to return. I noted this observation in the first column of the Word document. Figure 4.1 shows an example of some analytic memos in the left column, the transcript text in the middle, and the initial codes on the right.

It seemed that Devin had trouble remembering what the study lesson looked like at first. Started remembering what the lessons were like.	**Devin:** I felt pretty good about the work I had, but I did feel a little stressed because it was a lot to do and a little unmotivated because of how much it was just seeing all of it at once. **ES:** Gotcha. Was it like that first page of the lesson in particular or just like in general, the whole unit? **Devin:** I would just say the one lesson. I did like it a lot better doing this because it kind of was interactive and was easier for me to like understand it and learn. And it didn't feel as much as of workload after I did it for a week. **ES:** I gotcha. OK, so did the prior knowledge part help or did that just make you feel like it was more work, or do you feel like it helped you get the information you needed to remember? **Devin:** I think it helped. I don't think it really added too much on.	Initial stress Too much information *Interactive* Easy to understand Less work Helpful

Figure 4.1. Sample of First Round of Initial Codes

Initial codes. I created the initial codes by reading the transcripts line-by-line with the goal describing the participants' meaning concisely or using the participants' own words with in vivo codes, when appropriate (Creswell & Creswell, 2018). Being immersed in the data by reading and coding it line-by-line helps "the researcher in being methodical and, perhaps, pedantically focused on identifying textual subtleties fueling the construct of meaning" (Williams & Moser, 2019, p. 51). Through the line-by-line initial coding, I began this process of constructing meaning. The first round of coding produced 261 codes.

After reviewing the initial round of coding with my advisor, I found many sections needed additional codes to fully describe the participants' point of view, often related to participants' expression of feelings and emotions. I conducted a second round of coding by reading through the three-column transcription document line-by-line and adding additional codes when needed. This process produced an additional 115 codes, for

a total of 376 codes. Figure 4.2 shows the same sample of codes as Figure 4.1 after the additional round of coding.

It seemed that Devin had trouble remembering what the study lesson looked like at first. Started remembering what the lessons were like.	**Devin:** I felt pretty good about the work I had, but I did feel a little stressed because it was a lot to do and a little unmotivated because of how much it was just seeing all of it at once. **ES:** Gotcha. Was it like that first page of the lesson in particular or just like in general, the whole unit? **Devin:** I would just say the one lesson. I did like it a lot better doing this because it kind of was interactive and was easier for me to like understand it and learn. And it didn't feel as much as of workload after I did it for a week. **ES:** I gotcha. OK, so did the prior knowledge part help or did that just make you feel like it was more work, or do you feel like it helped you get the information you needed to remember? **Devin:** I think it helped. I don't think it really added too much on.	Initial stress Too much information Satisfaction in work Somewhat unmotivated *Interactive* Easy to understand Felt like less work Enjoyed new lesson style Helpful prior knowledge Reasonable workload

Figure 4.2. Sample of Second Round of Initial Codes

Refinement 1. After these two rounds of creating initial codes, I copied the column of codes into an Excel file for further analysis. I refined the initial list of codes to use more concise and accurate language, referring to the original transcripts to ensure accuracy. For example, the initial codes *better than split lesson and assignment* and *better than a separate lesson and assignment* were refined into *all-in-one better format* to identify the participants' perception that including the lesson, practice, and quiz questions together provided a better format than a separate lesson and quiz. Other examples of refinements include changing *knowing what to do felt good* to *satisfaction with competence* and changing *everything grouped together* to *chunked information*. This refinement process enabled me to be more engaged with the transcripts and notice similar codes.

Classifications. Next, I analyzed the list of codes to create classifications. The process of identifying classifications for the codes began with being immersed in the transcriptions and initial coding. Through this undertaking and repeated examination of the initial codes, a total of four classifications emerged from elemental coding methods and affective coding methods (Saldana, 2021). The four classifications were descriptive, in vivo, emotion, and value.

Descriptive classification. The descriptive classification was most appropriate for many of the codes because the participants' responses often referred to specific sections or areas of the intervention in the study. Assigning labels to these different areas allowed the codes to be separated and organized in the same way for each participant. The following nine labels were used for the descriptive classifications: prior knowledge (codes that identified the prior knowledge section of the lessons), vocabulary (codes that identified the vocabulary section of the lessons, checks (codes that identified information about the checks for each question in the lessons), challenge (codes that identified the optional enrichment section of the lessons), learning (codes that referred to parts of the lessons that supported learning), lesson structure (codes that identified aspects of the lesson structure), peer interaction (codes that identified the forum section of the intervention), workload (codes that identified the amount of work required for the unit), and grade for lesson (codes that described the grading features of the lessons).

In vivo classification. The in vivo classification enabled me to capture the participants' own words in describing their experience. This classification is important in order to "prioritize and honor the participant's voice" (Saldana, 2021, p. 138). Figure 4.3 shows examples of some salient in vivo codes.

All-in-one	In Vivo
I knew what I was doing more	In Vivo
Interactive	In Vivo
Learn by example	In Vivo
Little reminders	In Vivo
Organized lessons	In Vivo
Better understanding	In Vivo
Not *a big page of information*	In Vivo
Not as *mushed together*	In Vivo
Not *jumping headfirst into a pool*	In Vivo
Not *plunging into new stuff*	In Vivo
Something to fall back on	In Vivo
Had something to fall back on	In Vivo
Community in the forums	In Vivo
Connect with my classmates	In Vivo
Helped me with stepping out of my comfort zone	In Vivo
I'm not the only one	In Vivo
Worthwhile	In Vivo

Figure 4.3. Sample of In Vivo Codes

Emotion and value classifications. Apart from the descriptive and in vivo elemental coding classifications, I identified two affective coding classifications: emotion and value. I used the emotion classification because of the many feelings noted by the participants. I applied this classification to codes such as *not trapped*, *no pressure*, and *increased confidence*. Some of the feelings expressed went beyond emotion and displayed "a participant's values, attitudes, and beliefs representing his or her perspectives" (Saldana, 2021, p. 167). For example, codes such as *liked options*, *low stakes challenge*, *appreciated common struggles*, and *feedback satisfaction* went beyond feelings about the situation. These codes demonstrated that the participant valued the importance of or effect that these situations had on their experience.

The process of identifying classifications for the codes resulted in four major classifications: descriptive, in vivo, emotion, and value, with the descriptive classification having nine subtopics. Table 4.3 shows a breakdown of the classifications and the number of codes per classification for the 376 initial codes.

Table 4.3 *Number of Codes per Classification and Subtopic*

Classification	Subtopic	Number of Codes
Descriptive	Challenge	20
	Checks	38
	Grade for Lesson	7
	Learning	26
	Lesson Structure	28
	Peer Interaction	43
	Prior Knowledge	9
	Vocabulary	18
	Workload	6
In Vivo		69
Emotion		59
Value		53

Second refinement. Concurrently with the classifications, I conducted another round of code refinement. During peer debriefing with my dissertation advisor concerning my first refinement of codes, he suggested I focus on codes that have a common idea or intent from the participants. As a result, in this second refinement I especially focused on similar codes and the use of the same code for the same idea. For example, for the codes *low stress challenge*, *no pressure challenge*, and *no pressure options*, I used the new code *no pressure*. For the codes *extra challenge practice* and *option for extra practice*, I used the new code *extra practice*. During this process, I

referred to the original transcripts, as needed, to ensure the meaning of the participants' words was not being distorted.

Figure 4.4 shows a sample of the initial 376 codes, the first refinement of the codes, the classifications, and the second refinement of the codes.

Refinement 2	Classifications	Refinement 1	Initial Codes
Initial stress	Emotion	Initial stress	Initial stress
Too much information	Descriptive - Workload	Too much information	Too much information
Reasonable amount of work	Value	Reasonable amount of work	Satisfaction in work
Somewhat unmotivated	Emotion	Somewhat unmotivated	Somewhat unmotivated
Interactive	In Vivo	*Interactive*	*Interactive*
Less confusion	Descriptive - Learning	Understandable	Easy to understand
Lighter workload	Descriptive - Workload	Lighter workload	Felt like less work
Enjoyed structure	Value	Lesson style satisfaction	Enjoyed new lesson style
Helpful prior knowledge	Descriptive - Prior Knowledge	Helpful prior knowledge	Helpful prior knowledge
Reasonable workload	Descriptive - Workload	Reasonable workload	Reasonable workload
Video vocabulary	Descriptive - Vocabulary	Video vocabulary	Tried video vocabulary
List of words	Descriptive - Vocabulary	List of vocabulary	Preferred list of vocabulary
Liked options	Value	Willingness with choices	Options alleviate reluctance
Liked options	Value	Satisfaction with choices	Liked having options
All-in-one	In Vivo	*All-in-one*	*All-in-one*

Figure 4.4. Sample of Initial Codes, Refinement 1, Classifications, and Refinement 2

Second cycle coding. With the initial codes, refinements, and classifications organized in an Excel document, I was ready to transition into a second cycle of coding. According to Saldana (2021), "the primary goal during second cycle coding is to develop a sense of categorical, thematic, conceptual, and/or theoretical organization from your array of first cycle codes" (p. 297). In beginning this process, I read through the codes multiple times and thought about the different ways the codes could be grouped together. There were two main ways the data could have been organized.

One way I could have organized the data was to group it around the different sections of the intervention, such as forums, mixed practice, vocabulary, challenge questions, and prior knowledge. This method, however, broke up many of the emotion, value, and descriptive codes that belonged together but were in different sections of the

intervention. For example, the codes related to skipping optional material belonged together, but some were in reference to the vocabulary options, and some were in reference to the challenge questions. As another example, many of the codes referenced better, more usable resources throughout the intervention, but these were in connection with various parts of the intervention such as the challenge questions, forums, and vocabulary. This method of organizing the data did not best fit the intent of the participants' sentiments.

Instead, I elected to organize the data using the second possible method. This method of organization used focused coding of similar elements. In this way, the categories came about organically, from the codes, rather than from predefined sections. I initially identified categories from the codes that were most obvious because of the participants' repeated focus on these codes. For example, some of the initial categories included *lesson structure supported learning*, *prior knowledge helpful*, and *positive peer connections*.

As I moved and reorganized codes into different categories, I was able to analyze related codes and refine the categories to best encompass the related codes. For example, the many codes in *prior knowledge helpful* were split into the categories of *prior knowledge increased confidence for the lesson* and *prior knowledge gave useful information* to differentiate between the results of confidence and learning with the prior knowledge. As another example, the many codes in *positive peer connections* were split into the categories of *peer interactions aided in learning*, *positive peer connections*, and *shared experiences*. Through this process, I created 19 categories for the 376 codes.

To make continued analysis easier, I used colors for the second refinement of the codes and for the classifications. I used a distinct text color for codes that ended up exactly the same in the second refinement. Additionally, since the classifications were being split up and moved around into the different categories, I attached a specific fill color to each classification and its associated code to make keeping track of them easier. Figure 4.5 shows a sample of the categories added to the original Excel file of initial codes, refinement 1, classifications, and refinement 2, along with the color coding of the text for refinement 2 of the codes and the fill color for the classifications.

Content chunking facilitated understanding	Chunking	Descriptive - Lesson Stru	Small chunks of informati	Small chunks of information
	Chunking	Descriptive - Lesson Stru	Useful content separation	Useful content separation
	Concise explanations	Descriptive - Lesson Stru	Concise explanations	Less lengthy run-on explana
	Better understanding	In Vivo	*Better understanding* with	*Better understanding* with v
	Not *a big page of information*	In Vivo	Don't have to remember a	Don't have to remember *a b*
	Not *a big page of information* a	In Vivo	Not *a big page of informa*	Not *a big page of informatio*
	Not as *mushed together*	In Vivo	Lesson not as *mushed to*	Lesson not as *mushed toge*
Scaffolding aided understanding	Less confusion	Descriptive - Learning	Less lesson confusion	Less trouble with the lesson
	Less confusion	Descriptive - Learning	Less teacher questions	Less teacher questions
	Less confusion	Descriptive - Learning	Understandable	Easy to understand
	Step-by-step help	Descriptive - Learning	Learning snowballed	Building on learning through
	Step-by-step help	Descriptive - Learning	Step-by-step	Step-by-step
	Step-by-step help	Descriptive - Learning	Step-by-step guidance	Step-by-step guidance
Prior knowledge increased confidence for the lesson	Oriented the learner	Descriptive - Prior Knowle	Oriented the learner	Oriented the learner
	Oriented the learner	Descriptive - Prior Knowle	Orienting the learner	Orienting the learner
	Oriented the learner	Descriptive - Prior Knowle	Prepared by prior knowle	Confidence before entering
	Increased confidence	Emotion	Assurance with prior knov	Assurance with prior knowle
	Increased confidence	Emotion	Confidence to advance	Confidence to move on with
	Increased confidence	Emotion	Confidence with prior knc	Confidence with prior knowl
	Liked prior knowledge	Emotion	Liked prior knowledge	Liked prior knowledge
	Not *jumping headfirst into a poc*	In Vivo	Not *jumping headfirst into*	Not *jumping headfirst into a*
	Not *plunging into new stuff*	In Vivo	Not *plunging into new stu*	Not *plunging into new stuff*
	Something to fall back on	In Vivo	*Something to fall back on*	*Something to fall back on*
	Felt prepared	Value	Felt more prepared	Felt more prepared
	Felt prepared	Value	Prior knowledge satisfact	Happy about reminder of im
	Felt prepared	Value	Satisfaction with prior knc	Satisfaction with prior knowl

Figure 4.5. Sample of Initial Codes, Refinements, Classifications, and Categories

Throughout the process of focused coding, it became apparent that certain categories were connected and came together to explain a broader idea or theme. A summary of how the categories connect to the themes, along with the number of codes in each category, is provided in Table 4.4.

Table 4.4 *Number of Codes for Themes and Related Categories*

Theme	Categories	Number of Codes
Participants expressed that the elements of the lesson structure were supportive of their learning and not overwhelming.	• Lesson structure supported learning	44
	• Content chunking facilitated understanding	11
	• Scaffolding aided understanding	6
	• Prior knowledge increased confidence for the lesson	15
	• Prior knowledge gave useful information	9
	• Challenge questions revealed deeper content	6
	• Options improved motivation	34
	• Skipped optional material	5
	• Accessible resources	20
	• Good weekly expectations	18
After some initial stress, participants indicated a high level of assurance and an increase in understanding through the feedback features within the lesson.	• Feelings of stress	5
	• Checking answers increased confidence	61
	• Informative feedback improved learning	23
	• Appropriate content level	9
	• Grade increased motivation	31
Despite expressing frustration with the forums at times, participants articulated that the positive peer relationships and common struggles supported their learning and connectedness.	• Peer interactions aided in learning	26
	• Positive peer connections	31
	• Shared experiences	16
	• Forum frustrations	6

Theme one emergence. From being immersed in the qualitative data through the first and second cycle coding processes, certain categories were noticeably related. For example, *prior knowledge increased confidence for the lesson*, *prior knowledge gave*

useful information, *challenge questions revealed deeper content*, and *accessible resources* all related to how elements of the lesson structure supported participants in different ways. Some of these categories referred to specific sections of the lessons and others referred to the general functionality of the lessons, such as *scaffolding aided understanding*, *lesson structure supported learning*, *content chunking facilitated understanding*, and *options improved motivation*. These eight categories came together naturally to develop the broader idea of lesson elements and functionality, as they relate to participants' experience in the lesson.

Two additional categories were subsumed into this theme: *skipped optional material* and *good weekly expectations*. The codes within *skipped optional material* related to either skipping the options within the vocabulary section or skipping the challenge questions, both of which are built-in features of the lesson functionality meant to support participants. The codes within *good weekly expectations* include *lighter workload*, *reasonable workload*, *less skipping*, and *not cumbersome*. These codes build upon how the basic structure of the lessons affected participants' expressed feelings of encumbrance, or lack thereof. Since both of these categories related to the lesson structure, they were added to the previous eight categories in this theme. These ten categories came together to reveal the following theme: *participants expressed that the elements of the lesson structure were supportive of their learning and not overwhelming*. Based on this theme, I developed the assertion that *an all-in-one lesson structure including prior knowledge, optional help and challenge, and content chunking elements supported participants' autonomy and competence, ultimately improving their*

motivation. The relationship between these categories, theme, and assertion will be elaborated upon in the Presentation of Findings section below.

Theme two emergence. In a similar development process as the first theme, five categories contributed to the formation of the second theme. I grouped the categories *checking answers increased confidence* and *informative feedback improved learning* together because they related to the ability for participants to check their answers directly in the lesson and receive immediate feedback on their responses. The feedback included informative feedback with a hint for how to complete the question as well as correctness feedback based on their response. At this point, a theme about informative and correctness feedback for improving assurance among participants began to emerge. One more category supported this theme because it related to a grade, which is a form of correctness feedback, benefitting participants. This category is *grade increased motivation*.

Less obvious, but still important in developing this theme are the categories *appropriate content level* and *feelings of stress*. I chose to include *appropriate content level* in this theme because the ability for participants to improve and feel assurance through checking the question is related to the content level of the question. For example, if the question was much too easy, participants would likely not need to check it to feel assurance. Conversely, if the question was much too difficult, receiving correctness feedback and a hint would likely not aid in the participants' ultimate success with the question. I chose to include the final category, *feelings of stress*, in this theme because the codes in this category tended to revolve around *initial* stress. This stress was lessened as

participants worked through the lessons, checking and receiving feedback about their competence along the way.

Based on the interconnectedness of these five categories surrounding feedback, the following theme emerged: *after some initial stress, participants indicated a high level of assurance and an increase in understanding through the feedback features within the lesson*. Based on this theme and research related to autonomy and competence within self-determination theory, I developed the assertion that *immediate correctness feedback and hints, coupled with an appropriate level of challenge within a lesson, improved participants' perception of competence and autonomy, ultimately increasing their motivation.*

Theme three emergence. Four categories came together in creating the third and final theme. The *peer interactions aided in learning*, *positive peer connections*, and *shared experiences*, all related to the positive ways participants felt and interacted with other participants through the forums. These categories began to emerge into a theme about peer relationships and interactions. Another category, *forum frustrations*, also related to these peer interactions, but in a negative way. As a result, the following theme arose from these four categories: *despite expressing frustration with the forums at times, participants articulated that the positive peer relationships and common struggles supported their learning and connectedness*. Based on this theme, I developed the assertion that *negative feelings that may have been initially associated with forums were outweighed by the positive effects of participant interactions, which allowed for feelings of relatedness, ultimately improving participants' motivation*.

With the analysis of the qualitative data complete including three assertions, three themes, 19 categories, and 376 codes, I conducted member checking as an extra measure to ensure the accuracy of the analysis. The member checking included emailing the interviewees a digital copy of their transcript as well as a summary of the themes and categories found from the interview transcripts, as shown in Table 4.4. A summary describing the qualitative analysis process was also provided with the table. Participants were asked to respond with any feedback or concerns about the information provided. After e-mailing each of the participants, none of them responded with feedback for changing the information provided.

Presentation of Findings

Throughout the presentation of findings, pseudonyms will be used to identify participants and quotes from the participants will be verbatim. The pseudonyms used for the interviewees and related demographic information is provided in Table 3.2. The following three emergent themes, along with their assertions and categories, will be expatiated upon in the sections below: (a) participants expressed that the elements of the lesson structure were supportive of their learning and not overwhelming, (b) after some initial stress, participants indicated a high level of assurance and an increase in understanding through the feedback features within the lesson, and (c) despite expressing frustration with the forums at times, participants articulated that the positive peer relationships and common struggles supported their learning and connectedness. Table 4.5 provides a summary of the qualitative findings, including the assertions, themes, and categories.

Table 4.5 *Summary of Qualitative Findings*

Assertion	Theme	Categories
An all-in-one lesson structure including prior knowledge, optional help and challenge, and content chunking elements supported participants' autonomy and competence, ultimately improving their motivation.	Participants expressed that the elements of the lesson structure were supportive of their learning and not overwhelming.	• Lesson structure supported learning • Content chunking facilitated understanding • Scaffolding aided understanding • Prior knowledge increased confidence for the lesson • Prior knowledge gave useful information • Challenge questions revealed deeper content • Options improved motivation • Skipped optional material • Accessible resources • Good weekly expectations
Immediate correctness feedback and hints, coupled with an appropriate level of challenge within a lesson, improved participants' perception of competence and autonomy, ultimately increasing their motivation.	After some initial stress, participants indicated a high level of assurance and an increase in understanding through the feedback features within the lesson.	• Feelings of stress • Checking answers increased confidence • Informative feedback improved learning • Appropriate content level • Grade increased motivation
Negative feelings that may have been initially associated with forums were outweighed by the positive effects of participant interactions, which allowed for feelings of relatedness, ultimately improving participants' motivation.	Despite expressing frustration with the forums at times, participants articulated that the positive peer relationships and common struggles supported their learning and connectedness.	• Peer interactions aided in learning • Positive peer connections • Shared experiences • Forum frustrations

Theme 1: Participants expressed that the elements of the lesson structure were supportive of their learning and not overwhelming. Specifically, participants indicated that the all-in-one lesson functionality, prior knowledge openers, optional help and challenge items, and content chunking elements of the lesson aided in their understanding, enjoyment, and confidence within the lesson. For example, Eddie explained how the optional help buttons provided throughout the lessons improved his understanding: "I didn't use all the help buttons because I, on some of the lessons, I definitely had a better understanding, but I did throughout use the help buttons, and I think it did help me better understand." Blake identified that the structure of the lesson was enjoyable and helpful: "I quite liked [the multipage structure of the lessons] because it was separated by what all I was learning in that lesson. So, I found it useful for the way I learned." Ava described the increased confidence that resulted from the prior knowledge checks: "I liked completing [the prior knowledge check] because it gave me confidence that I knew what I was doing so that I could then complete the lesson." Each of these examples show how elements of the lesson structure supported the participants' learning or confidence.

The categories in this theme relate directly to elements of the lesson and not to the forums or quizzes students took part in during the intervention. Additionally, although some codes within these categories may tangentially relate to the checks or immediate feedback within the lesson, the element of computer feedback within the lesson is comprehensively addressed in theme two, not in this theme. Theme one focuses on facets that participants expressed related to all other lesson elements, whether that be an expression of feelings, values, or learning related to the lesson elements. Perhaps due to

this broad focus, theme one has the most categories and codes compared to the other two themes. Table 4.6 shows the number of categories and codes corresponding to each theme.

Table 4.6 *Number of Categories and Codes for Themes*

Theme	Number of Categories	Number of Codes
Participants expressed that the elements of the lesson structure were supportive of their learning and not overwhelming.	10	168
After some initial stress, participants indicated a high level of assurance and an increase in understanding through the feedback features within the lesson.	5	129
Despite expressing frustration with the forums at times, participants articulated that the positive peer relationships and common struggles supported their learning and connectedness.	4	79

The general lesson structure in the study was created based on Gagne's nine events of instruction. It is not a new phenomenon, then, that participants identified this structure as positively affecting their learning. For example, Ullah, Rehman, and Bibi (2015) conducted a study on Gagne's nine events of instruction and concluded that "a deliberate effort should be made to stimulate learners to recall the relevant prior knowledge" and "presenting the new content bit by bit with repeated summaries and chunking helps in retention" (p. 538). Similarly, in Jaiswal's (2019) study of using Gagne's nine events as an instructional model, the researcher concluded that "Gagne's series of nine events provided a sequence of events that were easy to follow as a process in order to obtain the intended learning outcomes explicitly outlined at the beginning of

the learning program" (p. 1078). Davies, Pon, and Garavalia (2018) echoed the effectiveness of Gagne's nine events when utilized to structure lessons.

In combination with the general lesson structure adhering to Gagne's nine events of instruction, specific lesson elements were designed based on Ryan and Deci's autonomy and competence components of self-determination theory. The relationship of the lesson elements to autonomy and competence is shown in Table 4.7 and is further explained in the analysis of the categories in this theme.

Table 4.7 *Relationship of Theme 1 Categories and SDT Needs*

SDT Needs	Theme 1 Categories
Autonomy	Lesson structure supported learning Content chunking facilitated understanding Options improved motivation Skipped optional material Accessible resources Good weekly expectations
Competence	Lesson structure supported learning Content chunking facilitated understanding Scaffolding aided understanding Prior knowledge increased confidence for the lesson Prior knowledge gave useful information Challenge questions revealed deeper content

The participants' dialogue about the lesson structure and elements, and the connection of those elements to autonomy and competence, led to the following assertion from this theme: *an all-in-one lesson structure including prior knowledge, optional help and challenge, and content chunking elements supported participants' autonomy and competence, ultimately improving their motivation*.

