

Utah State University

DigitalCommons@USU

All Graduate Theses and Dissertations

Graduate Studies

5-2023

How Preservice Teachers Develop Awareness and Beliefs About Design Features and Academic Language Features When Choosing and Evaluating Digital Math Games for English Language Learners

Allison L. Roxburgh
Utah State University

Follow this and additional works at: <https://digitalcommons.usu.edu/etd>

 Part of the [Teacher Education and Professional Development Commons](#)

Recommended Citation

Roxburgh, Allison L., "How Preservice Teachers Develop Awareness and Beliefs About Design Features and Academic Language Features When Choosing and Evaluating Digital Math Games for English Language Learners" (2023). *All Graduate Theses and Dissertations*. 8718.
<https://digitalcommons.usu.edu/etd/8718>

This Dissertation is brought to you for free and open access by the Graduate Studies at DigitalCommons@USU. It has been accepted for inclusion in All Graduate Theses and Dissertations by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.



HOW PRESERVICE TEACHERS DEVELOP AWARENESS AND BELIEFS ABOUT
DESIGN FEATURES AND ACADEMIC LANGUAGE FEATURES WHEN
CHOOSING AND EVALUATING DIGITAL MATH GAMES FOR
ENGLISH LANGUAGE LEARNERS

by

Allison L. Roxburgh

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Education

Approved:

Patricia S. Moyer-Packenham, Ph.D.
Major Professor

Beth MacDonald, Ph.D.
Committee Member

Jessica Shumway, Ph.D.
Committee Member

Sarah Braden, Ph.D.
Committee Member

Jody Clarke Midura, Ed.D.
Committee Member

D. Richard Cutler, Ph.D.
Vice Provost for Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2023

Copyright © Allison L. Roxburgh 2023

All Rights Reserved

ABSTRACT

How Preservice Teachers Develop Awareness and Beliefs about Design Features and
Academic Language Features when Choosing and Evaluating Digital Math
Games for English Language Learners

by

Allison L. Roxburgh, Doctor of Philosophy

Utah State University, 2023

Major Professor: Patricia S. Moyer-Packenham, Ph.D.
Department: Teacher Education and Leadership

This mixed methods study examined how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for English language learners. The overarching research question for this study was, “How do preservice teachers develop awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for English language learners (ELLs)?” During the study, 21 elementary preservice teachers participated in learning modules about design features and academic language features. During the modules, preservice teachers chose and evaluated three digital math games for ELLs based on their awareness of the design features and academic language features in the games. Preservice teachers completed a pre- and post-belief survey, a pre- and post-evaluation rubric, two module reflections, and participated in semistructured interviews.

The study included qualitative and quantitative data, which I analyzed using descriptive coding, pattern coding, frequency tables, bar graphs, a Wilcoxon signed ranked test, and a narrative comparison. Descriptive and pattern coding helped me to identify common themes among open-ended responses on the surveys and evaluation rubrics, module reflections, and responses to the semistructured interviews. I used frequency tables to understand preservice teachers' beliefs and bar graphs to visualize and summarize the frequency tables from the Likert scale responses and evaluation rubrics. Additionally, I computed a Wilcoxon signed ranked test to examine changes in beliefs from pre- to post-surveys and to examine evaluation scores from pre- to post-evaluation rubrics. Finally, I used a narrative comparison to compare the results from these analyses.

Results indicated significant changes in preservice teachers' beliefs about their preparation for using digital math games to support mathematics learning for ELLs from pre- to post-surveys. Preservice teachers also self-reported changes in their awareness of the design features and academic language features in the digital math games. This indicates that the learning modules, and the processes that the preservice teachers engaged in while evaluating the digital math games, supported positive changes in their beliefs, increased awareness of the features, and their ability to choose and evaluate features of the digital math games for ELLs.

(185 pages)

PUBLIC ABSTRACT

How Preservice Teachers Develop Awareness and Beliefs about Design Features and Academic Language Features When Choosing and Evaluating Digital Math Games for English Language Learners

Allison L. Roxburgh

This mixed methods study examined how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for English language learners. The overarching research question for this study was, “How do preservice teachers develop awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for English language learners (ELLs)?” During the study, 21 elementary preservice teachers participated in online learning modules about design features and academic language features in digital math games. During the modules, preservice teachers chose and evaluated three digital math games for ELLs based on their awareness of the design features and academic language features in the games. Preservice teachers completed a pre- and post-belief survey, a pre- and post-evaluation rubric, two module reflections, and participated in semistructured interviews.

I analyzed qualitative and quantitative data by identifying common themes among open-ended responses on the surveys and evaluation rubrics, module reflections, and responses to the semi-structured interviews. I then used frequency tables to count the themes that emerged and visualized the frequency counts using bar graphs. I then

examined the changes in beliefs from pre- to post-surveys and scores from pre- to post-evaluation rubrics. Finally, I compared the results from these analyses to examine how the qualitative and quantitative results agreed or disagreed.

Results showed a positive change in preservice teachers' beliefs about using digital math games to enhance mathematics instruction for ELLs after they participated in the learning modules. Results also showed an increase in preservice teachers' awareness of design features and academic language features. This indicates that using the learning modules, and the opportunity to choose and evaluate the digital math games, supported a positive impact on preservice teachers' beliefs and awareness of design features and academic language features.

ACKNOWLEDGMENTS

I want to thank those who supported me during my doctoral journey. First, I would like to thank previous teachers who inspired my love for learning. To Mr. Le Vuong, my high school mathematics teacher, who always told me to pursue mathematics. My desire to learn about English language learners in mathematics started with you. Your story is an inspiration! To Dr. Eric Packenham, thank you for helping me shift to a growth mindset in my undergraduate studies. Without this mindset, I would not have persevered through my graduate school challenges.

I want to express my deepest appreciation to my mentor, Dr. Patricia Moyer-Packenham. Words cannot express my gratitude for your kindness, patience, and expertise throughout this journey. Your mentorship has been life changing! I have grown so much as a researcher, teacher, presenter, and as an individual. I would also like to extend my deepest gratitude to my committee members: Dr