The following ten categories came together to represent the first theme: (a) lesson structure supported learning, (b) content chunking facilitated understanding, (c) scaffolding aided understanding, (d) prior knowledge increased confidence for the lesson, (e) prior knowledge gave useful information, (f) challenge questions revealed deeper content, (g) options improved motivation, (h) skipped optional material, (i) accessible resources, and (j) good weekly expectations.

Lesson structure supported learning. Lesson structure refers to the inclusion and arrangement of activities over multiple pages within a lesson. Specifically, a lesson was split up into the prior knowledge and vocabulary on the first page, examples on the following pages, and graded practice on the final page. A lesson, then, included both the presentation of information and graded practice. This differs from a lesson presented on one continuous webpage followed by a separate quiz assignment.

This category relates to the other nine categories in this theme. For example, the categories *content chunking facilitated understanding* and *scaffolding aided understanding* are also in reference to the arrangement of the lesson on multiple pages, but the former narrowly focuses on the presentation of chunks of information and the latter identifies the step-by-step progression of content with checks for understanding along the way. The following categories target a particular section of the lesson structure, such as the prior knowledge or enrichment: *prior knowledge increased confidence for the lesson*, *prior knowledge gave useful information*, *challenge questions revealed deeper content*. Some of the categories refer to elements built into the lesson structure rather than the specific layout or sections of the lesson. For example, *options improved motivation* and *skipped optional material* refer to the element of choice built into the lesson structure

and *accessible resources* refers to the tools and supports built into the lesson structure. Finally, the category *good weekly expectations* refers to the result of the lesson structure on participants' workload or emotions related to workload.

Multiple participants expressed that the lesson structure, or the inclusion and arrangement of the activities over multiple pages in the lesson, was supportive of their learning:

> Finley: [The multipage structure] felt nice. It made the whole transition from lessons into assignments in different parts of the lesson, and made it feel like it flowed a bit better rather than just like a big page of information and then a lone quiz on it.
>
> Devin: I like [the multipage structure] because then it was kind of like here's like the lesson and learning it and then kind of enforcing it all in one, but it's like still sectioned, so you could go back if you needed to, like, look at it while still being in the lesson. And I found it useful.
>
> Cameron: I felt like I could like implement the information I learned right away instead of waiting for to do an assignment or a quiz, [the multipage structure] felt just more organized and better.

Each of these participants indicated that the multipage structure of the lessons was helpful. This seems to have been a general perception of the new unit. For example, Eddie reflected on his prior learning compared to his learning in this unit.

> Eddie: I think throughout the year, through at least from quarter one and two, I think this that we took in quarter three, I think I liked it

> better. And the lesson, the way it was set up and structured, I liked it better than what we did before.

In thinking about a broad comparison between the previous lessons and the intervention lessons, Eddie recognized the lesson structure as a salient difference. This category had strong support in the interviews, evidenced by the 44 codes associated with it. This is the second highest number of codes associated with any of the categories, as shown in Table 4.4.

The multipage structure of the lessons is consistent with research on providing a supportive structure to foster an environment for autonomy and competence to flourish. For example, splitting content up onto multiple pages based on the content and following a consistent structure for the pages with free navigation for the learner provides non-controlling structure, supporting autonomy. Hartnett (2015) found that a lack of structure resulted in decreased feelings of competence, while Ryan and Deci (2020) indicated that "the need for competence is best satisfied within well-structured environments" (p. 2). In this category, *lesson structure supported learning*, participants indicated that the multipage structure was useful and as Ava said, "it made me feel good to know what I was doing." This structure with guided examples over multiple pages was built as a design component into the intervention based on the implementation strategies for the psychological needs of autonomy and competence, as shown in Figure 3.1.

Content chunking facilitated understanding. Although very similar to the multipage structure of the lessons in the previous category and related to both autonomy and competence, this category zeroes in on the presentation of content in small chunks of information. For example, on the first example page of the lessons, a small chunk of

information is presented, followed by a check for understanding. Each example page contains two or three of these chunks of information. This category, *content chunking facilitated understanding*, is similar to the next category, *scaffolding aided understanding*. Both are referring to the chunks of information presented throughout the lessons. This category differs in that scaffolding focuses on how the chunks build on one another to form a step-by-step guide through the lessons.

Participants expressed that the content chunking element of the lesson structure was useful for their learning. For example, in comparing the lessons from the study to other lessons in the course, Blake said "I look at the lessons like in different units and I see like how long they are, and I'm one for action…they helped me a lot more than in previous lessons." According to Blake, these "different units" of information within the lesson were helpful. Similarly, Finley noted that "rather than just, you know, like I said before, a big page of information and then just do all these problems and remember it." In this statement, he seemed to indicate that the smaller chunks of information were more useful for retention than a lengthy lesson page. Like Blake and Finley, Ava also made a comparison between the previous lessons and the intervention lessons.

> Ava: I really like the organization that was used with [the lessons], because in the, you know, in the regular lessons, it's kind of all just like buttons and tabs, if you know what I mean. And it kind of all like mushed together.

The "buttons and tabs" Ava referred to concerning the "regular lessons" is describing the previous lesson setup. Buttons and tabs were used for displaying information on the page, but all the content was presented together on one webpage. To Ava, that previous setup

was more “mushed together” than the intervention lessons that were chunked based on the content onto different pages.

Participants’ statements that formed the category *content chunking facilitated understanding* are echoed in other research. For example, Ullah, Rehman, and Bibi (2015) found that content chunking improved retention in their study of Gagne’s nine events of instruction in a postgraduate course. Jaiswal (2019) stated that “it is helpful to organize and chunk the academic content into small manageable sections to avoid overwhelming students with cognitive overload” (p. 1076). This chunking is in reference to Gagne’s fourth event: presenting the content. This type of content chunking was used in the lesson as part of the scaffolding process. The chunks build on one another throughout the lesson to support participants’ competence and autonomy with scaffolding, possible leading to improved autonomous motivation (Ryan & Deci, 2020).

Scaffolding aided understanding. The multipage lesson structure and content chunking in the first two categories were used as part of the scaffolding process for the lessons to support the psychological need for competence. Spreading out the content over multiple pages helped to limit the information around a learner’s zone of proximal development (Vygotsky, 1978). The content chunking aided in guiding students through that zone and into new learning. *Scaffolding aided understanding* specifically describes the step-by-step building of information and checks for understanding throughout the lesson to support growth in student learning.

Participants expressed that the scaffolding in the lessons was less overwhelming and gave them more confidence as they worked through the lessons independently:

Cameron: Yeah, I got more confident, especially because like I was like, oh, I already learned this, but then it's like, oh, wait, I didn't really like retain what I had learned, so it's like I felt a little confident. And then I was like, oh, wait, I didn't remember that part, and then you learn like you get the review and then you get more confident. So, yeah, I did feel more confident as I was going through the lesson.

Eddie: I liked how [the lesson is] structured and set up because it gave me a chance to kind of see like what was the practice at the end and kind of what I should be knowing in the beginning, so it wasn't all put together and made me feel a little bit more calm and not as stressed, seeing everything all together that I could split it up.

Cameron's description included the idea of working through the zone of proximal development with the explanation that building on current knowledge with support throughout the lessons increased confidence. Eddie identified feeling less stressed because of the scaffolding, specifically because only the next step of information was presented at one time.

Like Cameron and Eddie, Finley found working through the content and practicing one section at a time to be more helpful than trying to grasp all the content at once. Finley explained: "I was steadily working through something than just doing nothing and trying to take in information and then using all that information at once." By "doing nothing" Finley was referring to the previous lessons that did not have check for understanding questions with informative and correctness feedback that counted towards a grade embedded within them. Instead, students were expected to learn and retain all the

lesson information and then demonstrate their understanding on a subsequent graded quiz. In contrast, practicing one segment of information before moving onto the next building block in the lesson was more helpful because Finley was "steadily working" through the content. These examples from Cameron, Eddie, and Finley help elucidate theme one in that the scaffolding element of the lesson structure was supportive of their learning and not overwhelming.

Using scaffolding to aid learners' movement through the zone of proximal development is a typical process used in research based on Vygotsky's (1978) work. Although moving through this zone is best accomplished within the social interaction between a learner and teacher (Harwood & Brett, 2019; Vygotsky, 1978), the video support, help with common errors, and examples with text and images were developed to reflect that interaction. Scaffolding has also been used in research on motivation relating to improving self-regulation among mathematics students (Bell & Pape, 2014) and self-efficacy in web-based environments (Valencia-Vallejo et al., 2018). Research suggests that providing a felicitous environment for the psychological needs of autonomy and competence to thrive through a clear supportive structure and scaffolding can improve students' self-efficacy and confidence (Kapp, 2012; Kirchener et al., 2006; Rayburn et al., 2018).

Prior knowledge increased confidence for the lesson. The next two categories relate to the prior knowledge element in the lesson. A statement of prior knowledge was already a part of the Algebra 2 lessons based on Gagne's third event of instruction: stimulating recall of prior knowledge (Gagne, 1985). In addition to a statement, an explanation with an example or video was provided to help participants recall the prior

knowledge. A check for understanding with informative and correctness feedback and the option to attempt the question again was also incorporated as a part of the intervention. These additional design components were built into the intervention lessons based on the implementation strategies for competence. Stimulating recall of prior knowledge is a key element in learners' acquisition of new knowledge (Gagne et al., 1992). Additionally, in a study of online middle school physics students, Chen (2014) found "prior knowledge can determine how well learners acquire information from e-learning systems and ultimately influence their learning outcomes in e-learning systems" (p. 351). Activating prior knowledge also supports students' perceptions of self-efficacy and competence (Li & Baker, 2018).

This category, *prior knowledge increased confidence for the lesson*, specifically refers to participants' expressions of increased confidence or assurance to begin the new lesson content because of the prior knowledge section. This category differs from the next category, *prior knowledge gave useful information*, in that the next category is focused on the quality of information presented in the prior knowledge, not participants' feelings related to completing it. In contrast, this category focuses on participants' values and emotions, evidenced by 12 of the 15 codes for this category having the emotion, value, or in vivo classifications. Table 4.8 shows the breakdown of the codes per classification for this category.

This category further develops theme one because the specific prior knowledge element of the lesson structure was supportive of participants' learning and lessened feelings of stress for entering the lesson.

Table 4.8 *Codes and Classifications for Prior Knowledge Increased Confidence*

Classification	Unique Codes	Number of Codes
Descriptive – Prior Knowledge	Oriented the learner	3
Emotion	Increased confidence Liked prior knowledge	4
In Vivo	Not "jumping headfirst into a pool" Not "plunging into new stuff" "Something to fall back on"	3
Value	Felt prepared	5

For example, Cameron described the feelings of preparedness that resulted from completing the prior knowledge:

> Cameron: OK, I'm glad [the prior knowledge section] was there so I can like make sure I know this before I go into the lesson because a lot of the stuff I forgot. So they were really helpful and I felt a little more confident going into the lesson.

Similarly, Ava stated "I liked completing [the prior knowledge sections] because it gave me confidence that I knew what I was doing so that I could then complete the lesson." Ava was referring to the information presented in the prior knowledge and then the check for understanding with immediate informative and correctness feedback. These items provided a feeling of enjoyment because of the confidence that resulted to move on in the lessons. Finley described a similar sentiment: "I wasn't just like plunging into new stuff without making sure I remembered the older topics." Finley's phrase "I wasn't just like plunging into new stuff" seems to indicate an increased level of confidence or assurance

from completing the prior knowledge before the lesson content. Lastly, Blake suggested a feeling of satisfaction from the prior knowledge: "I felt satisfied because sometimes my brain forgets things that I've learned before." Each of these examples demonstrates that orienting the learners through the prior knowledge section helped support their feelings of assurance and competence.

Prior knowledge gave useful information. Although still referring to the prior knowledge section of the lesson structure, this category focuses on the quality of content within the prior knowledge rather than participants' feelings about completing it. This category contributes to the idea that the prior knowledge element of the lesson structure was supportive of participants' learning. Researchers corroborated this idea in a study of prior knowledge activation among fifth grade students in finding it is likely "that if students have some sort of prior knowledge (whether that is topic knowledge or metacognitive knowledge), their learning can benefit from activating this knowledge" (Kostons & van der Werf, 2015, p. 272). Other researchers have also found that taking steps to identify, trigger, and support prior knowledge retrieval helps the learning process (van Blankenstein, Dolmans, van der Vleuten, & Schmidt, 2013; Wetzels, Kester, Merri, & Broers, 2011).

Participants indicated that the prior knowledge contained useful content at an appropriate level. For example, Eddie stated "[the prior knowledge] gave me just a quick review on what we were about to start. And I think it was a good tool to have before I started the lesson." He seems to identify that stimulating prior knowledge was an appropriately "quick review" with the content being a "good tool" to orient him before

the lesson examples. Similarly, other participants referred to the prior knowledge as a refresher, indicating a succinct presentation of the content:

> Finley: [The prior knowledge] definitely helped, going over the older topics and kind of refreshing it in my mind.
>
> Blake: [The prior knowledge] was a nice refresher so I could continue on with the lesson.

Based on these examples, the information contained within the prior knowledge section seems to have been useful for the participants' learning process while having a reasonable amount of content.

Challenge questions revealed deeper content. The category *challenge questions revealed deeper content* pertains specifically to the optional enrichment questions within the lesson. This category is related to *options improved motivation* and *skipped optional material* because the challenge questions are one of the optional features in the lesson. Since the optional enrichment is one of the sections of the lesson structure and because they are scaffolded within the lesson examples, this category is also related to *lesson structure supported learning* and *scaffolding aided understanding*.

Like the prior knowledge section of the lesson, the optional enrichment or challenge questions are a separate section of the lesson used as a part of the scaffolding process, designed to support competence. Ryan and Deci (2000) suggested that optimal challenges provide a means for fulfilling one's need for competence or perception of self-efficacy. Researchers found support for this idea within the virtual environment and suggest that a design should "provide users with optimal challenges but not overwhelming obstacles in creating an individual's competence satisfaction" (Huang et

al., 2019, p. 604). Martin, Kelly, and Terry (2018) acknowledged the difficulty of creating optimal challenge across different levels of learners and suggested providing help for students as well as increasing the level of challenge throughout the course. By incorporating the challenge questions as part of the scaffolded material in the lesson, there was not a large gap in difficultly level leading up to the challenge questions. Informative feedback was also provided to students upon trying the challenge questions to give hints about common mistakes or explain the process for completing the question, as discussed in more detail in theme two.

Perhaps due to the scaffolding and supports used in designing the optional enrichment questions, participants expressed that these questions benefitted in extending their learning and thought processes:

> Cameron: And [the challenge question] was like kind of challenging but good because like since it was like a longer thing, I had to, that's actually how I developed that method that I did for the forum post to help with the students. I like looked at what I did in the question and was like, oh, well, and I just like found a pattern because it went on longer so I could see what's happening in the equation better. And I did something wrong the first time, but when I actually like looked closer, it's like, oh, I missed this. And then it was like helpful.

In this instance, Cameron was referring to factoring a difference of squares multiple times in one problem, whereas leading up to this challenge question, participants were only asked to factor one difference of squares at a time. Cameron was able to find a pattern for this process and so gained a deeper understanding of the content. The supports provided

in the challenge question also helped Cameron move toward a correct understanding. In a similar way, the supports provided within the challenge questions helped to create an optimal challenge level for Devin:

> Devin: I did use the extra challenge questions if I didn't understand the topic as much just to get a feel for it, and they did help because they gave you a little explanation with it if you got it wrong, so I used those and then I did use to help if I didn't fully understand like an equation or like where to put something.

Devin noted using these questions and their supports to help improve understanding on certain topics. In contrast to clarifying difficult concepts within the lesson, Eddie found the challenge questions helpful in elucidating how the content could be extended beyond the lesson: “I think [the challenge question] gave me a chance to look at what these problems could be in the future and how they get tougher.” In each of these examples, participants described the perception that the challenge questions revealed deeper content for them in a digestible way, cultivating the theme that the lesson structure was supportive of their learning and not overwhelming.

Options improved motivation. Unlike the previous three categories pertaining to prior knowledge or enrichment and focused on a specific section of the lesson, the categories *options improved motivation* and *skipped optional material* refer to an element of the lesson structure found in numerous places throughout the lessons. Optional features of the lessons include choice in the method for learning vocabulary, the optional enrichment question, and optional help and check buttons throughout the lesson. These features were based on the implementation strategies for autonomy. This category

addresses the feelings participants had when interacting with these options, which tended to improve their motivation. The category *options improved motivation* reinforces theme one: *participants expressed that the elements of the lesson structure are supportive of their learning and not overwhelming* because the optional elements reduced pressure, making the lessons less overwhelming, and the optional elements were described as helpful in participants' learning processes.

In describing the options, participants expressed feeling less pressure, valuing the use of the options, and feeling helped by them. This variety of responses is represented by the rather evenly distributed classifications used for this category, ranging from 6 to 11, as shown in Table 4.9.

Table 4.9 *Distribution of Classifications for Options Improved Motivation*

Classification	Number of Codes
Descriptive	11
Emotion	6
In Vivo	7
Value	10

For example, Blake noted "I found [the options] useful in how we got different ways that we can learn the vocabulary, which was nice." Blake's perception of useful options is made more explicit by Eddie's details:

Eddie: I wanted to definitely watch the video and I did go through all the words to make sure I had a clear understanding before I started.

And if I did have any problems, I did go back and review, so I made sure I had a clear understanding of the vocab that was used.

Eddie's explanation shows the helpfulness of using the video and list of words options in improving his understanding of the vocabulary.

In addition to the participants describing the options as useful, the participants also felt less stress and valued the options provided in the lesson. For example, some participants described that the options reduced feelings of pressure and nervousness for them:

Blake: [The optional enrichment] didn't make me feel pressured, which I like, I didn't feel pressured at all. So if I felt like doing the challenge question, I could, and if I didn't, I didn't have to.

Finley: I feel that [the options] just helped me to not feel so like nervous.

Other participants' feelings went beyond temporal emotions of reduced stress and described perceptions of value towards the options in the lessons:

Ava: I really enjoyed [the options], because typically it's just the vocabulary words and they're very easy to miss because they're off to the side. But with those, you kind of had to get through those. Like there wasn't any going around them. So I did enjoy those.

Cameron: [The options] felt like more good because I felt like I had more options to like for additional review if I needed it, or just more like assurance that I will get what I'm getting into with the lesson so that I'm just, so I can like retain everything better.

These participants valued the options because they had the opportunity to use them, if needed, to improve their learning. Ava also seemed to indicate that having the vocabulary more visible, not hidden "off to the side" of the lessons, incited her to work through the vocabulary options. She seemed to enjoy this, in the same way that Cameron felt good about the "additional review", because of the value they placed on this content.

The helpful, low pressure, valuable options described by the participants were built into the lesson structure because of the research supporting student choice in improving motivation, an implementation strategy for autonomy. For example, Schunk and DiBenedetto (2020) explained that choice is a key element influencing motivation in learners. Ryan and Deci (2020) further postulated that student choice can improve the perception of autonomy, thereby increasing motivation: "when students experience a *sense of choice* they feel more ownership of activities and greater autonomy, resulting in an enhanced intrinsic motivation" (p. 3-4). Two different studies of motivation in online learners supported this finding based on their results: "autonomy can be encouraged by creating pathways that involve meaningful choice and limited extrinsic pressures" (Martin et al., 2018, p. 51) and "when a learner personally chooses an assignment topic to explore, autonomy may increase" (Durksen et al., 2016, p. 255). These examples demonstrate that a student's perception of control and feelings of reduced pressure is related to the presence of choice. From a different approach, Bourgeois and Boberg (2016) found that a lack of authentic choice dampened the perception of autonomy among middle school mathematics students. Creating choice in the design of the lessons was intended to support students' sense of autonomy.

Skipped optional material. This category, *skipped optional material*, is referring to the same student choice elements in the lessons as the previous category, *options improved motivation*, but identifies the instances where participants indicated skipping the options. Despite containing only five codes, this category helped to distinguish participants' descriptions of opting out of these lesson elements from their experience of interacting with the options.

The significance of this small category is to show authentic student choice, since the participants did, at times, choose to skip these parts of the lessons. For example, Blake shared: "I didn't try any of the challenge ones" and Cameron explained an instance of skipping the vocabulary options: "but since I already knew [the vocabulary], I just did the check for understanding." The check for understanding was the only required part of the vocabulary section. In these examples, the participants seemed to feel that they had a true choice, without negative consequences, to skip those specific items in the lessons.

Accessible resources. Resources refer to the extra help and supports built into the lesson structure. These include the following parts of the lesson: the information contained in the help buttons, the video explanations, the list of vocabulary words and vocabulary videos, as well as the extra practice provided in the challenge questions. This category only includes the vocabulary and challenge questions insomuch as they provide extra resources and practice, not in terms of their optional features, as in the previous categories. The resources built into the intervention lesson were meant to support students' need for autonomy. The category *accessible resources* describes participants' suggestions that these resources were easy to access and useful.

Building on theme one, these accessible resources supported students' learning and helped make the lessons less overwhelming. For example, Eddie and Finley explained the usefulness of the help buttons in their learning.

Eddie: I did throughout use the help buttons, and I think it did help me better understand.

Finley: If I needed to go back on the help buttons and everything I could, and it didn't feel like I was just kind of backed against a wall and I need to open a whole other tab and look at the lesson and everything.

Finley was referring to lessons and quizzes before the intervention, which would have required finding and opening the lesson in a separate tab to view example information while taking a quiz, if needed. Having these help buttons available with simple explanations, common mistakes, and key ideas made it easier to find the information they needed to continue in the lesson.

In addition to the information available as a resource, some participants found that extra practice was a useful resource. Ava and Eddie described using the challenge questions as an extra practice resource.

Ava: I remember one time I was having issues with one of the lessons and I took me a while and I thought I eventually got it, but there weren't any more problems. But then I did the challenge problems to really make sure that I got it. And those came in handy then.

Eddie: I think [the challenge question] gave me an extra opportunity to really show my skills and what I learned throughout the lesson.

Upon finishing the core parts of the lesson, these participants expressed the usefulness of the extra practice in ensuring their understanding.

Providing extra resources to aid student learning and autonomy has been supported by research. For example, in a study of vocabulary acquisition among English language learners Qian and Sun (2019) found that providing resources helped activate student learning and foster autonomy. In a multiple case study of 965 participants in online courses, Hew (2016) found that resources cultivated autonomy among learners, leading to better engagement in online course material. This improved engagement because of the available resources is likely to lead to better performance, as Hostager (2014) suggested in a study of 158 university students: "the study strongly suggests that efforts to encourage and support the increased use of online learning resources by students will bear significant fruit in the form of improved performance through higher course grades" (p. 330). Murray (2012) qualified this finding of providing extra resources in an exploratory study of 100 asynchronous online students that showed the resources must be relevant and useful in improving students' grades, otherwise students will opt not to use them. It is likely, and supported by the participants statements above, that providing useful and relevant resources can foster student autonomy and enrich student learning.

Good weekly expectations. Weekly expectations refer to the work required for a student to complete in a week within the lessons and contribute to students' perceptions of autonomy. The work includes two lessons, each containing prior knowledge, vocabulary, examples, and graded practice. The category *good weekly expectations* pertains to the other categories in this theme by describing the perception of workload in

connection with them. For example, *content chunking facilitated understanding* and *scaffolding aided understanding* may have been an overall detriment to the lesson structure if they caused it to be too elaborate or involved. Similarly, the seemingly positive categories of *prior knowledge increased confidence for the lesson*, *prior knowledge gave useful information*, *challenge questions revealed deeper content*, *options improved motivation*, and *accessible resources* may have been less favorable if the combination of all of them resulted in an overwhelming workload for the week.

Participants indicated that the weekly lesson expectations were reasonable, contributing to theme one in that the lesson structure was not overwhelming. For example, Cameron described feelings about scheduling the work:

> Cameron: [The required work] felt like more compact instead of it more like spaced out in the week. So I felt like I had, like when scheduling, I had, I felt like I had more time to do things...it felt just more organized and better.

Having the lesson and graded practice together in an organized way seemed to have a positive effect on Cameron's perception of the workload. Devin articulated this perception as well:

> Devin: I really liked how [the required work] was laid out. I feel like it didn't make it seem as much of work for the week, which was nice compared to all the other classes, and it was kind of like all grouped together, I really liked that.

Once again, having the required work "grouped together" into the lessons seemed to reduce feeling overburdened. Blake expressed a similar sentiment, but focused on the

benefit of the content being split up over multiple pages: “I'd say [the setup] helped me because sometimes I look at the lessons like in different units and I see like how long they are...they helped me a lot more than in previous lessons.” Blake was referring to the lengthy lesson pages before the intervention, in which all the content was presented on one continuous webpage. Splitting up this content onto different pages in the lesson while also combining the graded practice with the lesson seems to have reduced feelings of stress for the participants.

In research, a heavy workload has been associated with reduced autonomy and a lighter workload has been associated with increased self-regulation. For example, Hartnett (2015) found that “perceptions of *high workload* emerged as the most salient theme that undermined the autonomy of participants” (p. 90). A heavy workload can make learners feel less capable, reducing their perceptions of proficient self-regulation. Bandura’s (1989) social cognitive theory related these negative feelings of self-regulation to lowered self-efficacy. In essence, if learners’ feel incapable of controlling their environment, then they will feel incompetent to interact with it (Bandura, 1989).

Theme 1 summary. Theme one demonstrated the ways that participants’ found elements of the lesson structure to be supportive of their learning without overwhelming them. This theme germinated from ten categories, which amplified various lesson elements. These elements include the multipage lesson layout, content chunking, scaffolding, prior knowledge, challenge questions, optional components and resources, and overall expectations for the lessons. Participants consistently conveyed that these elements were useful in their learning, helped them progress through the content effectively, increased their confidence, and reduced levels of stress in the lessons. In

general, the statements of the participants aligned with prior research pertaining to facilitating perceptions of autonomy and competence in educational environments.

Theme 2: After some initial stress, participants indicated a high level of assurance and an increase in understanding through the feedback features within the lesson. These features included correctness feedback, hints to improve, a second chance on practice items throughout the lesson, and the grading system for the lesson. For each question in the lesson, participants had the option to press a "check" button. Once pressed, the page indicated whether the selected answer was correct or not. If incorrect, a preprogrammed hint for the question based on the steps to complete the question and common mistakes made by students on similar questions was provided. Additionally, once the correctness feedback and hint were viewed, participants had the option to press a "try again" button to attempt the question a second time, if needed.

Participants indicated that the correctness feedback, hints, and second chance improved their confidence, reassurance, learning, and understanding. For example, Ava expressed extreme satisfaction with the use of the check buttons:

> Ava: I really liked, I really, really enjoyed [the check buttons] because I'm always nervous that my answers are incorrect, and I, I just I really liked knowing that I was correct, and if I wasn't correct, I would do it again and see what I did wrong.

Not only was Ava's nervousness assuaged, but she was also able to identify her mistakes through this process. Eddie described how his confidence and understanding grew through this process:

Eddie: My confidence level definitely went up, especially when at first you don't understand, but using all those tools and the checks, it does help you understand and it does give me more confidence knowing that now I understand the lesson better than when I started.

These examples demonstrate the positive effects, including feelings of competence and increased understanding, of using the feedback features within the lesson.

The categories in this theme relate specifically to feedback and grading features within the intervention lessons and do not include the forums and tests in the intervention. Although elements other than the feedback features in the lessons may have contributed to improving confidence and understanding, those were addressed in theme one and are excluded here. This theme is made up of five categories with a total of 129 codes, as shown in Table 4.10.

Table 4.10 *Theme Two Categories and Number of Codes*

Category	Number of Codes
Feelings of stress	5
Checking answers increased confidence	61
Informative feedback improved learning	23
Appropriate content level	9
Grade increased motivation	31

The participants' descriptions of the feedback features within the lessons are consistent with research on motivation, specifically in the areas of self-efficacy and the

need for competence in self-determination theory. Participants' desire to interact effectively within the lessons demonstrates White's (1959) effectance motivation and the internal psychological need for competence (Deci & Ryan, 1985). An environment that facilitates effective interaction includes informative feedback (Ryan & Deci, 2020), such as the feedback participants utilized within the check buttons. Appropriate challenge in this type of environment increases motivation (Huang et al., 2019), whereas insufficient feedback decreases feelings of self-efficacy and motivation (Yantraprakorn et al., 2018).

In addition to improved self-efficacy, the feedback features gave participants' authentic control in their environment, which is a catalyst for an improved perception of autonomy (Rayburn et al., 2018; Ryan & Deci, 2020). As detailed in the categories that follow, participants expressed the ability to gauge their own understanding, gain understanding with the feedback, and fix their work through the second chance provided. These features align with Schunk and DiBenedetto's (2020) description of self-regulatory behaviors: "monitoring performances, adapting one's approach as needed, reflecting on one's progress, and sustaining motivation for task completion" (p. 5). The feelings of assurance, confidence, and motivation participants expressed in relationship to being able to check and fix their work through the feedback features in the lessons are supported by this research on self-efficacy, competence, self-regulation, and autonomy.

Based on the participants' descriptions and research described above, the following assertion emerged from this theme: *immediate correctness feedback and hints, coupled with an appropriate level of challenge within a lesson, improved participants' perception of competence and autonomy, ultimately increasing their motivation*.

The following five categories combined to create the second theme: (a) feelings of stress, (b) checking answers increased confidence, (c) informative feedback improved learning, (d) appropriate content level, and (e) grade increased motivation.

Feelings of stress. Two participants expressed feelings of stress associated with the unit of study in the intervention. In contrast to the other four positive categories in this theme with a combined 124 codes, *feelings of stress* contains only five codes. Although this category is very small in comparison, identifying the starting point of some of the participants may give a better understanding of how their confidence changed and grew throughout the unit. This category helps support the theme by showing that despite feelings of initial stress when approaching the lessons, the feedback features caused participants to overcome and replace those feelings with feelings of assurance and confidence.

The feelings of stress generally pertained to the amount of information, lack of confidence, or lack of motivation in beginning the unit. For example, Devin noted: "I did feel a little stressed because it was a lot to do and a little unmotivated because of how much it was just seeing all of it at once." Devin seemed to indicate feeling somewhat overwhelmed when first approaching the lessons, but later acknowledged: "I did like it a lot better doing this because…it didn't feel as much as of workload after I did it for a week." Devin's stress decreased after working in the intervention for a week. Similarly, Eddie acknowledged hardships with some lessons compared to others: "there was definitely some tougher lessons than others," but goes on to say that his confidence increased because of "using all of the tools that were provided" in the lessons. The tools included the feedback features built into the lesson.

Barriers to feelings of competence and assurance in the online environment can lead to feelings of stress. For example, tasks that are too lengthy and detailed may cause feelings of anxiety (Hartnett, 2015). A fear of failing or of being evaluated negatively can also cause anxiety (Ibrahim et al., 2017). Feelings of stress or anxiety may signal that a student feels incompetent or incapable of completing the task at hand (Schunk & DiBenedetto, 2020). As will be shown in the following categories, the feedback features in the lessons helped to alleviate the initial stress participants may have had when approaching the intervention.

Checking answers increased confidence. Participants expressed that the ability to check their answers for correctness increased their confidence throughout the lessons, which is directly related to the psychological need for competence. By ensuring the selections they thought were correct were actually correct, participants were able to move on with assurance that they understood the material so far. They had an accurate barometer of their understanding level. This category specifically relates to the correctness feedback provided by the check buttons, not the informative feedback or the grade given for the lessons. The category *checking answers increased confidence* supports the idea in theme two that participants indicated a high level of assurance because of the feedback features in the lessons, which in this case refer to the check buttons. The importance of this category may be highlighted by the large number of codes associated with it. Table 4.4 shows that this category, containing 61 codes, has the most codes associated with it compared to any other category.

The underlying idea of this category (i.e., the checks increased confidence by providing solid assurance of the answers selected) was pinpointed in Finley's statement:

“I just felt like I could, you know, check and make sure rather than just hoping that it was right.” Finley had assurance in the answers selected, “rather than just hoping.” Other participants echoed this sentiment in their descriptions of increased confidence through the check buttons:

Cameron: I think I used [the check buttons] after every answer just to check that I was doing my work right and, you know, just to prove that I was actually learning…So, yeah, I did feel more confident as I was going through the lesson.

Devin: I did feel more confident going through [the lessons] like I felt better about my work because I kind of felt more reassured with the work I was doing because of the checks and everything, so I knew I was on the right track.

Ava: I think the check buttons, like when you were done, you checked if you got it correct, and then you could do it over again or see what the correct answer was if you got it wrong, I think those helped my confidence the most.

Blake: When I would be able to, like, check through each question and I'd get them correct, and I found that in like assignments and even quizzes, I was getting more stuff correct in that boosted my confidence in math.

Each of these participants described the confidence that resulted from knowing with certainty that the answers they selected were correct. The checks gave assurance that the participants were “actually learning” and that they were “on the right track.”

Through this process, participants were able to gauge their level of understanding and identify mistakes. Both actions supported their confidence in learning through the lessons. For example, Eddie explained how the use of the challenge questions with correctness feedback, mistake identification, and the ability to assess his own understanding improved his confidence:

> Eddie: [The optional challenge questions] definitely made me more confident, especially when I saw them that I got that question correct. Especially when you have multiple tries that even if you would mess up the first time, you could go back and look at your mistakes. I think it definitely made me feel more confident on my ability to learn the lesson.

In this case, Eddie identified looking at his mistakes because of the correctness feedback he received. Devin described a similar situation where the correctness feedback aided in identifying small mistakes in various scenarios:

> Devin: I liked [the check buttons] because then I could like see like, oh, like I didn't do that part right in one…you can kind of like see then with the check questions like, oh, like I didn't, like switch this or like put the exponent on that verse.

In this depiction, Devin explained that small mistakes that may normally be overlooked could be identified with the opportunity for a second look at the answer, knowing the choice was incorrect the first time. Cameron described a situation with using the check button on a challenge question: “And I did something wrong the first time, but when I actually like looked closer, it's like, oh, I missed this. And then it was like helpful.”

Simply the action of finding out the answer was incorrect through the check button and the opportunity to look at it again was enough for Cameron to identify and learn from the mistake.

Based on the participants' descriptions in the interviews, correctness feedback provided through the check buttons tended to increase confidence in their learning. This assertion is supported by a study of 26 learners that found confidence was increased through correctness feedback, especially among participants that started with low confidence (Wang & Yang, 2021). Feedback about correctness, in combination with informative feedback, is a key component of one the events in Gagne's nine events of instruction: providing learning feedback (Lee & Lee, 2012). Feeling effective and competent within a learner's environment are essential factors in improving a learner's motivation (Deci & Ryan, 1985; White, 1959). By using the check buttons to gauge their understanding and identify mistakes, the participants indicated that their perception of competence grew.

Informative feedback improved learning. Although very related to the previous category, the category *informative feedback improved learning* is specifically in reference to the hints and steps provided when a participant used the check buttons. In addition to receiving correctness feedback, as discussed in the previous category, participants could also receive information about common mistakes and procedures needed to complete the problem, supporting both autonomy and competence. This informative feedback appeared if an answer was incorrect upon using the check buttons. This supports theme two by demonstrating that an increase in understanding occurred because of the feedback features within the lessons.

Some participants explained that the feedback provided within the check buttons helped them in addition to the correctness feedback. For example, Cameron described using the feedback to find and learn from a mistake.

> Cameron: I think [the check buttons are] really helpful with, like I said, just like reviewing and if I got it wrong and then it like provided feedback, I can just see where I went wrong… since there's like feedback, then I can see, oh, yeah, I did that one wrong.

In this situation, Cameron was able to find the mistake by using the informative feedback provided in the check question. In a similar instance, Eddie explained that the process of using the check buttons allowed him to identify his mistake.

> Eddie: Especially when you have multiple tries that even if you would mess up the first time, you could go back and look at your mistakes. I think it definitely made me feel more confident on my ability to learn the lesson.

Eddie's response was in the context of using the check buttons where participants received informative feedback if their answer was incorrect. Devin also described using the check buttons on a challenge question to gain a deeper understanding of the math content.

> Devin: [The challenge questions] did help because they gave you a little explanation with [the check buttons] if you got it wrong, so I used those and then I did use to help if I didn't fully understand like an equation or like where to put something.

In this case, Devin not only made a mistake, but also did not understand the format for an equation. The informative feedback in the check button supported this issue and helped with understanding the math.

The check buttons improved learning by providing informative feedback in a non-controlling way. In a study about causes of failure in online language learners, the researchers identified the importance of providing informative feedback in addition to correctness feedback to support learning (Yantraprakorn et al., 2018). With the use of Gagne's nine events of instruction, providing remedial feedback that guides the learning process is essential as opposed to simply stating whether answers are right or wrong (Gagne et al., 1992; Jaiswal, 2019). This type of informative feedback supports the perception of competence among learners (Hartnett, 2015) and can be especially important for building understanding in the online environment where students may feel isolated (Jeffery & Ahmad, 2018). While the informative feedback likely supported feelings of competence, the method of giving participants choice in using the check buttons and feedback may also have supported self-regulation.

Appropriate content level. The explication of the first three categories in this theme demonstrated that although participants had initial *feelings of stress*, the correctness feedback enabled participants to feel that *checking answers increased confidence*, and the *informative feedback improved learning* by providing specific learning guidance. The corrective and informative feedback would not have eased the feelings of stress, however, if the content level was too difficult for the students to grasp. The importance of this category, *appropriate content level*, is to show that the difficulty level was optimal for participants to progress in their learning, but not beyond their reach.

This optimal challenge level provided a felicitous environment for participants' perceptions of competence and self-efficacy to thrive.

During the interviews, various participants commented on the difficulty level as it related to the challenge questions. These questions were based on the lesson objectives and were presented after the examples in the lessons as part of the scaffolding process, as discussed in more detail in theme one. These questions represented the highest difficulty level of a question in the lessons. Although the participants found these questions challenging, they expressed that they were appropriately challenging. For example, Cameron realized the necessity of these questions:

> Cameron: Some [challenge questions] I felt like were a bit hard, but I feel like it's necessary to have harder questions because they're all easy to feel like you don't really learn anything. But yeah, I felt like it was necessary to be a bit challenging, but not so much that you don't understand what's going on.

Cameron pointed out that these questions represented a challenge as the most difficult questions in the lessons, but they were not beyond comprehension. Additionally, changing the level from easier questions to more difficult questions aided in the perception of learning. Devin described the level of challenge as a "good push" and not "overwhelming."

> Devin: [The challenge questions] definitely did push me a little to more grasp the concept, but I think it was like a good push, like it wasn't like overwhelming.

Based on Devin's description, the questions helped her grow in learning without dismantling feelings of competence. Similarly, Ava commented that these questions were at an optimal level of difficulty:

> Ava: I think [the challenge questions] were, they made me feel like they were good level of challenge. They weren't too hard or too easy.

With this optimal level of challenge described by the participants, it might be inferred that the feedback features, in addition to other elements of the lesson structure, provided a suitable environment for participants to feel autonomously effective with their interactions in the lessons, even when facing the most difficult questions.

This assertion is supported by research on intrinsic motivation, specifically as it relates to fulfilling the psychological needs of competence and autonomy. For example, optimal challenges in online learning have been associated with intrinsic motivation and enjoyment (Chen & Jang, 2010; Ryan & Deci, 2020). As Ryan and Deci (2000) explained: "optimal challenges, effectance promoting feedback, and freedom from demeaning evaluations are all predicted to facilitate intrinsic motivation" (p. 58). Other research has supported the claim that an appropriate difficulty level combined with supportive feedback facilitates the perception of competence, leading to increased motivation (Gagne & Deci, 2005; Hartnett, 2015). When students can be self-directed, such as with the optional check buttons in the intervention, appropriately challenging tasks can promote the perception of autonomy in learners (Huang et al., 2019). This research supports the idea that the appropriate challenge level of the intervention lessons, combined with the autonomous feedback features through the check buttons, may have facilitated the perceptions of autonomy and competence.

Malone (1981) described what this intrinsically motivating optimal challenge looks like: "[environments] should be novel and surprising, but not completely incomprehensible. In general, an optimally complex environment will be one where the learner knows enough to have expectations about what will happen, but where these expectations are sometimes unmet" (p. 362). For example, the lesson content and check for understanding questions with feedback informed participants' expectations for the challenge questions. However, these expectations were sometimes beyond them, prompting the use of the check buttons with informative feedback to guide their learning processes. It is possible that these appropriately challenging tasks provided in the lessons with corrective and informative feedback may have enhanced participants' motivation.

Grade increased motivation. After completing the lessons, including optional multiple attempts and feedback on the questions within the lessons, participants received a grade for their performance on the lesson. This grade was based on the final answers of any questions attempted multiple times. The category *grade increased motivation* was included in this theme because a grade is a type of correctness indicator providing feedback to the learner about performance and supporting the need for competence.

Based on the participant responses, it seems that this grade supported and enhanced the motivation of the participants to complete the lessons. For example, Ava explained that the grade motivated her to focus on the content and take her time in the lessons: "I liked [the grade] because it kind of gave me an incentive to not rush through it and to actually, like really, really pay attention to everything." This motivation to pay closer attention to the information in the lessons was also expressed by Devin.

Devin: [The grade] didn't really change how I felt about [the lesson]. I just feel like it was kind of a make sure you read the lesson and you actually like paid attention, that way it's not like you get to the quiz and you lose points because you didn't pay attention to it.

Devin seemed to indicate that the grade did not have much effect on the way she felt about the lesson, but she wanted to make sure she didn't lose any points. This is similar to Blake's description:

Blake: [The grade] made me feel more motivated to do the lessons because sometimes on like Mondays when I'm trying to get through the lessons, I like really didn't want to do them, but I knew since it was graded, it gave me more motivation to do those.

Blake explained that the external motivator of the grade was enough to get her to complete the lessons because, like Devin, she did not want to lose any points in her grade. Eddie's sentiments also reflected the importance of earning points: "I didn't mind [the grade]. I think it gave me, just more of an opportunity to get more grade, like more points…I didn't mind having points for going through some practice questions." He explained that the grade did not have a negative effect on his motivation and that he enjoyed earning more points because of the lesson. Each of these examples highlights the motivation felt by participants from an extrinsic source, the grade, to complete the lesson.

In contrast, some participants seemed to internalize and place value on the purpose of the grade. For example, Finley expressed feeling like the grade encouraged her to work through the lesson step-by-step and supported the development of her learning.

Finley: [The grade] just made it feel more like I was steadily working through something than just doing nothing and trying to take in information and then using all that information at once… It helped the lesson to feel a bit more like I was doing something that was worthwhile and helped to kind of like know what parts of the lesson I really needed to go over.

The grade helped guide her learning and direct her to areas that she needed to review. Cameron described feeling that the grade helped ensure understanding, which was "gratifying."

Cameron: I felt more like motivated to do them because I felt like when you do a lesson, it's not really common that you get points for like check for understanding or anything like that, so I felt like more motivated to complete the lesson because I'm like, okay, I can get graded for doing this and like making sure I understand it and like a graded practice all in one. And it just kind of felt gratifying after I finished and got points.

Cameron seemed to indicate that the grade not only motivated her to complete the lessons, but also helped her gauge her understanding level of the material. Associating the grade with learning in these ways may show that Finley and Cameron internalized the value of the grade in the process of completing the lessons.

The classifications for this category may help shed light on the way some participants internalized and placed *value* on the grade, while others experienced an *emotion* of enjoyment with the grade for more external reasons. Table 4.11 shows the

classifications and number of codes for each classification for the category *grade increased motivation*.

Table 4.11 *Codes and Classifications for Grade Increased Motivation*

Classification	Number of Codes
Value	11
Emotion	9
In Vivo	6
Descriptive	5

The effectiveness of a grade in improving motivation has been discordant in research. Some researchers contended that although intended to be extrinsically motivating, evaluations in the form of grades can have a controlling significance and cause stress and anxiety in learners, reducing their motivation (Gagne & Deci, 2005; Ryan & Deci, 2020). Bourgeois and Boberg (2016) acknowledged the benefit of grades as a controlled extrinsic motivator, but clarified that their effectiveness may lessen over time compared with more authentic intrinsic motivators and may be dependent on receiving positive grades (Bourgeois & Boberg, 2016). In contrast, Weidinger, Steinmayr, and Spinath (2017) found that negative feedback with grades did not undermine competence or decrease motivation among 542 elementary math students. Still other researchers have acknowledged that learners may internalize the importance of the grade in association with the meaningful content acquired, boosting the perception of competence, and causing the grade to serve as an autonomous extrinsic motivator (Rinfret et al., 2014; Wijsman et al., 2019). Based on phrases used by the participants

above, such as by Finley: “I was doing something that was worthwhile” and by Cameron: “I can get graded for…making sure I understand…felt gratifying,” it could be argued that the grade in this situation moved towards autonomous extrinsic motivation. Yet other phrases used by the participants, such as by Ava: “gave me an incentive” and by Eddie: “opportunity to get more…points” may indicate that the grade functioned more as a controlled extrinsic motivator for some of the participants. None of the participants in the interviews indicated that the grade caused negative feelings, although Devin noted indifference: “[the grade] didn’t really change how I felt about it.” This evidence seems to indicate that although the grade may have fallen somewhere on the continuum from controlled extrinsic motivation to autonomous extrinsic motivation, it likely did not reduce the motivation for these participants.

Theme 2 summary. The categories in this theme exposed the function of the feedback features within the lessons as they related to participants’ confidence and learning. Although some participants felt initial stress about the lessons, the correctness and informative feedback helped reduce this stress and foster the perception of competence. The perception of competence was further supported by the appropriate level of challenge within the lessons. Since the correctness and informative feedback within the check buttons was optional for the participants, the feedback features were presented in a non-controlling manner. Additionally, although somewhat controversial in research, the overall correctness feedback for the lessons in the form of a grade did not seem to dampen participants’ motivation. Instead, the grade produced controlled extrinsic motivation for some while others found value and autonomous extrinsic motivation with the grade. The descriptions by the participants concerning the feedback features in the

lessons and the research associated with these topics led to the assertion that correctness and informative feedback, provided with an appropriate level of challenge, may have fostered competence and autonomy, thereby increasing motivation.

Theme 3: Despite expressing frustration with the forums at times, participants articulated that the positive peer relationships and common struggles supported their learning and connectedness. This theme encompasses the interactions that took place within the three weekly forums in the intervention, which participants were asked to participate in a minimum of three times throughout each week. Some participants questioned the necessity of the forums, expressed nervousness with initial posts, or expressed irritation when peers did not respond. Despite these frustrations, participants detailed ways in which their understanding improved because of the forums and expressed positive feelings of connectedness and camaraderie through the forums. For example, Ava summarized some of these differing feelings:

> Ava: I think it might depend on the person because like if I was doing it and I really needed help on a question, that would be super helpful to me to have the forum to ask questions and have them answered, but if I didn't need any help, I think it would be more on the unnecessary side… I felt very connected to the other students because it made me think like, wow, I'm not alone in being confused in this specific subject or I'm not the only one who doesn't understand this.

In this example, Ava wondered if the forums were necessary, while also expressing that they were "super helpful" for answering questions and could see that "I'm not the only one" struggling with different concepts.

Distinct from themes one and two, which apply only to the lessons, theme three applies only to the forums in the intervention. Also, this theme is the only theme that deals with interaction with others and is directly related to the psychological need for relatedness. Similar to themes one and two, this theme emphasizes the ways in which student learning improved. The categories in this theme relate to the feelings of connectedness, positive relationships, and frustrations participants expressed about the forums as well as descriptions of how the forums aided in their learning. Table 4.12 shows the number of codes for each category in theme three.

Table 4.12 *Theme Three Categories and Number of Codes*

Category	Number of Codes
Peer interactions aided in learning	26
Positive peer connections	31
Shared experiences	16
Forum frustrations	6

The participant responses about the forums in the intervention are consistent with research about forums in online courses and the facilitation of the need for relatedness in self-determination theory. For example, Sun and Rueda (2012) suggested that discussion boards can facilitate positive emotional engagement in the online setting, while other researchers found that discussion boards can reduce anxiety levels in the online

mathematics setting (Thompson et al., 2019). Similarly, in a study of motivation in virtual environments, the researchers found that "feeling connected with others in virtual worlds [links] to increased intrinsic motivation" (Huang et al., 2019, p. 604). Additionally, Martin, Kelly, and Terry (2018) suggested that forums can be used to facilitate relatedness or feelings of connectedness in an online course. In spite of these positive aspects of forums, the satisfaction of relatedness may be more difficult to achieve in the online environment (Durksen et al., 2016), which is in line with some of the forum frustrations participants shared in this study.

The participants' comments about their positive relationships, shared experiences, and some frustrations with the forums alongside the research pertaining to online course forums and relatedness led to the following assertion for theme three: *negative feelings that may have been initially associated with forums were outweighed by the positive effects of participant interactions, which allowed for feelings of relatedness, ultimately improving participants' motivation*. The following four categories came together to create theme three, in support of this assertion: (a) peer interactions aided learning, (b) positive peer connections, (c) shared experiences, and (d) forum frustrations.

Peer interactions aided learning. One of the positive effects of the forums, reported by the participants in this study, was that the interactions in the forums helped their learning process and understanding of the content. This category, like the other categories in this theme, pertains only to the forum posts that took place throughout the intervention. Unlike the other categories in this theme, this category focuses on the content of the posts and how that content affected participants' learning processes and

understanding levels. This contrasts with a focus on peer connections, positive relationships, feelings of camaraderie, or feelings of stress related to the forums.

The forums took place asynchronously over the three weeks in the study. Each week had a distinct discussion board for participants to ask questions and provide explanations about the content in the lessons for that week. Some of these posts shed light on participants' learning process and understanding. Figure 4.6 shows a sample of some of the forum post interactions between five different participants related to this category. The last post in the thread below says, "I like your example a lot, it helps me better understand other equations!" Although this category was created based on participants' explanations in the interviews, some of the participant interactions within the forums provide additional evidence for this category because they show that participants' learning was supported through the forums.

This category illuminates the ways in which student learning was improved through the forums, as described in theme three. For example, multiple participants explained that their understanding of the content was clarified or improved by the forums:

Eddie: One week I did have a question and I was a little confused on the lesson after I finished and one of my peers did help me through it.

Devin: I could go and be like and ask my question and see if I understood how someone else worded it better than the lesson and make me like grasp the concept more.

Blake: If I had trouble learning with one thing, I could look through the classmates' forums. And that helped me understand that lesson better.

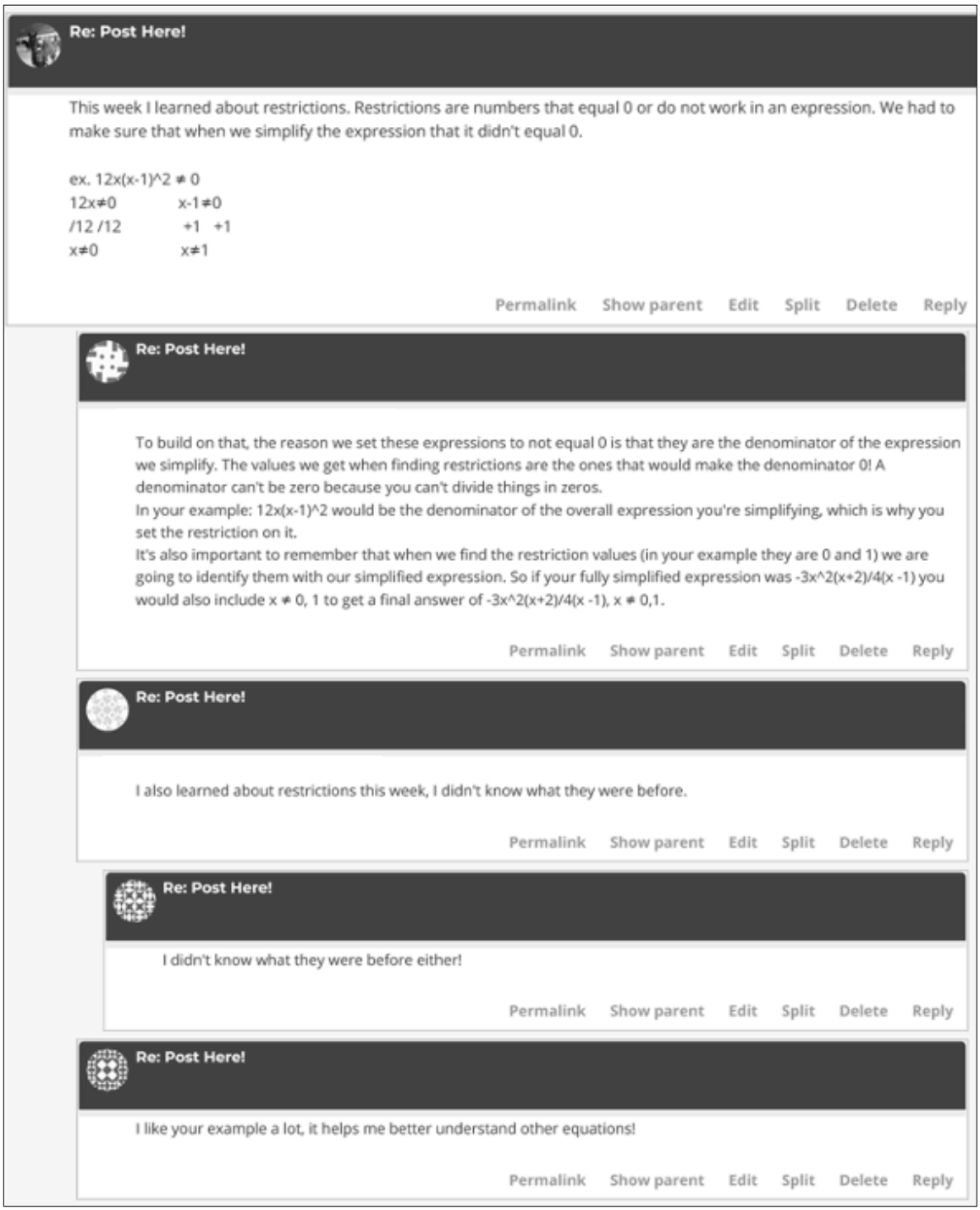

Figure 4.6. Sample of Forum Posts Related to Learning Support

Each of these participants was having trouble with a concept but was able to improve understanding through interacting in the forums. Similarly, Ava explained that the in-depth answers of another participant to her questions was very helpful: “I would typically ask questions. And there was this one student who answered like everyone's questions in crazy detail and like, but he answered my questions, I think, one or two times, and that was very, very helpful.” Conversely, Cameron enjoyed creating the explanation to help others’ learning: “I felt like I actually got the material and I could apply it and make other people understand it better, too.” Finally, in addition to topics being clarified for various participants in the forums, Finley expressed that the forums helped with recall of the topics: “the fact that we had a check back throughout the week made it feel better because it was refreshing the topics.” Whether through gaining clarity, providing explanations, or revisiting important information, participants indicated that the forums supported their learning.

Research has suggested that forums are useful in the learning process in online environments. For example, Thompson, Leonard, and Bridier (2019) noted that forums are the primary means for transferring knowledge in graduate level online courses and that they are “strong mechanisms for delivering sound instructional content” (p. 25). In this vain, the Algebra 2 forums in the intervention provided a vehicle for the transfer of knowledge and instructional content between participants. Figure 4.7 shows an example from the forums of instructional content being effectively delivered by a participant. The worked-out example with the step-by-step processes explained provided a beneficial presentation of the content.

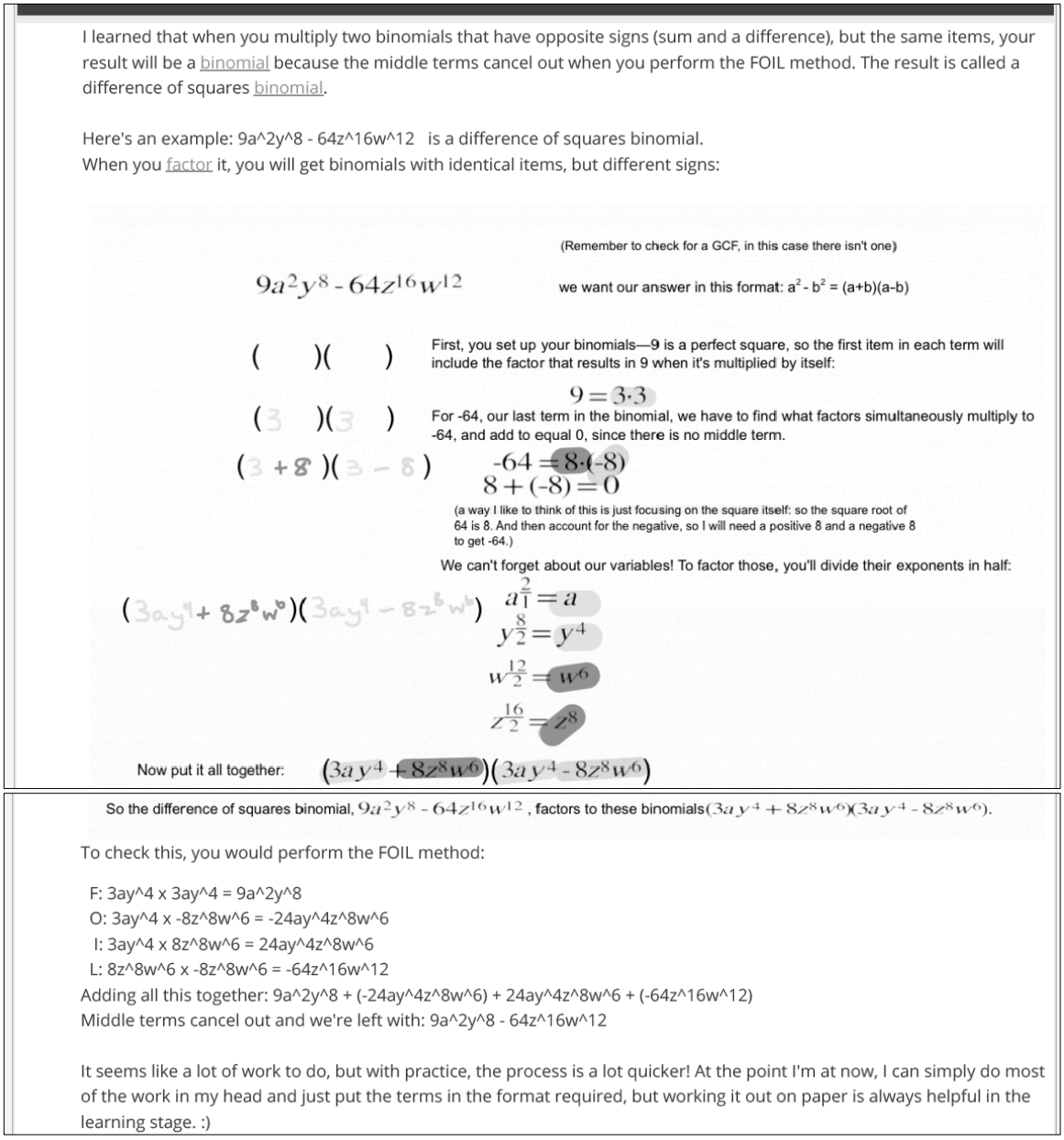

Figure 4.7. Sample Forum Post of a Participant Presenting Content

The effectiveness of the forums may be contingent on the back and forth social interactions between participants, which promote engagement and learning (Dixson, 2015). For example, Figure 4.8 shows the social interactions that took place after the participant's initial post explaining the content in Figure 4.7.

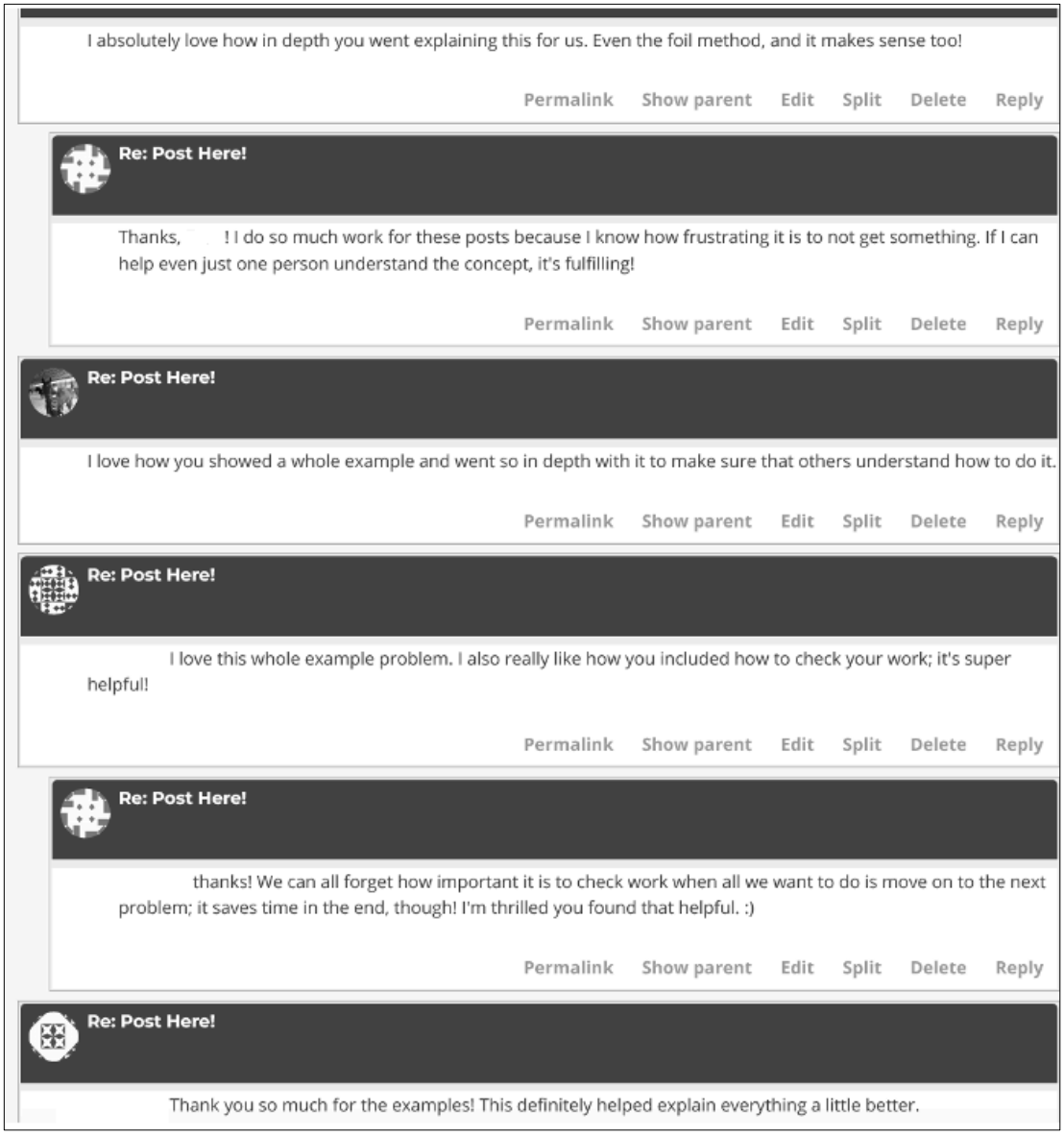

Figure 4.8. Sample Interactions of Participants in Forum After Content Explanation

These interactions show the value participants expressed in the in-depth explanation as well as the original poster's feelings of satisfaction from helping others. These interactions likely contributed to a heightened sense of relatedness among participants, supporting motivation in the learning environment (Ryan & Deci, 2020).

Positive peer connections. The discussion shown in Figure 4.8 demonstrated positive peer interactions as they related to the learning and understanding of the lesson

content. In this category, the focus shifts to general positive peer connections through the forums. In other words, this category relates to the level of connectedness participants expressed toward one another as a result of interacting in the forums. This is slightly different than the following category, *shared experiences*, which specifically depicts feelings of walking in one another's shoes, not being alone, or feelings of camaraderie found through the forums.

This category helps elucidate the positive peer relationships that support connectedness as described by theme three. For example, Eddie stated: "I think the forums give us a chance to kind of talk one on one with each other," and "I definitely felt a sense of connection, especially when since we're all doing the same lesson." By interacting with other participants throughout the week about the lesson content, Eddie expressed feeling more connected to the other participants. Similarly, Finley, Devin, Blake, and Ava expressed feelings of connectedness with other participants through interacting in the forums:

Finley: [The connectedness is] a pretty high level. And I think that just got higher with the more we were, higher with the amount of replies and everything we made.

Devin: I liked the forums. I think that was like a way to interact with the class good because I don't really, we didn't really get a chance to, like, interact with everyone before.

Blake: I'd say I felt a lot more connected than I have before, especially in quarantine. So it was helpful to be able to connect with my

classmates and see what they're struggling with and what they learned.

Ava: I felt very connected to the other students.

The participants felt they had a higher number of and more consistent opportunities to interact with one another through these forums, increasing their feelings of connectedness with one another. Cameron told a story that helps explicate the feelings of connectedness within the forums:

Cameron: I found a pattern and I made something new just so she could understand it better. And I went to check to see if she had saw it, and there was actually another student who I didn't reply to, but said that it really helped them understand it better. And I felt really happy about that because I, sometimes I felt like I was going overboard with the posts because I can do that sometimes, where I feel really passionately about something and I want to get it all out, and seeing that it actually helps people was like really, really gratifying for me. And I just felt like in a better mood after reading that it helped…they're all really like grateful and it felt like it was like a little community in the forums. So it really helped me with stepping out of my comfort zone and just like reaching out to interact with other people.

Through Cameron's explanation of the content and interactions surrounding this explanation, she found "a little community" and felt the interactions were "really, really

gratifying," which even caused her to have "a better mood." Cameron's story shows the depth of connectedness some participants achieved through the forums.

Feelings of connectedness or relatedness through the use of forums in an online setting is supported by research. For example, in a study of three large online courses, Hew (2016) found that peer connections and interactions in forums helped promote course engagement. Martens, Gulikers, and Bastiaens (2004) suggested that these feelings of connectedness within an online course improve motivation in the learners. These findings likely stem from "an inbuilt propensity to feel a psychological sense of connectedness and belonging to other human beings" (Carr, 2020, p. 333), which is also characterized by the need for social relatedness in self-determination theory (Ryan & Deci, 2020).

Shared experiences. The category *shared experiences* refers to participants' expressions of dealing with similar situations as other participants. Participants expressed feeling less isolated and more connected to other participants because of these shared experiences. *Shared experiences* may overlap with the previous category, *positive peer connections*, but this category specifically isolates codes that relate to feelings of camaraderie and not feeling alone.

This category helps build on theme three by highlighting the common struggles that increased feelings of connectedness. For example, multiple participants expressed feeling less isolated because of the forums:

> Eddie: [The forums] made me feel more confident about the lesson that other people may have the same problem as me. And I'm not the only one.

Ava: [The forums] made me think like, wow, I'm not alone in being confused in this specific subject or I'm not the only one who doesn't understand this.

Finley: It was nice being able to see my classmates kind of struggling with the same thing because there's a certain time in cyber school where it just feels like everybody else is like, you're just detached from everybody else, and it feels like only you, like you're the only person going through this hard work and everything, and it just kind of makes it feel better, made me feel better knowing that I wasn't the only person having trouble with those topics sometimes.

Both Eddie and Ava used the phrase “I’m not the only one” and Finley said, “I wasn’t the only person.” Knowing that other participants were struggling in the same way helped increase feelings of confidence, according to Eddie, and helped decrease feelings of detachment, according to Finley. Similarly, Devin expressed feelings of reassurance because of common struggles: “You would respond to a classmate that made me feel like more reassured if I didn't get something, that other people also didn't understand it and it wasn't just me.” The phrase “it wasn’t just me” again underscores the increased feelings of connectedness among participants because of their common struggles and shared experiences.

The shared experiences of the participants were also evidenced in the actual forum posts. For example, Figure 4.9 shows four different participants interacting about a common struggle. The key phrases are highlighted in yellow.

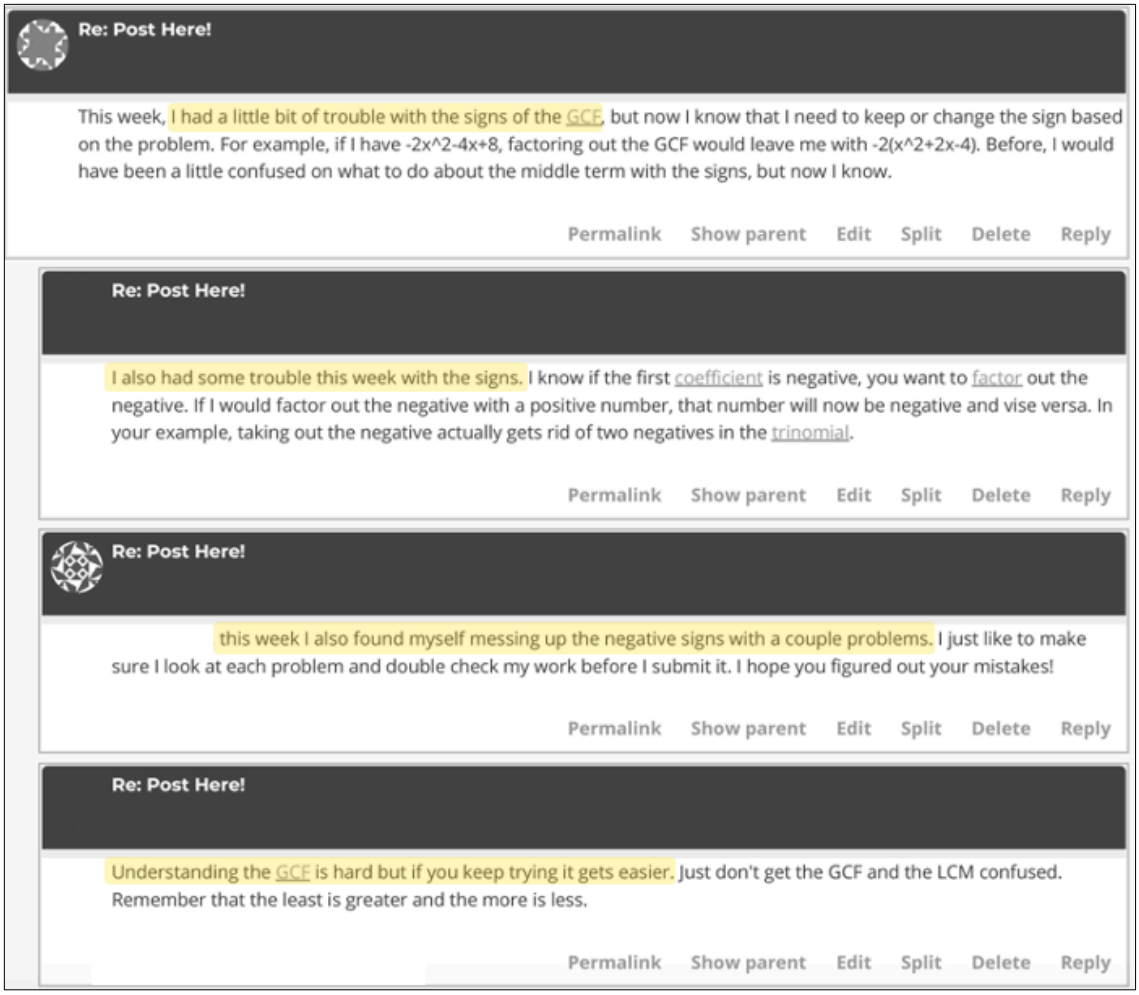

Figure 4.9. Sample of Common Struggles with Negatives in Forums

Each of these participants expressed difficulty using signs with the greatest common factor and offered advice for overcoming this common struggle. In another example, participants shared their struggles with identifying restrictions when simplifying rational expressions. Figure 4.10 shows the interactions of these five participants, with the key phrases highlighted in yellow. Students again identified a common struggle they were having and offered suggestions to each other to help overcome the struggle. These types of shared experiences are likely what the interviewees were referring to when expressing, "I'm not the only one" or similar sentiments.

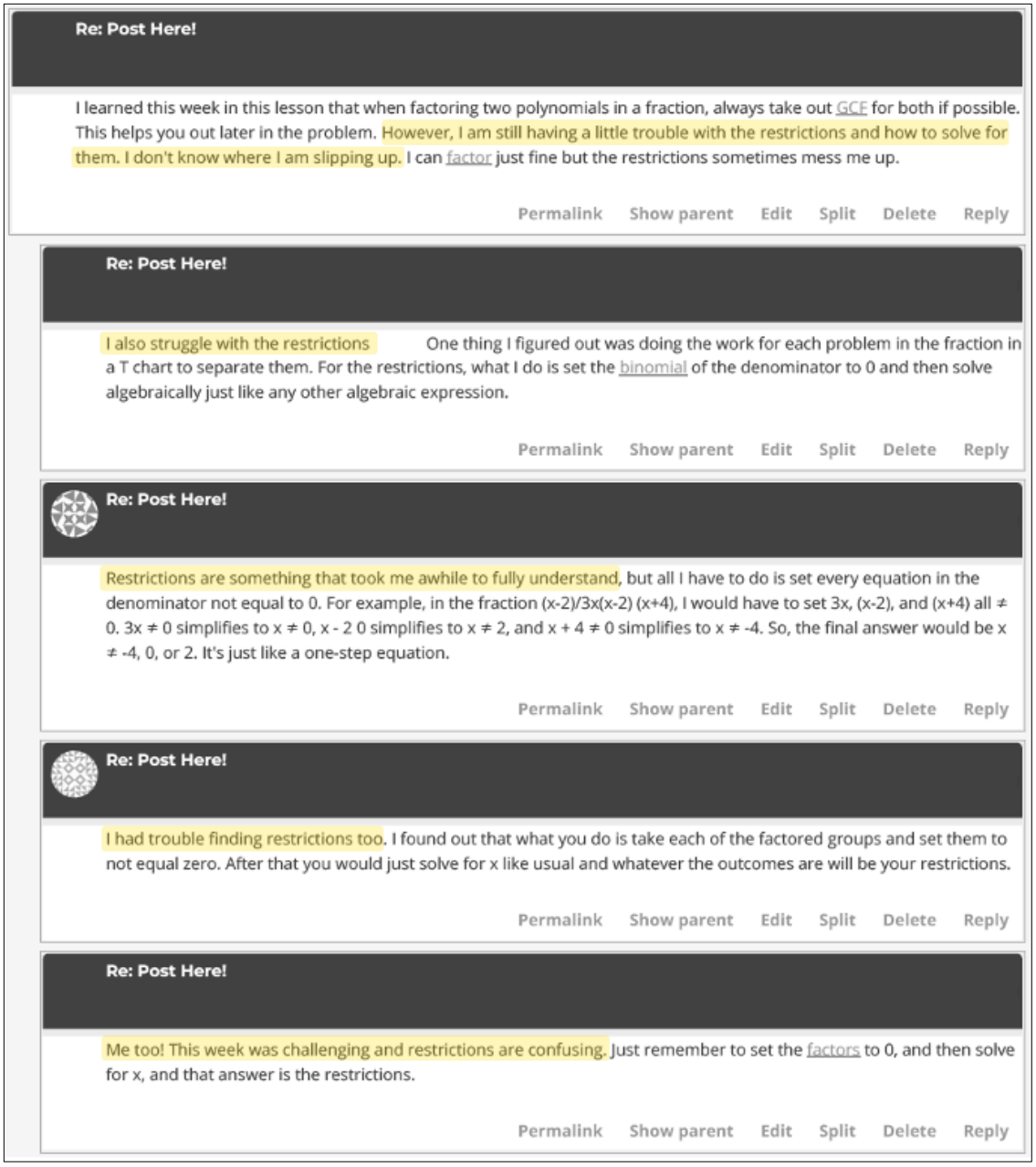

Figure 4.10. Sample of Common Struggles with Restrictions in Forums

The importance of connectedness in the online environment is evident in research. For example, a prominent and commonly identified obstacle for learning in the online environment is a learner's feelings of isolation, as cited in numerous articles (Dixson, 2015; Durak & Ataizi, 2016; Jeffery & Ahmad, 2018; Robinson & Hullinger, 2008). One way to create a more connected environment for online students is through the use of

forums (Bonk et al., 2018; Martin et al., 2018). Creating a "shared sense of belonging" is essential in overcoming these perceptions of disconnectedness (Kebritchi, Lipschuetz, & Santiague, 2017, p. 10), and developing a "community of learners" in the online environment can "alleviate a feeling of participant isolation" (Kebble, 2017, p. 40). Furthermore, Ryan and Deci (2020) suggested that thwarting the need for social connectedness or relatedness can undermine motivation.

Forum frustrations. The category *forum frustrations* refers to difficulties or impediments participants faced when interacting with the forum part of the intervention. Unlike the first three categories in this theme elucidating the positive learning and connectedness aspects of the forums, this category examines the negative aspects of the forums expressed by participants. In comparison to positive peer relationships and learning reinforcement that resulted from the forums, the number of forum frustrations expressed was very low, as shown by the number of codes. The first three categories in this theme have a combined total of 73 codes, while the category *forum frustrations* has a total of six codes.

This category helps show that although participants felt some different types of frustrations within the forums, these negative feelings did not outweigh the positive benefits of the forums. For example, Cameron found the inability to subscribe to the forums as a minor annoyance:

Cameron: We couldn't like subscribe to the forum posts was just a little frustrating because I felt like I wanted to make sure that the people I responded to got the help they needed and I didn't really get that

entirely, but I think that was the only thing that bothered me a little bit.

Cameron indicated that the option to subscribe would aid in monitoring other participants' responses to provide better interactions. Ava, on the other hand, questioned whether these forums were even necessary:

Ava: I didn't mind making a post. Sometimes I was I would think like, is this necessary, but then I was like, well, maybe it is because, you know, I'm getting my questions answered, I could be answering other people's questions, just a lot of help. It's, I kind of thought it was like for a help thing, if that makes any sense.

Although Ava questioned the necessity of the forums, she realized that they were helpful in learners' understanding of difficult topics. Having this place to seek and offer help was a benefit overall. Blake and Cameron expressed feelings of hesitation, dread, or nervousness when first approaching the forums:

Blake: I was a bit nervous, but my first forum that I did. But the more I did, the easier it came.

Cameron: At first when I saw we had to do the forum post, I was kind of like dreading it because I remember in my past online school, I think we had to do forum posts like every week or every two weeks, and just because I didn't, at that time, I wasn't as confident with math as I am now, I felt like I didn't know much, so I felt like that would translate over to this one. But then when I did the first one, I was like, oh, wait, these are actually kind of fun, when you really

> understand and you can help other people, it's even better. So as the weeks went on, I actually looked forward to doing the forum post.

Even though Blake and Cameron described negative feelings when first approaching the forums, both explained that these negative feelings did not last. Blake indicated that the forums became easier over time and Cameron noted that the forums were "actually kind of fun" and said, "I actually looked forward" to them. Whether participants described a lack of ability to subscribe, questioning the necessity of the forums, or nervousness in first approaching the forums, each of these participants also indicated that, for the most part, the forums were a positive and beneficial experience.

Theme 3 summary. Theme three demonstrated that despite some minor frustrations with the forums, the positive peer relationships and common struggles identified in the forums increased participants' feelings of connectedness and supported their learning. This theme was developed from the four categories: *peer interactions aided in learning*, *positive peer connections*, *shared experiences*, and *forum frustrations*. The overwhelming number of codes for the positive categories as opposed to the negative category helped support the overarching benefits of the forums. Specifically, participants were able give and receive help to sharpen their understanding of concepts, build positive peer relationships, and reduce feelings of detachment and isolation through the forums. The descriptions of the forums by the participants and the situated research led to the assertation that the forums fostered feelings of relatedness, ultimately improving participants' motivation.

Chapter Summary

Chapter 4 contained a presentation of the quantitative and qualitative data within the study along with a thorough description of the qualitative analysis process and interpretations. The quantitative data included descriptive and inferential statistics for the motivation questionnaire and the content knowledge test. Both of these utilized the pretest-posttest format. The qualitative analysis of the six participant interviews resulted in three emergent themes and assertions, supported by direct participant quotations and relevant literature. The quantitative and qualitative data from Chapter 4 will be analyzed in light of the two research questions for the study in Chapter 5 along with implications and limitations for the study.

CHAPTER 5

DISCUSSION, IMPLICATIONS, AND LIMITATIONS

This chapter situates the findings of the study within the literature on self-determination theory in the context of online course design. The purpose of this action research was to create and implement a self-determination theory-based online unit on factoring polynomials for mathematics students at Peacock Cyber School in order to improve students' motivation levels. Three themes emerged from the qualitative analysis of the interviews regarding a supportive lesson structure, efficacious feedback features, and peer connectedness within the forums (see Table 4.5). The quantitative content knowledge exam and motivation questionnaire indicated that content knowledge and competence, unlike autonomy and relatedness, significantly increased through the intervention. This chapter includes (a) a discussion integrating the findings in consideration of the two research questions, (b) implications, and (c) limitations of the research.

Discussion

The intervention in this study was based on self-determination theory, specifically introducing online course design components built from implementation strategies for autonomy, competence, and relatedness found in prior research (see Figure 3.1). In answering the research questions for this study, the quantitative and qualitative findings were integrated and situated within similar studies of self-determination theory. The discussion addresses the two research questions for this study:

- Research Question 1: How does the implementation of a self-determination theory-based unit on factoring polynomials in an online mathematics course affect students' motivation at Peacock Cyber School?
    a. How are students' feelings of autonomy affected?
    b. How are students' feelings of competence affected?
    c. How are students' feelings of relatedness affected?
- Research Question 2: To what extent does the implementation of a self-determination theory-based online unit on factoring polynomials in an online mathematics course affect students' mathematics content knowledge at Peacock Cyber School?

The discussion for each research question includes the relevant findings from the data in this study, relevant studies of self-determination theory, and the theoretical framework of self-determination theory.

Research Question 1: How does the implementation of a self-determination theory-based unit on factoring polynomials in an online mathematics course affect students' motivation at Peacock Cyber School? a) How are students' feelings of autonomy affected? b) How are students' feelings of competence affected? c) How are students' feelings of relatedness affected?

Within self-determination theory, the basic psychological needs mini-theory addresses a person's well-being and ill-being. Ryan and Deci (2017) posited that the satisfaction of autonomy, competence, and relatedness enhances a person's autonomous extrinsic and intrinsic motivation, thereby improving his or her overall well-being. Conversely, the frustration of these three needs leads to decreased motivation or

amotivation and the person's ill-being (Ryan & Deci, 2017). Researchers have found success with improving motivation in the online educational environment through the integration of self-determination theory (Hsu et al., 2019; Huang et al., 2019; Jacobi, 2018; Proulx et al., 2017).

The first research question aimed to examine the effects of the intervention on the three psychological needs of self-determination theory to explain the impact on participants' motivation. The intention of the intervention was to improve students' motivation in the Algebra 2 course by supporting the three needs through a self-determination theory-based online course design. Based on the quantitative results from the BPNSFS, there was a significant increase in competence but not in autonomy or relatedness. Based on the qualitative results, there were indications of positive impacts on all three needs with varying degree. Table 5.1 shows the number of categories and codes that emerged from the interviews that correspond to each need of self-determination theory.

Table 5.1 *Interview Categories and Codes Aligned with SDT Needs*

SDT Needs	Number of Related Categories	Total Number of Codes in Categories
Autonomy	6	132
Competence	10	215
Relatedness	3	73

This section will address the facilitation of (a) autonomy, (b) competence, and (c) relatedness in this study based on the results of the motivation questionnaire and interviews.

Facilitation of autonomy. Autonomy can be defined as a person's self-regulation, requiring internal volition and the perception and acceptance of one's willful actions (Ryan & Deci, 2017, 2020). Strategies that support authentic choice with clear expectations, appropriate scaffolding, vocabulary resources, and non-controlling structure can facilitate feelings of autonomy. The design components in the intervention based on these strategies, including a purposeful multipage lesson structure, vocabulary resources with options, optional self-check and remediation buttons, and optional guided enrichment questions, were meant to provide a felicitous environment for autonomy to thrive.

The motivation questionnaire provided quantitative data about participants' perceptions of autonomy based on the autonomy satisfaction and autonomy frustration subscales. The composite autonomy scores of the participants (n = 50) for the pretest (M = 3.23, SD = 0.51) showed a small and unreliable increase in the posttest (M = 3.42, SD = 0.65) based on the standard deviations, as shown in Figure 5.1. With an alpha value of .017, results of the Wilcoxon signed-rank test revealed that the intervention in this study did not cause any significant changes in participants' perceptions of autonomy from the pretest (Mdn = 3.25) to the posttest (Mdn = 3.31, W = 423.50, p = .092).

Although the quantitative data did not show a change, the qualitative data told a somewhat different story. Specifically, some categories in theme one, *participants expressed that the elements of the lesson structure were supportive of their learning and not overwhelming*, highlighted key areas where participants may have expressed feelings of autonomy due to the intervention.

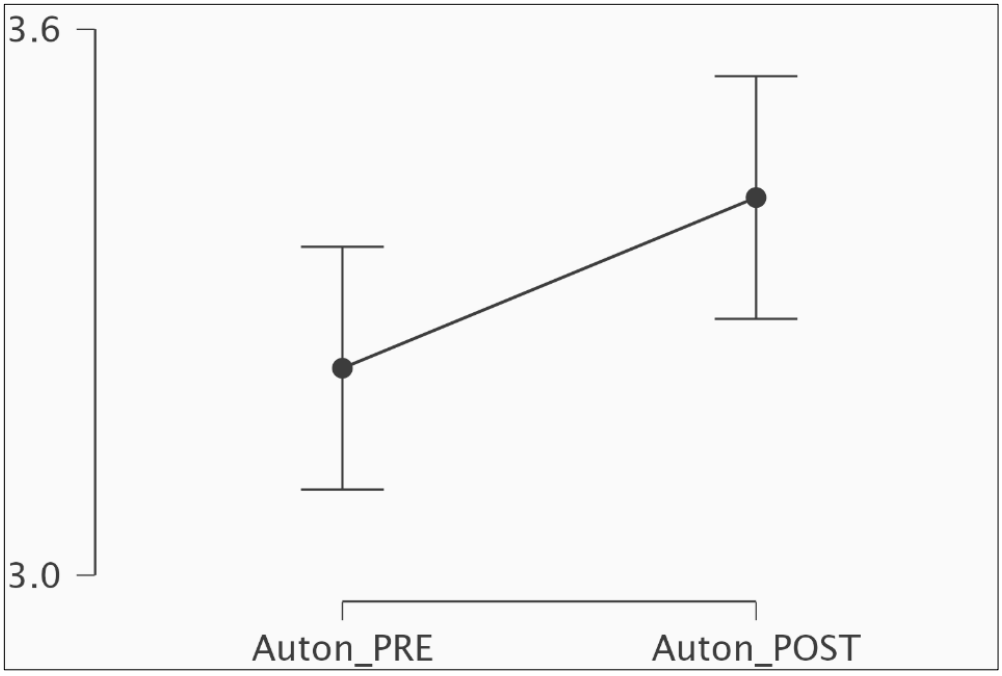

Figure 5.1. Means and Standard Deviations of Composite Autonomy Scores. This figure shows the mean of the autonomy pretest scores (Auton_PRE) and the mean of the autonomy posttest scores (Auton_POST) along with the standard deviation range. From JASP (Version 0.16, 2021).

Table 5.2 shows how the intervention design components for autonomy are related to the categories from the interviews and the number of codes associated with each one.

Table 5.2 *Autonomy Design Components and Associated Interview Categories*

Intervention Design Components for Autonomy	Associated Categories from Theme 1 of the Interviews	Number of Codes
Purposeful multipage lesson structure	Lesson structure supported learning	44
	Content chunking facilitated understanding	11
	Good weekly expectations	18
Vocabulary resources with options	Accessible resources	20
Optional self-check buttons	Options improved motivation	34
Optional remediation buttons	Skipped optional material	5
Optional guided enrichment		

The categories from the interviews shed light on the feelings of autonomy expressed by the participants in connection with the multipage structure, resources, and optional features of the lessons.

Multipage structure. Participants consistently commented on their satisfaction with the multipage structure of the lessons. Both the improved organization and check for understanding questions throughout the lessons provided a non-controlling structure. For example, Cameron described having more control over using the information learned: "I felt like I could like implement the information I learned right away instead of waiting for to do an assignment or a quiz, [the multipage structure] felt just more organized and better." The lesson content and practice that Cameron wanted to interact with was available and easy to find. Satisfaction from this non-controlling structure was also evident in Ava's comment about the lesson layout: "it made me feel good to know what I was doing." The participants seemed to indicate that they perceived legitimate opportunities for more self-regulation within the multipage lesson structure, increasing the fulfillment of autonomy.

Fostering autonomy through a noncontrolling structured environment has been substantiated in research. For example, a teaching environment that is perceived as controlling has led to reduced autonomous motivation, while a noncontrolling supportive environment has led to increased autonomous motivation (Haerens et al., 2015). When structure is provided with autonomy-supportive methods, it leads to increased engagement and internalization (Ryan & Deci, 2020). A supportive rather than controlling structure is part of enhancing the perception of autonomy.

Although a supportive structure can enhance autonomy, it primarily facilitates competence, which may help account for the insignificant results on the autonomy subscale of the motivation questionnaire in this study. For example, Ryan and Deci (2020) note that "structure can especially enhance competence satisfaction" (p. 4) and Hartnett (2015) found that unclear structure was the principal impediment to competence. In this study, a purposeful multipage structure was designed to enhance autonomy while a propitious structure with scaffolding and strongly guided instruction with practice was designed to enhance competence. The effects of the lesson structure may have been primarily construed by participants in increased competence rather than autonomy. Further research is needed to differentiate between the outcomes of a supportive structure on autonomy and competence.

Resources. Some participants indicated that the resources in the lessons, such as the vocabulary and extra help information, were easy to access and useful in their learning. These resources provided a means for the participants to access needed information and move on successfully in the lesson on their own volition, likely increasing their self-regulation. For example, in using the extra resources provided in the lessons, Finley explained: "[I] didn't feel like I was just kind of backed against a wall." These resources were accessible and usable in enabling Finley to move on in the lesson. Yet in comparison to the 73 codes associated with the multipage lesson structure design component of the intervention, only 20 codes were associated with the resources design component. Although resources seemed to be a positive aspect for some participants, the low number of occurrences may help explain the lack of increased autonomy results on the motivation questionnaire.

In research on self-determination theory, providing resources has been shown to facilitate autonomy in learners. Ryan and Deci (2020) indicated that resources play an important role in supporting autonomy. Based on the studies previously mentioned, resources that are relevant (Murray, 2012), especially those related to vocabulary acquisition (Qian & Sun, 2019), are likely to promote autonomy and better performance (Hostager, 2014). Although these resources provide a means for self-regulation in learners, they also enhance felt competence (Hew, 2016). This ambiguity between autonomy and competence with accessible resources, along with the lower number of codes, may also contribute to the lack of increased autonomy shown in the motivation questionnaire results.

Optional Features. Participants explained that the optional features in the lessons reduced feelings of pressure and provided authentic choice. For example, Blake described: "I didn't feel pressured at all. So if I felt like doing the challenge question, I could, and if I didn't, I didn't have to." Blake had volition and choice in interacting with these challenge questions, providing a means for self-regulation and autonomy to thrive. Similarly, Cameron expressed feelings of self-regulation in interacting with the vocabulary options: "but since I already knew [the vocabulary], I just did the check for understanding." Cameron was presented with an authentic choice to skip this material and made the self-directed choice to do so.

In contrast to the multipage structure and accessible resources, the optional features provided in the lessons are most clearly applicable to autonomy rather than competence. Meaningful and flexible choices promote autonomy (Durksen et al., 2016; Ryan & Deci, 2020) while a lack of choice has been shown to undermine autonomy

(Hartnett, 2015). The presence of choice has been shown to lead to feelings of autonomy and increased intrinsic motivation (Huang et al., 2019). While the perceptions of the small number of interviewees in this study seemed to align with this research on choice fostering autonomy, Jacobi (2018) found that participants in her study did not reference choice as a motivational strategy for autonomy. A more substantial investigation into the choices used in the intervention and the ways in which a larger population of the participants interacted with those choices may help shed light on the lack of significant results shown in the autonomy subscale of the BPNSFS.

Based on the motivation questionnaire, participants' feelings of autonomy did not significantly change due to the intervention, however, the interviews brought to light some areas of the lesson that may have improved these feelings. Specifically, the multipage structure, accessible resources, and optional features in the lessons provided a supportive framework and authentic choice for the participants. The ambiguity between autonomy and competence with the multipage structure and resources may help account for the insignificant findings in autonomy and significant findings in competence on the motivation questionnaire. With choice being the most distinct design component for autonomy, further investigation into the participants' use and perception of choices in the lessons may be helpful. The changes in autonomy due to the intervention remain somewhat questionable and need to be explored further, especially in connection with competence and choice.

Facilitation of competence. Competence can be defined by feelings of self-efficacy and mastery of optimal challenges within one's environment (Ryan & Deci, 2017; White, 1959). Strategies that support conceptual scaffolding with relevant prior

knowledge, work out examples, and optimal challenges in combination with informative and correctness feedback can provide an environment for competence to flourish. The design components in the intervention based on these strategies, including prior knowledge checks, strongly guided instruction and enrichment questions, and self-check buttons with informative and correctness feedback, were meant to enhance perceptions of competence among participants.

The motivation questionnaire provided quantitative data about participants' perceptions of competence based on the competence satisfaction and competence frustration subscales. The composite competence scores of the participants (n = 50) for the pretest (M = 3.65, SD = 0.79) showed a noticeable increase in the posttest (M = 3.91, SD = 0.76). With an alpha value of .017, the results of the Wilcoxon signed-rank test revealed that the intervention in this study likely caused a significant increase in participants' perception of competence from the pretest (Mdn = 3.63) to the posttest (Mdn = 4.00, W = 233.00, p = .001).

These findings were confirmed by the large amount of qualitative data from the interviews corresponding to an increased perception of competence. Specifically, various categories in themes one and two illuminated areas where participants may have expressed feelings of competence due to the intervention. Out of the three needs of SDT, the greatest number of categories and codes corresponded to the need of competence (see Table 5.1). Table 5.3 shows how the intervention design components for competence are related to categories that arose from the interview data and the number of codes associated with each of those categories. The categories from the interviews shed light on the feelings of competence expressed by the participants in connection with the prior

knowledge, strongly guided instruction, informative and correctness feedback, and enrichment questions.

Table 5.3 *Competence Design Components and Associated Interview Categories*

Intervention Design Components for Competence	Associated Categories from the Interviews (Theme #)	Number of Codes
Prior knowledge checks	Prior knowledge increased confidence for the lesson (1)	15
	Prior knowledge gave useful information (1)	9
Strongly guided instruction with practice	Scaffolding aided understanding (1)	6
	Lesson structure supported learning (1)	44
	Content chunking facilitated understanding (1)	11
Self-check buttons Correctness grade for the lesson	Checking answers increased confidence (2)	61
	Informative feedback improved learning (2)	23
	Grade increased motivation (2)	31
Optional guided enrichment questions	Appropriate content level (2)	9
	Challenge questions revealed deeper content (1)	6

Prior knowledge. Two categories in theme one related to the prior knowledge section of the lesson: *prior knowledge increased confidence for the lesson* and *prior knowledge gave useful information*. In these categories, participants expressed feelings of preparedness and increased confidence for the lessons as a result of the prior knowledge information and checks. For example, Finley explained, “I wasn’t just like plunging into new stuff without making sure I remembered the older topics” and Ava noted, “I liked completing [the prior knowledge] because it gave me confidence that I knew what I was doing so that I could then complete the lesson.” In both cases, the prior knowledge helped

orient the learners for the subsequent lesson material and provided feelings of self-efficacy or confidence for the lesson.

In self-determination theory, increasing students' confidence or feelings of self-efficacy relates to fulfilling the need for competence. Feelings of competence are heightened by higher levels of prior knowledge (Li & Baker, 2018). In analyzing influences that undermine competence in self-determination theory, Hartnett (2015) found that "fail[ing] to take into account the prior knowledge, skills and experience of learners can also undermine a learner's need to feel capable as not all students will believe they have the necessary knowledge and skills to succeed" (p. 96). In contrast to lack of prior knowledge supports thwarting competence, supporting prior knowledge, especially by scaffolding based on the level of prior knowledge, improves motivation and learning outcomes (Chen, 2014). Situated within this research and based on the interview responses, it is likely that competence was increased in this study partly due to the prior knowledge section of the lessons.

Strongly guided instruction. In addition to prior knowledge, strongly guided instruction likely contributed to the increased competence levels demonstrated on the BPNSFS. The following three categories in theme one that emerged from the interviews align with the strongly guided instruction design component for competence: *scaffolding aided understanding*, *lesson structure supported learning*, and *content chunking facilitated understanding*. The multipage structure of the lessons with information chunked onto the different pages and content scaffolded as participants progressed through the lesson seemed to facilitate feelings of competence. For example, Devin said that the lesson "is like sectioned…and I found it useful" while Cameron explained that

the multipage lesson structure "felt just more organized and better." Chunking the information by content in an organized way through the lessons was helpful. In the context of working through the lessons Cameron said, "I did feel more confident as I was going through the lesson" and Eddie described feeling "a bit more calm and not as stressed" by the supportive structure of the lessons. It is likely that the strongly guided instruction built into the lessons through the multipage structure, content chunking, and scaffolding helped feelings of competence thrive.

Research supports the relationship between these categories in the interviews and the facilitation of competence through strongly guided instruction. Kirchener, Sweller, and Clark (2006) indicated that strongly guided instruction enhances competence. The category *scaffolding aided understanding* is strongly related to the progression through Vygotsky's (1978) zone of proximal development. When learners perceive they are supplied with appropriate supports and able to be effective with them, feelings of self-efficacy and competence flourish (Rayburn et al., 2018). Based on the participants' responses in the interviews, the content chunking, structure, and scaffolding of the lessons likely helped increase their feelings of competence.

Informative and correctness feedback. The area of feedback in facilitating competence in the intervention contained the largest number of codes compared to the other areas with 115 codes (see Table 5.3). Informative and correctness feedback primarily stemmed from the intervention design component of the self-check buttons. Participants found the self-check buttons extremely helpful in building feelings of self-efficacy, as evidenced by Ava's description: "I really liked, I really, really enjoyed [the check buttons] because I'm always nervous that my answers are incorrect, and I, I just I

really liked knowing that I was correct." The knowledge of her own competence was important to Ava in working through the lessons. Similarly, Cameron interacted with the self-check buttons "after every answer just to check that I was doing my work right and, you know, just to prove that I was actually learning." Both examples show that feelings of competence improved through the self-check buttons and that these feelings were important to the participants.

Facilitating competence through feedback is strongly supported in research. Ryan and Deci (2017) indicated that the two foundational supports for competence are structure, described in the previous section, and feedback. Martin, Kelly, and Terry (2018) explained that "positive feedback that contains content from which meaning can be constructed is vital in terms of building competence" (p. 45). Positive informational feedback is best (Ryan & Deci, 2020), but feelings of self-efficacy have been shown to improve through both correctness feedback (Wang & Yang, 2021) and informative feedback (Hartnett, 2015; Yantraprakorn et al., 2018). Based on the qualitative results of this study, it appears that part of the quantitative increase in competence is due to the informative and correctness feedback provided in the intervention through the self-check buttons.

Enrichment questions. Although representing a smaller number of codes in the interviews than the other sections related to competence (see Table 5.3), the enrichment questions helped point to the optimal challenge levels in the lessons. For example, Cameron noted the enrichment questions were "a bit challenging, but not so much that you don't understand what's going on" and Devin explained that the enrichment questions were "a good push" but not "overwhelming." These sentiments about the

appropriate challenge level within the enrichment questions were echoed in Ava's statement that they were a "good level of challenge. They weren't too hard or too easy." In each of these examples, participants expressed that the enrichment questions in the lessons appropriately challenged them.

According to related research, providing optimal challenge is a part of facilitating competence and intrinsic motivation. Essentially, effectance motivation (White, 1959) arises from interacting effectively with optimal challenges in one's environment (Deci & Ryan, 1985). If the challenge level is too easy or too difficult, feelings of competence are not enhanced (Hartnett, 2015; Huang et al., 2019). If the challenge level is appropriate, then feelings of self-efficacy and intrinsic motivation improve (Tamborini et al., 2010; Tan, 2018). Based on the qualitative data from the interviews, it is likely that the appropriate challenge in the lessons had at least a small part in increasing the perception of competence among the participants.

The results from the motivation questionnaire indicated that participants' feelings of competence significantly increased after the intervention. These findings were strongly supported by the categories that emerged from the interviews. Specifically, the categories associated with the prior knowledge checks, strongly guided instruction, self-check buttons, and enrichment questions demonstrated the facilitation of competence. The satisfaction of competence through these intervention design components was evidenced by the participants statements surrounding increased confidence through the prior knowledge, supportive structure, scaffolding, content chunking, informative and correctness feedback, and appropriate content level of the lessons. Based on both the

quantitative and qualitative data in the study, it is likely that competence was enhanced through the intervention.

Facilitation of relatedness. Relatedness can be defined by feelings of genuine connectedness and social acceptance (Ryan & Deci, 2017). Strategies that support positive social interactions with clear communication expectations can facilitate feelings of relatedness. The design components in the intervention based on these strategies, including a discussion board and clear parameters for interaction, were meant to provide a felicitous environment for relatedness to thrive.

The motivation questionnaire provided quantitative data about participants' perceptions of relatedness based on the relatedness satisfaction and relatedness frustration subscales. The composite relatedness scores of the participants (n = 50) for the pretest (M = 3.52, SD = 0.66) showed a small and unreliable increase in the posttest (M = 3.66, SD = 0.76) based on the standard deviations, as shown in Figure 5.2. With an alpha value of .017, the results of the Wilcoxon signed-rank test revealed that the intervention in this study did not cause a significant increase in participants' perception of relatedness from the pretest (Mdn = 3.63) to the posttest (Mdn = 3.69, W = 368.00, p = .038).

The quantitative data for the relatedness subscale of the BPNSFS were the most surprising results of the study because the qualitative data told a much different story in this area. The third theme that emerged from the interviews, *despite expressing frustration with the forums at times, participants articulated that the positive peer relationships and common struggles supported their learning and connectedness*, predominantly corresponded to the relatedness component of self-determination theory. Even though less codes were associated with relatedness compared to autonomy and

competence (see Table 5.1), 73 out of the 79 codes were associated with positive elements of theme three (see Table 4.4).

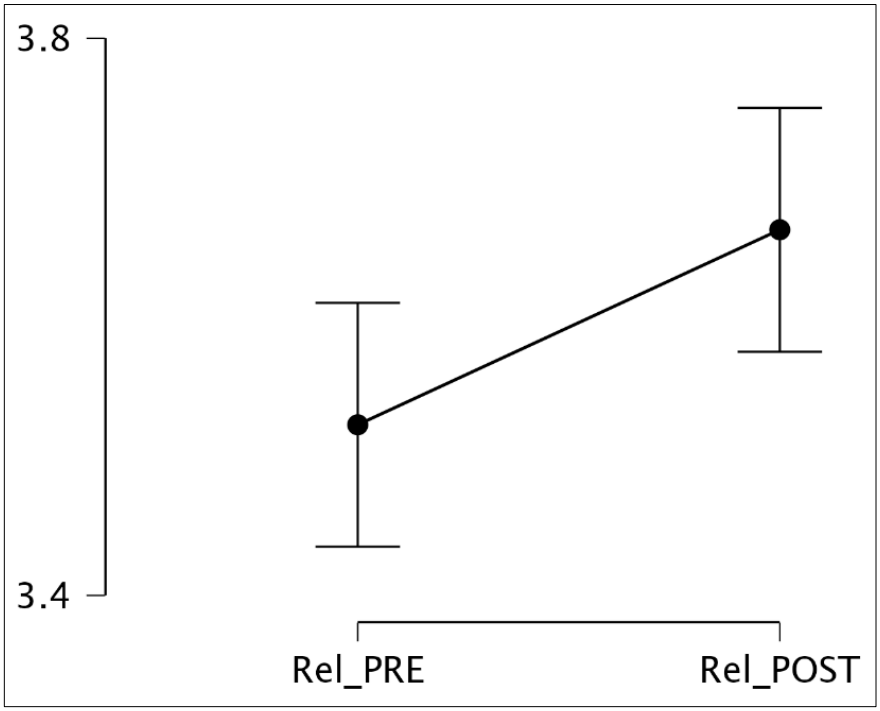

Figure 5.2. Means and Standard Deviations of Composite Relatedness Scores. This figure shows the mean of the relatedness pretest scores (Rel_PRE) and the mean of the relatedness posttest scores (Rel_POST) along with the standard deviation range. From JASP (Version 0.16, 2021).

Additionally, the strong connections to the core components of relatedness in research that were described by the participants showed promising evidence for an increase in relatedness. Table 5.4 shows the intervention design components for relatedness and corresponding categories and number of codes that arose from the interviews.

Deci and Ryan (1985) explained that there are two core components to the satisfaction of relatedness: feelings social connectedness and feelings of being a contributing member to a group. In their words, "both by feeling connected to close others and by being a significant member of social groups, people experience relatedness

and belonging" (Deci & Ryan, 1985, p. 3). The categories from the interviews elucidated participants' perceptions of these two defining characteristics of relatedness in the forums through expressions of reduced isolation and constructive connections.

Table 5.4 *Relatedness Design Components and Associated Interview Categories*

Intervention Design Components for Relatedness	Associated Categories from Theme 3 of the Interviews	Number of Codes
Discussion boards	Positive peer connections	31
Clear parameters for interaction	Shared experiences	16
	Peer interactions aided in learning	26

Reduced isolation. Participants indicated in the interviews that they felt less isolated and genuinely connected to other participants through the forums. For example, Finley explained that the connectedness felt in the forums was "a pretty high level. And I think that just got higher with the more we were, higher with the amount of replies and everything we made." Through consistent interactions, Finley felt more connected and less isolated. A large part of this reduced isolation was due to participants' feelings that they had common experiences. Eddie expressed that the forums "made me feel more confident about the lesson that other people may have the same problem as me. And I'm not the only one," and Ava said, "I felt very connected to the other students because it made me think like, wow, I'm not alone in being confused in this specific subject or I'm not the only one who doesn't understand this." These shared experiences that participants were able to realize through the forums supported feelings of connectedness.

The satisfaction of relatedness through reduced feelings of isolation and increased feelings of connectedness is supported in research. For example, Rayburn, Anderson, and Smith (2018) found that building on common skills in a teamwork setting helps foster

relatedness. Forums have been shown to provide an avenue for connectedness in online courses (Bonk et al., 2018). Specifically, peer-to-peer interaction in the online environment with immediacy likely facilitates relatedness (Jacobi, 2018). Based on the research and participant responses in the interviews, it is possible that feelings of isolation in this study were reduced in spite of the results shown on the BPNSFS.

Constructive connections. Participants expressed the positive emotions associated with constructive communication among their peers. For example, Cameron described the emotional effect that contributing to her classmates' learning produced.

> Cameron: Seeing that [my post] actually helps people was like really, really gratifying for me. And I just felt like in a better mood after reading that it helped…[the other participants] are all really like grateful and it felt like it was like a little community in the forums.

The constructive posts Cameron made had a positive effect on her emotions when she saw it aided others and that others were grateful for her detailed explanations. Similarly, Devin explained "it was a lot more of a connection than beforehand…you can help them and they can help you. And it's kind of more of a unit than like individual." Receiving help and helping others increased connectedness among the participants.

According to Deci and Ryan (1985), in combination with feeling socially connected to others, "equally important to relatedness is experiencing oneself as giving or contributing to others" (p. 3). A key part of relatedness, then, is the perception that one's actions are useful and important to others in a community of learners. Learning and motivation are improved by the fulfillment of relatedness (Rayburn et al., 2018). This satisfaction of relatedness also increases emotional involvement in the group (Huang et

al., 2019). Based on this research and the participants' descriptions, it is likely that relatedness was improved as a result of contributing to others' learning progress, at least for some of the participants in the study.

The BPNSFS did not show a significant improvement in relatedness, but participants in the interviews provided strong support in their descriptions surrounding the defining characteristics of relatedness. Particularly, participants expressed feeling less isolated and having constructive connections with their peers. This seeming contradiction in the results may be illuminated by two studies. Martin, Kelly, and Terry (2018) found that the satisfaction of relatedness was possible in the online environment, but that it was the most difficult need to satisfy. Hartnett (2015) found that attempting to make connections across a large online class or group undermined relatedness as opposed to making connections with a small group of peers. The already isolated environment of online learning (Durksen et al., 2016) and the relatively large class size in the present study may have contributed to the lack of increased relatedness shown by the BPNSFS.

Research Question 2: To what extent does the implementation of a self-determination theory-based online unit on factoring polynomials in an online mathematics course affect students' mathematics content knowledge at Peacock Cyber School?

Research has shown that self-determination theory can improve motivation, which results in increased achievement. Ryan and Deci (2020) posited that the fulfillment of autonomy, competence, and relatedness boosts intrinsic motivation, which bolsters achievement. For example, Froiland, Davidson, and Worrell (2016) found that applying self-determination theory to teachers' satisfaction of autonomy resulted in increased

achievement among mathematics students. Leong, Tan, Lau, and Yong (2018) found that improved motivation resulted in higher performance among science students, especially when intrinsic motivation was increased. In the online environment, Hsu, Wang, and Levesque-Bristol (2019) found that the use of self-determination theory increased both motivation and achievement. Although an indirect result of utilizing self-determination theory, the second research question aimed to determine if learner achievement was affected by using this theory in the online mathematics course design at Peacock Cyber School.

To answer this question, a content knowledge exam was given as a pretest and posttest. The quantitative findings show a significant increase from the content knowledge pretest ($M = 0.65$, $SD = 0.20$) to the content knowledge posttest ($M = 0.92$, $SD = 0.12$); $t(50) = 9.88$, $p < .001$. Based on these results, the use of a self-determination theory-based online mathematics unit seemed to have a significant positive effect on student achievement. These findings align with prior research about achievement and self-determination theory, yet the use of self-determination theory was not compared to other pedagogical approaches in this study. Further research is needed to determine the relationship between achievement and motivation based on a self-determination theory-based online course design for mathematics students.

Implications

This research study on the use of self-determination theory in online mathematics course design has implications for my personal growth, for the research setting of Peacock Cyber School, and for future research. This section addresses three levels of

implications: (a) personal implications, (b) recommendations for Peacock Cyber School, and (c) implications for future research.

Personal Implications

Through this study, I have grown in many areas that will help in my professional practice as a designer, developer, and educator. Three of these areas include: (a) the application of theory to practice, (b) the integration of multiple analysis methods, and (c) sharing and receiving feedback on my findings.

The application of theory to practice. The gap between theory and practice has been a longstanding issue in education. Despite exhaustive efforts to connect the two, "teachers continue to cling to an image of theory as incomprehensible 'jargon' that has nothing to do with their everyday problems" (Carr, 1980, p. 60). Yet the integration of theory and practice is vital to make the practice worthwhile and have a chance at improvement. In this study, I had the opportunity to examine self-determination theory at its roots, consider studies that attempted the application of that theory in various contexts, and then apply that theory in my practice.

Through the process of applying self-determination theory to my own sphere of influence, I have learned three vital steps for connecting theory and practice: (a) a comprehensive examination of the theory, (b) a review of the literature in which the theory has been applied to various contexts, and (c) a consideration of how to apply the theory to one's specific context.

A comprehensive examination of the theory. A comprehensive examination of a theory includes the theory itself, related theories in the same context, and the overarching theme for the theories. For example, in the study of a theory on motivation, I first had to

examine the roots of motivation, such as extrinsic and intrinsic motivation, and the types of theories that have arisen concerning motivation, such as mechanistic and organismic theories. This included an overview of key authors like Murray, Skinner, and Atkinson. Next, I found it essential to read the works of the originators of self-determination theory, Ryan and Deci. The books (1985, 2017) gave a comprehensive and foundational understanding of the intricacies of the theory while the related articles (2000, 2020) provided updated findings and important applications of the theory. These readings led to further explorations about the beginnings of self-determination theory, such as White's effectance motivation. Finally, in order to situate self-determination theory, it was important to consider other relevant theories, such as Bandura's social cognitive theory and Wigfield and Eccles expectancy value theory. By examining the overarching theme of motivation, self-determination theory, and other related theories, I was able to gain a solid base of understanding for the workings behind self-determination theory.

A review of the literature in which the theory has been applied. Yet a foundational understanding of the theory itself was not enough for me to efficaciously apply it to my sphere of influence. As Dewey (1904) suggested, "it is possible for a student to acquire outward form of method without capacity to put it to genuinely educative use" (A.2 section, para. 5). This capacity can be built through an analysis of how others have applied the theory in varying contexts. For example, other studies that have employed self-determination theory in educational contexts and the online environment guided my decision making. Understanding the successes and failures in the fulfillment of autonomy, competence, and relatedness in their studies helped me to identify the implementation strategies that were best suited for my context. In this way, I

was not blindly practicing grand ideas, but rather building upon the shoulders of a collective group of experienced researchers and practitioners.

A consideration of how to apply the theory to one's specific context. With a solid foundation in the theory and its applications in related contexts, I needed to consider how the theory would best be applied in my context. I had the benefit of many years of teaching and developing at Peacock Cyber School, but also utilized the experienced opinions of my colleagues. Math teachers, other developers, instructional designers, and administrators were involved in the consideration of my course design to best support students' motivation at Peacock Cyber School. With a knowledgebase of theorists and researchers in one hand and an experience-base of my personal background and colleagues' expertise in the other, I created the intervention design components based on self-determination theory for the online mathematics course at Peacock Cyber School.

The integration of multiple analysis methods. While quantitative research normally attempts to test a theory and qualitative research normally explores a human problem, a mixed methods approach can use "distinct designs that may involve philosophical assumptions and theoretical frameworks" (Creswell & Creswell, 2018, p. 25). By combining a measured and exploratory approach, whether that be simultaneously or sequentially, the researcher has the opportunity to find patterns or consider ideas that one method alone may have concealed. A mixed methods approach to a problem can help give a more complete picture of what is happening in the situation.

A surprising occurrence in the present study utilizing a convergent mixed methods design was the strong positive language used by participants in the interviews concerning certain design features, such as the forums, and the lack of support for that

feature shown in the motivation questionnaire. This seeming contradiction between the qualitative and quantitative data in the study helped me understand the importance of gathering and analyzing both types. Had I only gathered quantitative data, I may have dismissed the use of forums based on the results and tried different methods. Had I only gathered qualitative data, I may have embraced forums for all students after hearing about the great positive impacts they had on the interviewees. By gathering both types of data, I was able to grasp a more complex situation occurring within the forums. While they may be extremely helpful and motivational for some, there is more to be learned in this area. Perhaps limiting the number of students in a group for a forum or offering the forums as an option may better satisfy the need for relatedness for some while not undermining it for others. In any case, the mix of data revealed that more research is needed in my context to ascertain how forums might best support students.

Sharing and receiving feedback on my findings. Upon completion of my intervention and analysis, I met with key individuals at Peacock Cyber School to share my findings and recommendations. I met with the curriculum director, the high school principal, the leader of instructional systems design, and the mathematics department head in a semi-formal virtual meeting. I presented the general design of my study, key aspects of self-determination theory, the connection between the implementation strategies and design components for autonomy, competence, and relatedness within the online unit, the results of the study, and recommendations for future course design at Peacock Cyber School. All personnel involved were very receptive of the presentation and found the recommendations useful. I am currently utilizing these recommendations to design and develop an updated Algebra 1 course at Peacock Cyber School. The specific

recommendations given in the presentation are described in the Recommendations for Online Mathematics Course Design section below.

Recommendations for Online Mathematics Course Design

Through this study, certain positive motivational online course design features emerged from the findings and interpretations. Both the quantitative data and the qualitative data in this study strongly supported these competence design components along with the related research. The following three implications arose for motivating mathematics students by improving their perception of competence through online course design: (a) consistent self-check buttons with informative and correctness feedback, (b) prior knowledge explanations with self-check practice, and (c) content chunking with scaffolding.

Self-check buttons. Isolation is a common challenge in the online educational environment (Dixson, 2015). Although often thought of as a connectedness or relatedness issue (Hartnett, 2015; Robb & Dunn, 2017), isolation also affects students' need for competence. Students may find it difficult or be hesitant to ask for help on issues, especially when students may consider them to be small or insignificant questions about their work. As Jeffery and Ahmad (2018) suggested, "informative feedback is often more important in an online environment than a traditional environment because students feel isolated due to a lack of nonverbal and visual signals" (Jeffery & Ahmad, 2018, p. 8). With a lack of these signals and proximate access to help, immediate feedback throughout the learning process becomes more important.

One way to incorporate feedback and provide an avenue for students to build appropriate confidence in their abilities is through self-check buttons on check for

understanding questions throughout the lessons. The check for understanding questions are meant to assess a single skill or concept acquired from the preceding content. In completing these questions, students are required to enter an answer first and then may press a check button to see whether their answer was right or wrong. If their answer was wrong, they receive preprogrammed informative feedback and may choose to try the question again. By providing these buttons consistently throughout a lesson, students can check their understanding on the new material acquired. Based on the correctness and informative feedback given, students can be appropriately confident about their new abilities or realize that they need to seek additional support.

Based on this study, utilizing self-check buttons may be beneficial in asynchronous online mathematics courses and I have recommended they be implemented in future curriculum at Peacock Cyber School. I am now integrating these buttons into the new Algebra 1 course as I design and develop it for Peacock Cyber School. For example, Figure 5.3 shows a sample of an example in a lesson with a check for understanding question and corresponding blue check button for the new Algebra 1 course.

Prior knowledge. Activating learners' prior knowledge about a topic is likely to be a helpful and necessary introduction to a lesson. For example, Gagne, Briggs, and Wager (1992) explain:

> The learning of intellectual skills is most clearly influenced by the retrieval of other intellectual skills that are *prerequisite*…the retrieval of these prerequisite skills has a direct supporting effect on the learning of the targeted intellectual skill. In fact, the absence of any of the skills in a subordinate box markedly decreases the ease of learning the superior skill to which it is connected. (p. 111)

Accessing prior skills that are building blocks to the current learning is an essential component of the new learning. Without first activating those prior skills, grasping the subsequent skill becomes more difficult.

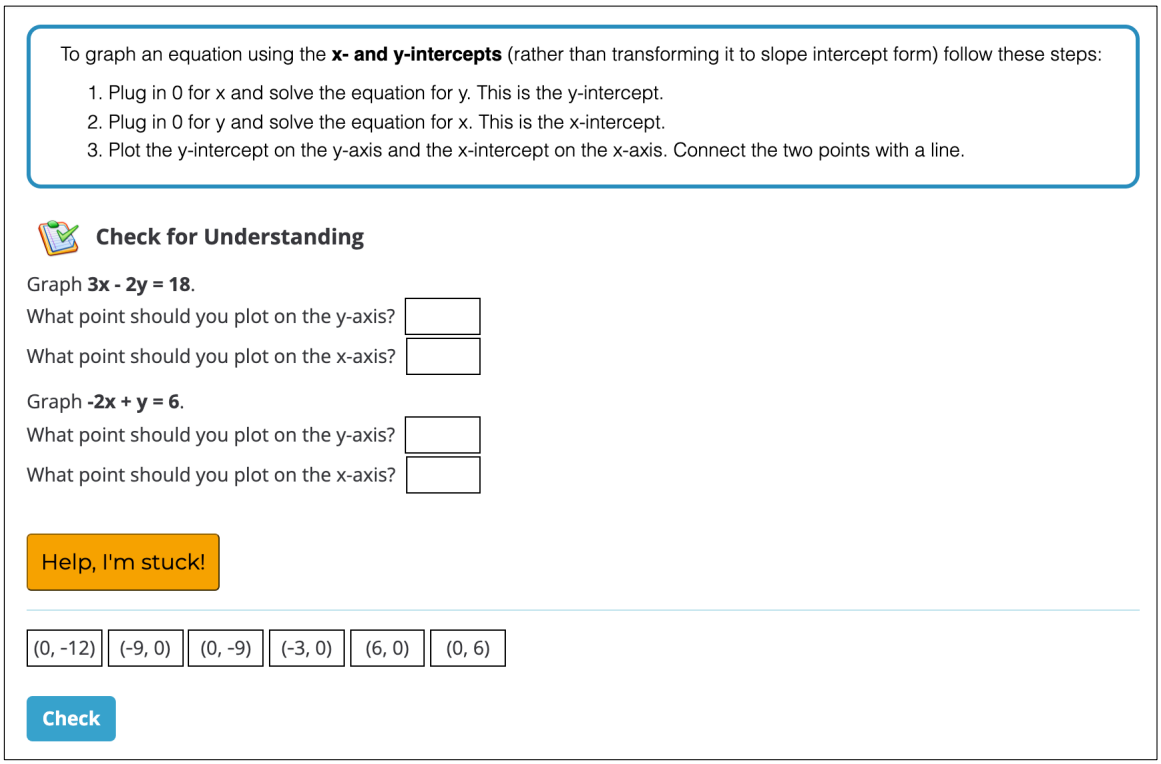

Figure 5.3. Sample of Check Button Used in New Course. From "Algebra 1 (Development): Graphing Linear Equations Lesson." Reprinted with permission.

Yet if the activation of prior knowledge relies on an abundance of relatively new learning, the effect can be reversed. Researchers found that prior knowledge stimulation may increase cognitive load and cause more exertion during learning, negating the positive effects (P. Li, Toh, & Kapur, 2017). This increase in cognitive load and overexertion of working memory is likely due to a lack of existing schemas for learners to integrate new knowledge (Kirchener et al., 2006). Therefore, introducing short segments of learning along with the activation of prior knowledge can support self-efficacy (Margolis & McCabe, 2004), likely without a negative impact on cognitive load.

The results of this study seemed to indicate that introducing prior knowledge in an asynchronous online environment by presenting the prerequisite information, providing a check for understanding, and giving the option for informative and correctness feedback improved participants' feelings of competence and motivation to complete the lesson. For example, as Ava said concerning the completion of the prior knowledge section: "I liked completing them because it gave me confidence that I knew what I was doing so that I could then complete the lesson." The prior knowledge contained only the prerequisite skills required to successfully complete the subsequent topic. In addition to the prior topics being stated, a worked-out example showing how to do the skill was provided. In this way, students who already possessed the prerequisite skills could skip to the check for understanding question, while those requiring more guidance could utilize the example. Additionally, all participants had the option to check their answer on the check for understanding question to ensure accuracy, likely increasing feelings of self-efficacy.

Based on this study, prior knowledge activation with the features described above may be beneficial in online mathematics courses and I have recommended it be included in new curriculum at Peacock Cyber School. My recommendations for presenting the prior knowledge include using an example, check for understanding, and check button for learners to ensure accuracy and receive additional help if needed. I am currently integrating these prior knowledge lesson features into the new Algebra 1 course, as shown in Figure 5.4. In the new course, the worked-out examples are provided within a "Remind me!" button to promote increased self-regulation and reduce the amount of material presented at once.

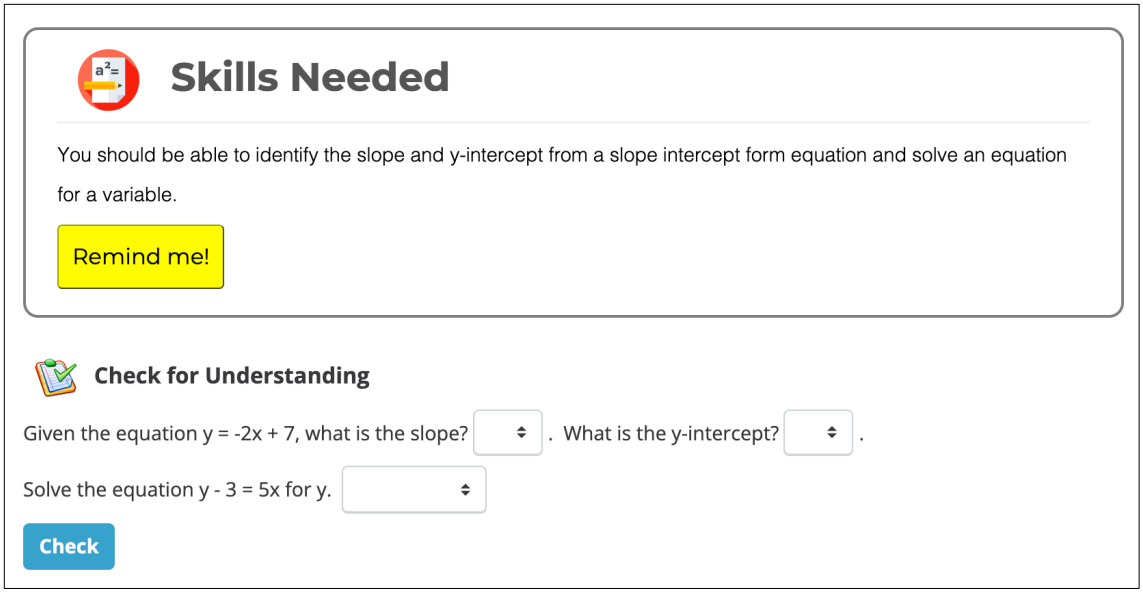

Figure 5.4. Sample of Prior Knowledge Used in New Course. From "Algebra 1 (Development): Graphing Linear Equations Lesson." Reprinted with permission.

Content chunking with scaffolding. Teachers at Peacock Cyber School have identified obstacles students face when a lesson is presented all at once in a long webpage of information. Based on their experiences, students tend to feel overwhelmed by this much information, have trouble remembering the different parts, and tend to skip the lessons altogether.

To counteract these obstacles and support feelings of competence, lessons in this study were presented with related information chunked together and with purposeful conceptual scaffolding throughout the lessons. These design components were based on implementation strategies of self-determination theory. For example, Ryan and Deci (2020) explained that a scaffolded structure fosters autonomy and competence. Similarly, Hartnett (2015) found that a lack of appropriate scaffolding undermines the perception of competence. Participants indicated that this lesson structure was helpful for their learning. For example, in referring to how the content was split up, Blake commented, "I

quite liked it because it was separated by what all I was learning in that lesson. So, I found it useful for the way I learned" and Eddie explained, "it wasn't all put together and made me feel a little bit more calm and not as stressed." The results of this study seem to indicate that chunking and conceptual scaffolding with online mathematical content may support students' competence and acquisition of knowledge.

These recommendations are further supported by cognitive load theory. Sweller (1994) suggests that mathematics tends to involve high element interactivity because much of the content is connected and needs to be understood together to build new schema. This high element interactivity increases intrinsic cognitive load, leaving less room for extraneous cognitive load (Sweller, 1994). By reducing extraneous cognitive load, then, students may have better success with developing new mathematical concepts. Chunking information together or using spatial contiguity, especially with mathematical figures, and excluding unnecessary information, or using coherence, can reduce extraneous cognitive load (Mayer, 2017). Additionally, worked out examples (Sweller, 1994) and scaffolding (Ak, 2016) can also help reduce extraneous cognitive load.

Based on the recommendations for chunking and scaffolding within a lesson structure, the new Algebra 1 lessons at Peacock Cyber School are being designed with these features. Figure 5.5 shows a sample of how a new lesson is organized over multiple pages with prior knowledge and vocabulary on the "Get Ready" page, examples on the next two pages, and a summary with exercises on the last page. Within this lesson organization, chunking of information and conceptual scaffolding is also utilized. For example, Figure 5.6 shows an example of a specific piece of information that is needed in a complete understanding of solutions to linear inequalities. This information removes

extraneous detail and is a building block for the next example on testing solutions for inequalities.

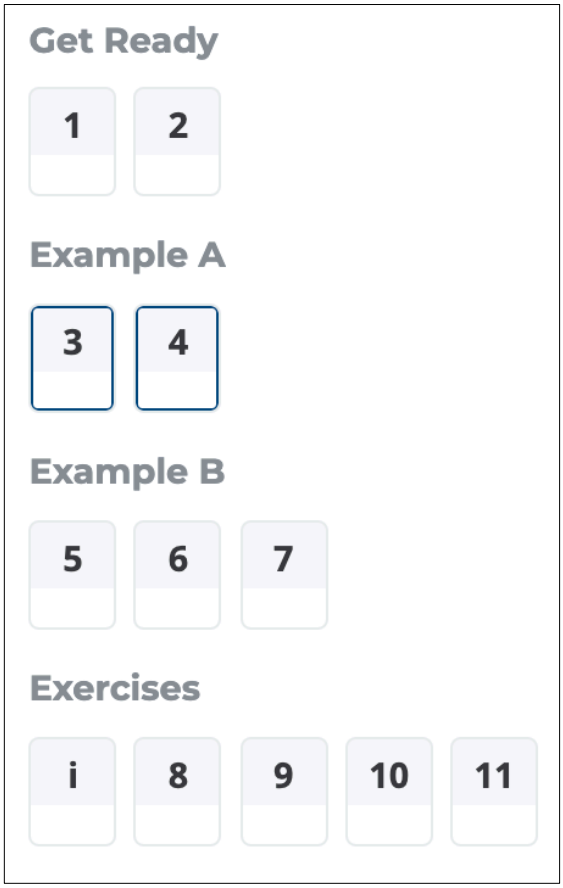

Figure 5.5. Sample of Lesson Organization Used in New Course. From "Algebra 1 (Development): Solutions to Linear Inequalities Lesson." Reprinted with permission.

Implications for Future Research

The findings and interpretations in this study left some questions unanswered. Although the design components for competence were strongly supported by both the quantitative and qualitative data in the study and were utilized in the recommendations for future online mathematics course design, the lesson features for autonomy and relatedness were more ambiguous.

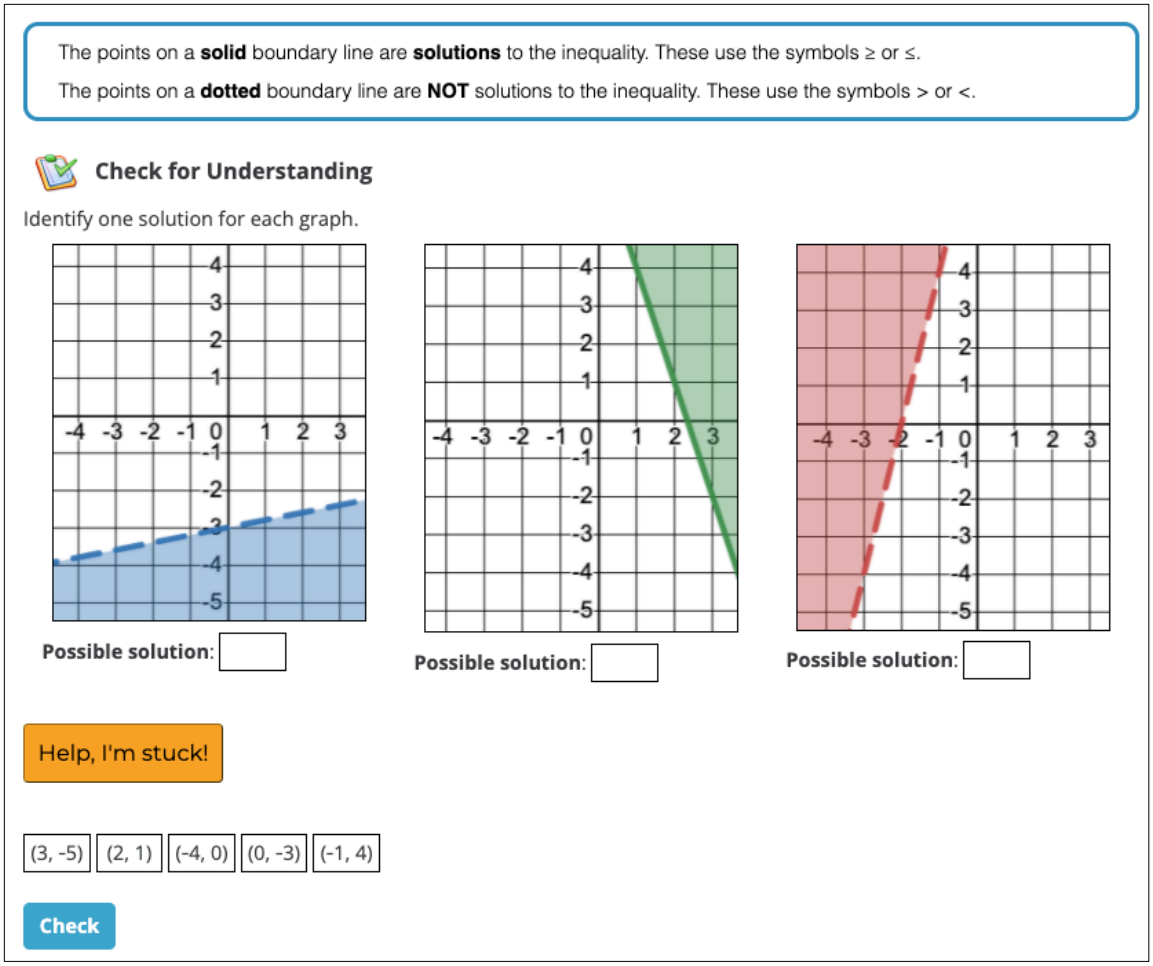

Figure 5.6. Sample of Chunking and Scaffolding Used in New Course. From "Algebra 1 (Development): Solutions to Linear Inequalities Lesson." Reprinted with permission.

Specifically, three areas arose that warrant further research based on the results of this study: (a) the distinction between online lesson design components for autonomy and competence, (b) the effect of choice on autonomy in online lesson design, and (c) the efficacy of forums in facilitating relatedness in online courses.

Distinction between design components for autonomy and competence. The results regarding the effectiveness of the design components in the facilitation of autonomy were mixed. The quantitative data did not show a significant change in participants' perception of autonomy while the student interviews showed some evidence

of improved autonomy. Based on the descriptions by participants of the multi-page lesson structure supporting their learning, it seems that autonomy may have been facilitated. For example, Devin found the structure useful and was able to navigate to needed sections without outside help.

> Devin: I like [the multipage structure] because then it was kind of like here's like the lesson and learning it and then kind of enforcing it all in one, but it's like still sectioned, so you could go back if you needed to, like, look at it while still being in the lesson. And I found it useful.

This structure may have given Devin a sense of control during the learning process with the ability to navigate and find help independently. However, a supportive structure can facilitate both autonomy and competence (Ryan & Deci, 2020), which may have obscured the results. In future research, a study of how a supportive structure can specifically facilitate autonomy, distinct from competence, may be helpful in determining the best use of structure in online course design to foster both autonomy and competence.

Effect of choice on autonomy. Similar to lesson structure, the design component for choice produced somewhat mixed results in this study. Although a small number of participants indicated in the interviews that the optional features were supportive, the quantitative data did not show a significant change in the perception of autonomy. The use of choice is a distinctive support for autonomy (Hartnett, 2015; Ryan & Deci, 2020). For example, in designing for increased control and self-regulation among learners, Cordova and Lepper (1996) explain: “the provision of choice has long been the paradigmatic procedure for manipulating intrinsic motivation” (p. 716). Yet a more

recent study did not show that the provision of choice increased autonomy (Jacobi, 2018). Further research in this area may shed light on the use of choice in online lesson design for the purpose of fostering autonomy.

Efficacy of forums in facilitating relatedness. The most surprising result in this study was the lack of a significant change in participants' perception of relatedness from the motivation questionnaire when compared with the qualitative responses about the great benefits of the forums in the interviews. Participants elaborated upon the increased connectedness, shared experiences, and reduced isolation they felt because of the forums used in the intervention. For example, Cameron explained: "it felt like it was like a little community in the forums. So it really helped me with stepping out of my comfort zone and just like reaching out to interact with other people." In adding to this community feeling, Finley expressed reduced feelings of isolation because of interacting in the forums: "it just kind of makes it feel better, made me feel better knowing that I wasn't the only person having trouble with those topics sometimes." The sentiments expressed by the participants suggested an increase in feelings of relatedness.

Despite the positive connections in the forums described by the participants, the quantitative data did not yield the same results. Hartnett (2015) suggested that forums may be more beneficial to small groups rather than a large course. Martin, Kelly, and Terry (2018) found that relatedness was the most challenging need to support in the online environment. Perhaps Ava was able to explain the inconsistency with forums fostering relatedness in her interview comments.

Ava: I think it might depend on the person because like if I was doing it and I really needed help on a question, that would be super helpful

> to me to have the forum to ask questions and have them answered, but if I didn't need any help, I think it would be more on the unnecessary side.

Although research has shown that forums can facilitate relatedness (Bonk et al., 2018; Sun & Rueda, 2012; Thompson et al., 2019), their effectiveness may be dependent upon the person or certain parameters surrounding the forums. Further research on the efficacy of forums in facilitating relatedness in various online course settings may help isolate the boundaries for their applicability in fostering relatedness.

Limitations

This action research study contained certain limitations that are important to consider alongside the results and recommendations. These limitations pertained to the action research design, the research methodology, and the intervention.

A benefit of action research is the deep understanding a researcher has of a problem in his or her sphere of influence, but this may cause researcher bias. Adelman (2006) described a situation that participatory action research can guard against: "there was an alarming gap between the aspirations of education policy-makers, who decided on expenditure for curriculum development, and the implementation of programmes of curriculum change in classrooms" (p. 18). As a former teacher and a current curriculum designer and developer at Peacock Cyber School, I have first-hand in-depth knowledge of the goals of the curriculum and the results of its implementation. Yet being an insider in the research context can result in bias or subjectivity (Herr & Anderson, 2005) and may cause "predetermined assumptions and ways of behaving" to hinder the research process (Buss & Zambo, 2014, p. 7). With many years of experience at Peacock Cyber School,

the normal operating procedures and my role within the institution may have caused me to create and implement the intervention in specific ways.

Related to researcher bias due to the insider role is the effect that role may have on participant responses. It is best to select participants with whom the researcher does not have a dual relationship (AERA, 2011). Participants were aware that I am employed by Peacock Cyber School and design the mathematics courses for the school, which may have affected their responses in the questionnaire or interviews.

When samples are confined to a specific location and small size, the results may be unreliable (Pyrczak & Tcherni-Buzzeo, 2019). Using a limited purposive sample may also mean that the results are not generalizable (Saldana, 2021). In this study, there was a small sample size (n = 50), participants were all selected from one course at one school, and the intervention was conducted over a short timeframe. As Mertler (2017) suggests concerning action research, "there may be no generalizable conclusions at all, as the findings are context specific and unique to the particular participants and their settings and situations" (p. 26). Although I was able to provide assertions and recommendations based on the results of this study, these should be considered in light of specific context variations and requirements.

The research methodology in this study also had some limitations. Using interviews can provide detailed information, but the results are based on a small number of participants and their views (Creswell & Creswell, 2018). The lack of anonymity and small number of interviewees may also affect the content of the interview responses (Mertler, 2017). The inductive analysis process of the interview transcripts can be subjective. With only one researcher involved in the coding process, independent

analyses or evidence of inter-rater reliability was not present (Pyrczak & Tcherni-Buzzeo, 2019).

The content knowledge exam used to triangulate the data and identify a change in participants' achievement was not able to consider other pedagogical approaches. The improvement from the pretest to posttest may have been a result of participants' exposure to the material, in general, and not necessarily better as a result of utilizing self-determination theory in the design.

Finally, there were limitations associated with the basis for the intervention and the technology used to implement the intervention. Self-determination theory is well-established, but implementation strategies for online contexts vary. The design components chosen for this study were based on the population and needs of Peacock Cyber School and may vary for different contexts. The use of some of the features in the intervention, such as check buttons, may be dependent on a specific learning management system's functionality and may not be possible in all situations.

Closing Thoughts

Peacock Cyber School mathematics students have lacked motivation to complete lessons, resulting in lower achievement. The goal of this action research was to find a way to improve student motivation levels for online Algebra 2 lessons at Peacock Cyber School. Using research on motivation, self-determination theory, and its applications in various contexts, design components were created for these lessons with the goal of facilitating autonomy, competence, and relatedness in the Algebra 2 students. These design components were integrated into the current design of the Algebra 2 lessons, which align with Gagne's nine events of instruction.

The findings of this study were somewhat mixed overall. Both the quantitative and qualitative data indicated that students' perceptions of competence likely improved. Specific design components for competence that were strongly supported by the interviews included the check buttons, prior knowledge section, and chunking information with scaffolding throughout the lessons. The findings for autonomy were more ambiguous. No significant change was shown in the quantitative results, yet the qualitative responses seemed to support the satisfaction of autonomy. The participant responses in the interviews indicated that the design components for autonomy may have been confused with the design components for competence. The ambiguity between these two areas of autonomy and competence may have caused the disparate results. Finally, the findings for relatedness were the most surprising. Although the quantitative data showed no significant change in the satisfaction of relatedness, the qualitative data showed strong support for the defining characteristics of relatedness. This divergence may have resulted from the small number of interviewees. The ambiguity with the results for autonomy and the disagreement with the results for relatedness may offer a focal point for future iterations of this study.

Based on the recommendations from this action research, new Algebra 1 course development at Peacock Cyber School is now utilizing certain motivational design components. These recommendations stem from the strong support for the competence design components in this study. Specifically, the check buttons with correctness and informative feedback, prior knowledge information with checks, and chunking information with conceptual scaffolding throughout the lessons are currently being built into the new Algebra 1 course at Peacock Cyber School.

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APPENDIX A

UNIVERSITY OF SOUTH CAROLINA: CONSENT TO BE A RESEARCH SUBJECT

Motivation in Online Design: Action Research Using a Self-Determination Theory-based Mathematics Unit to Improve Students' Autonomy, Competence, and Relatedness

KEY INFORMATION ABOUT THIS RESEARCH STUDY:
You are invited to volunteer for a research study conducted by Emily Shank (eshank@email.sc.edu). I am a doctoral candidate in the Department of Education at the University of South Carolina. The University of South Carolina Department of Education is sponsoring this research study.

The purpose of this study is to create and implement a self-determination theory-based online unit on factoring polynomials for mathematics students at Peacock Cyber School in order to improve students' motivation levels. You are being asked to participate in this study because you are a student at Peacock Cyber School enrolled in the Algebra 2 course. This study is being done at Peacock Cyber School utilizing online platforms including Moodle and Jigsaw and will involve approximately 200 volunteers.

The following is a short summary of this study to help you decide whether to be a part of this study. More detailed information is listed later in this form.

PROCEDURES:
If you agree to participate in this study, you will do the following:

1. Complete a pretest questionnaire on your current levels of motivation related to online mathematics learning. This will provide a baseline measure of your current motivation levels.
2. Complete a pretest on the content knowledge you will be expected to learn in the following unit. This pretest provides a baseline measure of your knowledge about the subject matter before completing the unit.
3. Complete the intervention unit. This unit will be integrated into the Algebra 2 course in Moodle like any other unit. It will include a different design and additional features with the goal of improving motivation. One of these features is a discussion forum that you will be asked to participate in by posting short text-based information three times throughout each week, for three weeks. This could include helping another student who is stuck on something in a lesson, asking for help about a particular item in a lesson, or a brief explanation about how to do something in a lesson. The lessons and discussion forums will be completed asynchronously, meaning you can complete them at any time that is convenient for you during the three weeks and you do not need to log in at a specific time.

4. The unit will include instruction on the objectives you are expected to understand by the end of the unit.
5. Once you have completed the intervention unit, you will complete a posttest on the stated objectives, much like you have a test at the end of each unit in the course. Just like those tests, this posttest will be graded for correctness and the grade will appear in your gradebook.
6. Next, you will complete a posttest motivation questionnaire about your feelings towards various components of the unit. This will include closed-ended questions and will be completed through a quiz format in Moodle where you may select your responses.
7. Finally, 5-10 participants will be selected at random to participate in an interview about their experience. You may choose not to participate in the interview even though you are participating in this study. The interview will be conducted over the computer using audio and video software. You may choose to use audio only. The audio portion of the interview will be recorded to ensure the details that you provide are accurately captured. If you are selected, you will be given more information about the interview beforehand and asked to sign a form to agree to participate in the interview.
8. The pretest-posttest motivation questionnaire, pretest-posttest content knowledge, and interview transcripts will be analyzed. Although quotes from the interviews or discussions forums may be used, no identifiable information for any particular student will be part of the final report.

DURATION:
Participation in the study involves completing the above procedures over a period of five weeks.

RISKS/DISCOMFORTS:
There are no risks or discomforts anticipated.

BENEFITS:
You may benefit from participating in this study by having a better experience in the factoring polynomials unit than you otherwise would have. It may also help the researcher understand how various features in the unit impact motivation, which may aid in creating better units in the future.

COSTS:
There will be no costs to you for participating in this study.

PAYMENT TO PARTICIPANTS:
You will not be paid for participating in this study.

CONFIDENTIALITY OF RECORDS:
Information obtained about you during this research study will remain confidential and released only with your written permission. Study information will be securely stored in locked files and on password-protected computers. Results of this research study may be

published or presented at seminars; however, the report(s) or presentation(s) will not include your name or other identifying information about you.

VOLUNTARY PARTICIPATION:
Participation in this research study is voluntary. You are free not to participate, or to stop participating at any time, for any reason without negative consequences. In the event that you do withdraw from this study, the information you have already provided will be kept in a confidential manner. If you wish to withdraw from the study, please call or email the principal investigator listed on this form.

I have been given a chance to ask questions about this research study. These questions have been answered to my satisfaction. If I have any more questions about my participation in this study, I am to contact Emily Shank at 407-861-2023 or email (eshank@email.sc.edu).

Concerns about your rights as a research subject are to be directed to, Lisa Johnson, Assistant Director, Office of Research Compliance, University of South Carolina, 1600 Hampton Street, Suite 414D, Columbia, SC 29208, phone: (803) 777-6670 or email: LisaJ@mailbox.sc.edu.

I agree to participate in this study. I have been given a copy of this form for my own records. If you wish to participate, you should sign below.

*For Minors 13-17 years of age:
My participation has been explained to me, and all my questions have been answered. I am willing to participate.

_____ _____
Print Name of Minor Subject / Participant Age of Minor

_____ _____
Signature of Minor Subject / Participant Date

_____
Print Name of Legal Guardian

_____ _____
Signature of Legal Guardian Date

*You only need to sign below if you are a student 18 years of age or older.

_____ _____
Signature of Subject / Participant Date

_____ _____
Signature of Qualified Person Obtaining Consent Date

APPENDIX B

SAMPLES OF ALGEBRA 2 GENERAL LESSONS PRIOR TO INTERVENTION

The images in this appendix are taken from a general lesson in Algebra 2 without any changes made based on self-determination theory.

Sample Introduction Section

Figure A.1 shows the title of the lesson, the goal of the lesson, the prior knowledge information paragraph, the vocabulary, and the lesson overview with attention grabbing information.

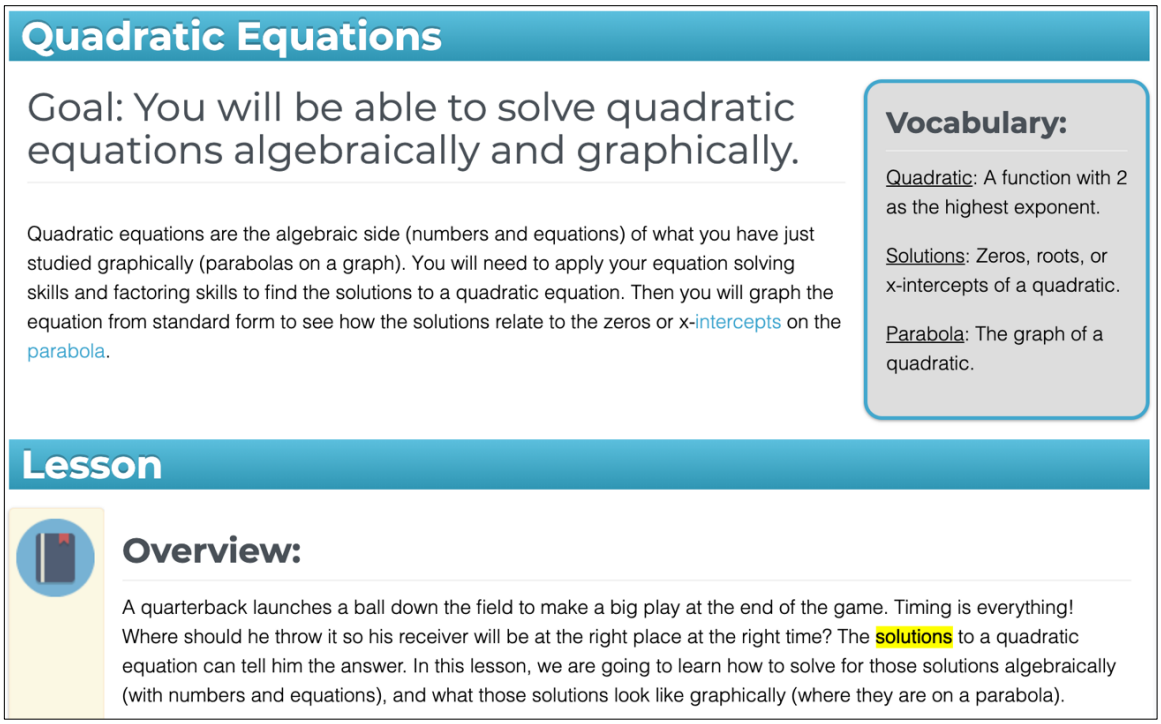

Figure A.1. Sample Introduction Section of General Algebra 2 Lesson. From "Algebra 2: Quadratic Equations." Reprinted with permission.

Sample Explanation Section

Figure A.2 shows a sample explanation section with a video and key information for the lesson.

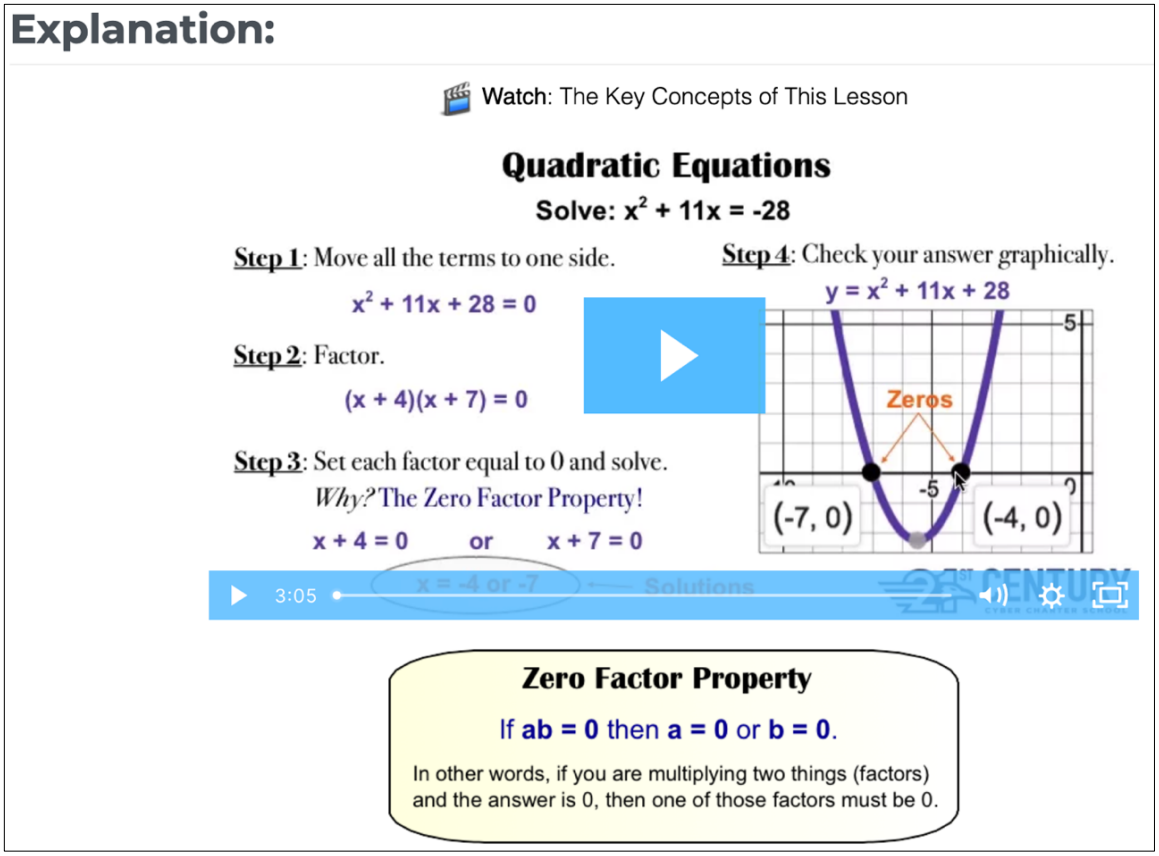

Figure A.2. Sample Explanation Section of General Algebra 2 Lesson. From "Algebra 2: Quadratic Equations." Reprinted with permission.

Sample Example

Figure A.3 shows a sample example with text, images, and audio as well as the steps or procedure required in the example. The example is titled "Solve a Quadratic Equation – Factor by Grouping" and is located inside of a button. The button has been opened in the figure to reveal its content.

Sample Summary and Ending Tabs

Figure A.4 shows a sample summary and the ending tabs section of an Algebra 2 lesson. The summary includes text, text elements, and the steps or procedure presented in the lesson. The ending tabs display the mixed practice with questions based on the examples presented in the lesson. The other tabs include answers to the mixed practice, additional student resources, citations for the lesson, and the state test and/or Common Core State Standards that the lesson content is aligned with.

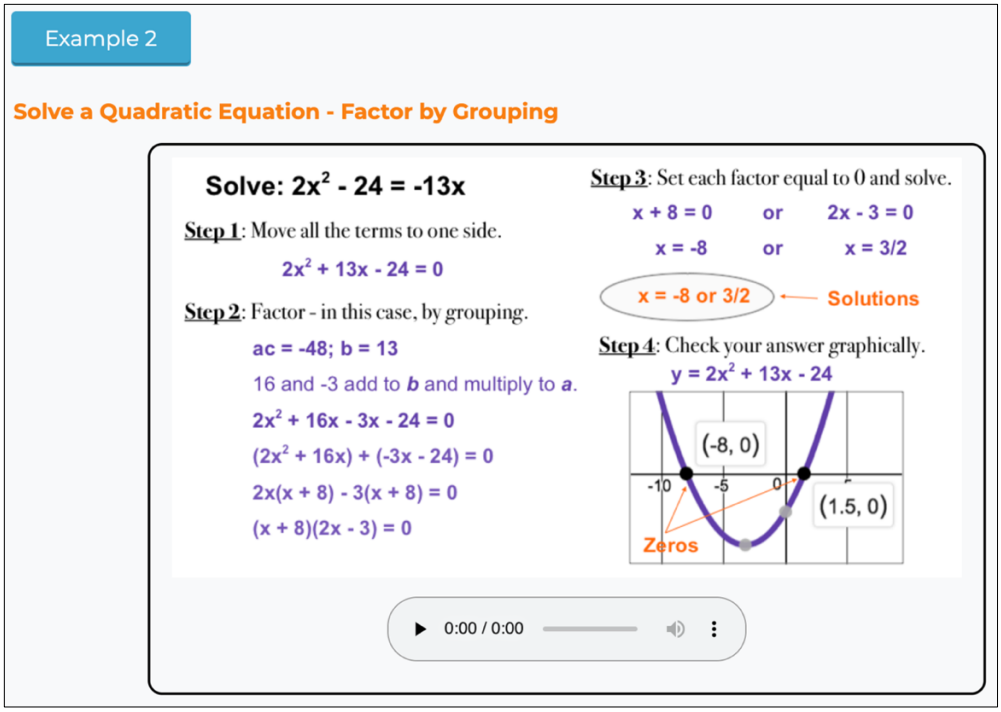

Figure A.3. Sample Example Section of General Algebra 2 Lesson. From "Algebra 2: Quadratic Equations." Reprinted with permission.

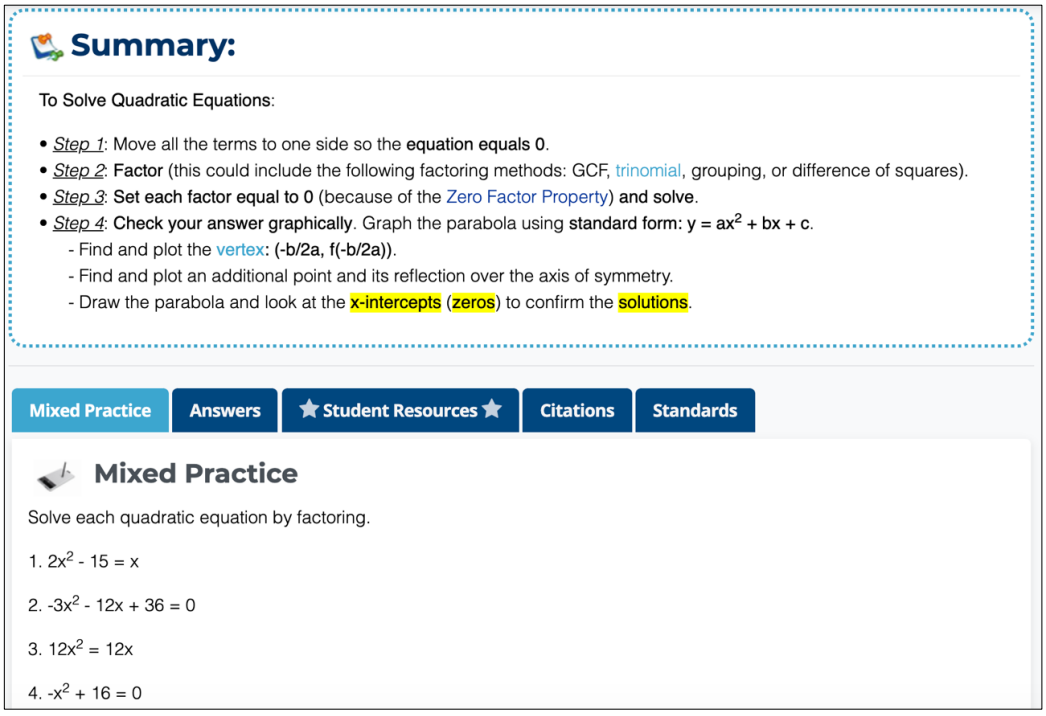

Figure A.4. Sample Summary and Tabs Section of General Algebra 2 Lesson. From "Algebra 2: Quadratic Equations." Reprinted with permission.

APPENDIX C

MOTIVATION QUESTIONNAIRE

The original items from the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS) are shown in Table A.1 below, alongside any changes made for use in this study. The order of the original items was changed to present the six categories to the participants in a varied way.

Table A.1 *Original Motivation Questionnaire Items and Changes*

Original BPNSFS Items	Changes original [change]
1. I feel a sense of choice and freedom in the things I undertake.	in the things I undertake [within the lessons]
2. My daily activities feel like a chain of obligations.	My daily activities [The activities in the unit]
3. I feel that the people I care about also care about me.	I care about also care about me [I help or ask for help also help or ask for help from me]
4. I feel competent to achieve my goals.	
5. I have the impression that people I spend time with dislike me.	people I spend time with [teachers or students I interact with]
6. I experience a warm feeling with the people I spend time with.	people I spend time with [teacher or students I interact with]
7. I feel insecure about my abilities.	
8. I feel that my decisions reflect what I really want.	what I really want [how I really want to work in the unit]
9. I feel the relationships I have are just superficial.	

10. I feel I can successfully complete difficult tasks.	
11. Most of the things I do feel like “I have to”.	
12. I feel close and connected with other people who are important to me.	with other people [with teachers or students in the course]
13. I feel my choices express who I really am.	who I really am [how I really learn]
14. I feel disappointed with many of my performance.	performance [quiz results]
15. I have serious doubts about whether I can do things well.	
16. I feel that people who are important to me are cold and distant towards me.	people [teachers or students]
17. I feel capable at what I do.	
18. I feel like a failure because of the mistakes I make.	
19. I feel I have been doing what really interests me.	interests me [interests me within the unit]
20. I feel pressured to do too many things.	
21. I feel connected with people who care for me, and for whom I care.	who care for me, and for whom I care [who I interact with throughout the unit]
22. I feel excluded from the group I want to belong to.	
23. I feel forced to do many things I wouldn’t choose to do.	
24. I feel confident that I can do things well.	

Note. Adapted from “Basic Psychological Need Satisfaction, Need Frustration, and Need Strength Across Four Cultures” by Chen et al., 2015, *Motivation and Emotion*, *39*(2), p. 227.

APPENDIX D

CONTENT KNOWLEDGE ASSESSMENT

1. Factored completely, the expression $3x^2 – 3x – 18$ is equivalent to:
   a. $(3x – 9)(x + 2)$
   b. $(3x + 6)(x – 3)$
   c. $3(x – 3)(x + 2)$ [correct]
   d. $3(x^2 – x – 6)$

2. Factored completely, the difference of squares binomial $16x^2 – 25y^2$ is equivalent to:
   a. $(4x – 5y)(4x + 5y)$ [correct]
   b. $(4x – 5y)(4x – 5y)$
   c. $(8x – 5y)(8x + 5y)$
   d. $(8x – 5y)(8x – 5y)$

3. Simplify the expression completely: $(-4x^3 + 12x^2 + 40x)/(-4x^3 – 16x^2 – 16x)$.
   a. $(x – 5)/(x + 2)$, $x \neq -2, 0$ [correct]
   b. $(x – 3)/(x + 2)$, $x \neq 0, 5$
   c. $(x – 3)/(x – 5)$, $x \neq -3, 0$
   d. $(x + 5)/(x – 2)$, $x \neq 0, 2$

4. What is the greatest common factor of $18a^2c$ and $42a^3bc$?
   a. $3a^3b$
   b. $6a^2c$ [correct]
   c. $3a^2c$
   d. $6a^3b$

5. Simplify the following expression completely: $(3x^2 + 24x + 45)/(3x + 15)$.
   a. $(x + 3)(x + 5)$, $x \neq -5$
   b. $x + 5$, $x \neq 5$
   c. $3(x + 5)$, $x \neq -5$
   d. $x + 3$, $x \neq -5$ [correct]

6. What are the factors of the difference of squares binomial $x^2 – 1$?
   a. $(x – 1)(x + 1)$ [correct]
   b. $(x – 1)(x – 1)$
   c. $(x + 1)(x + 1)$
   d. $(x + 2)(x – 1)$

7. What are the factors of the trinomial $x^2 – 5x + 6$?
    a. $(x – 2)$ and $(x – 3)$
    b. $(x + 2)$ and $(x + 3)$
    c. $(x – 6)$ and $(x + 1)$ [correct]
    d. $(x + 6)$ and $(x – 1)$

8. What is the least common multiple of $4x^4y^2z$ and $6xyz^3$?
    a. $2xyz$
    b. $24x^4y^2z^3$
    c. $12xyz$
    d. $12x^4y^2z^3$ [correct]

9. Factor the following trinomial by grouping: $12x^2 – 5x – 2$. Which of the options below is one of the factors?
    a. $(3x – 2)$ [correct]
    b. $(4x – 1)$
    c. $(6x + 1)$
    d. $(2x – 4)$

10. Factor the following trinomial by grouping: $9x^2 + 29x + 6$. Which of the options below is one of the factors?
    a. $(2x + 3)$
    b. $(3x + 1)$
    c. $(6x + 6)$
    d. $(9x + 2)$ [correct]

11. What is the least common multiple of $6xy$, $8yz$, and $12xz$?
    a. $12xyz$
    b. 4
    c. $576x^2y^2z^2$
    d. $24xyz$ [correct]

12. What is the greatest common factor of $10m^2n^3$ and $32n^2$?
    a. $2n^2$ [correct]
    b. $2mn^2$
    c. $160m^2n^3$
    d. $6mn$

13. Factor the following expression completely: $12x^2 – 75$.
    a. $3(4x^2 – 25)$
    b. $3(2x + 5)(2x – 5)$ [correct]
    c. $(6x + 25)(6x – 25)$
    d. $3(4x + 5)(x – 1)$

14. Factor using the greatest common factor: $14xy + 21xz – 7x$.
    a. $7x(2y + 3z – 1)$ [correct]

b. $7(2xy + 3xz – x)$
c. $7x(2y + 3z – 7)$
d. $7xy(2 + 3z – x)$

15. Factor using the greatest common factor: $75a^2b^2 – 125a^2b + 50a^3b^2$.
    a. $5ab(15ab – 25a + 10a^2b)$
    b. $5a^3b(15b – 12 + 5ab)$
    c. $25a^2b(3b – 5 + 2ab)$ [correct]
    d. $25ab(3ab – 15a – 2a^2b)$

16. Factor the following trinomial: $x^2 – 15x + 54$. Which of the following options is one of the factors?
    a. $(x + 6)$
    b. $(x – 3)$
    c. $(x – 9)$ [correct]
    d. $(x + 4)$

APPENDIX E

INTERVIEW PROTOCOL

Date and Time: Location:

Interviewer: Interviewee:

Audio File Information:

Thank you for agreeing to participate in this study. The purpose of this action research is to create and implement a self-determination theory-based online unit on factoring polynomials for mathematics students at Peacock Cyber School in order to improve students' motivation levels.

The purpose of this form is to obtain your agreement to participate in the interview portion of this study.

The purpose of the interview is to gain a deeper understanding about how you felt during the intervention lessons and post-assessment as it relates to motivation. Following is a list of key information about the interview and its use:

- The interview will last approximately 30-60 minutes and will be conducted over the computer.
- Pre-determined questions as well as follow up questions may be asked during the interview in a semi-structured format.
- The audio of the interview will be recorded and transcribed.
- You will be provided with the full transcription of the interview and given the chance to make any corrections.
- The interview transcript will be analyzed by the researcher of the study, Emily Shank, and may be seen by research advisors at the University of South Carolina during the research process. Beyond those individuals, identifiable information will be removed in any reference to the contents of the interview.
- The contents of the interview may be used in part or in its entirety in academic papers or presentations, in which identifiable information will be removed. For example, a pseudonym will be used.

- The contents of the interview in part or in its entirety will be stored on a password protected computer with access limited to the researcher, Emily Shank.

By signing and dating this form below, you are agreeing that:

- You have read the information above and have had the opportunity to ask any questions you may have. You are free to contact the researcher, Emily Shank (eshank@email.sc.edu) with any further questions you may have.

- You are agreeing to participate in the interview voluntarily and may change your mind at any point during the process.

- The audio of your interview will be recorded.

- You will receive a transcript of the recording and may make any changes you see fit to ensure accuracy.

- The contents of the interview may be used as described above.

_____ _____

Signature of Subject / Participant Date

_____ _____

Signature of Qualified Person Obtaining Consent Date

*For Minors 13-17 years of age:
My participation in this interview has been explained to me, and all my questions have been answered. I am willing to participate.

_____ _____

Print Name of Minor Age of Minor

_____ _____

Signature of Minor Date

_____

Print Name of Legal Guardian

_____ _____

Signature of Legal Guardian Date

APPENDIX F

INTERVIEW SCRIPT AND QUESTIONS

Introduction

Thank you for agreeing to participate in this interview. I am Emily Shank, the researcher, and will be asking you a series of questions related to the purpose of the study. The purpose of the study is to create and implement a self-determination theory-based online unit on factoring polynomials for mathematics students at Peacock Cyber School in order to improve students' motivation levels. During this interview, I will ask you questions related to your perceptions and feelings of motivation during the intervention lessons. Since I am asking about your perceptions and feelings, there are no wrong answers! Please feel free to share any feelings related to my questions, whether negative, neutral, or positive. Please also feel free to clarify any questions if you do not understand what I am asking.

The interview will last approximately 30-60 minutes. I will make an audio recording and create a transcription of the interview to ensure accuracy. To further ensure accuracy, I will provide the transcription to you so you may have the opportunity to change anything necessary. The audio recording and transcription will be kept confidentially on a password protected computer. I may discuss specific interviews with my academic advisors at the University of South Carolina during the research process, but beyond that, any use of the contents of this interview will be shared with a pseudonym and the removal of identifiable information.

Do you have any questions before we begin?

1. Describe how you felt after completing the prior knowledge checks on the first page of the lesson.

2. How did you interact with the options for learning the vocabulary: the video, the list of words, and the check for understanding?
   Follow up: How did these options affect your learning?

3. How did the multipage structure of the lessons make you feel, with the prior knowledge and vocabulary on the first pages, examples on the following pages, and summary with graded practice on the last page?

4. Describe a time when you used an optional help button or completed an optional challenge question if you did.
   Follow up: How did having the option to use these make you feel?

5. If you completed an optional challenge question, how did the level of challenge make you feel? If you did not, why did you choose to skip these questions?

6. Tell me about a time when you used the check buttons that appeared after each question in the lesson and provided feedback if you used one.
   Follow up: How did the check buttons help guide your thought processes?

7. Give me an example of how your confidence level changed as you worked through a lesson.
   Follow up: What parts of the lesson, in particular, affected your confidence?

8. If you recall, 10% of the grade you received for the lesson came from the check for understanding questions throughout the lesson and 90% of the grade came from the practice questions on the final page of the lesson. How did receiving a grade for the lessons like this make you feel?

9. Tell me about an interaction you had in one of the forums.

10. Describe the feelings you had when using the forums.

11. Describe the level of connectedness you felt to other students through the forums.

12. Do you have any other thoughts or feelings or anything I didn't ask that you would like to share?

Thank you very much for participating in this interview. If you have any further questions, please do not hesitate to contact me using the information provided.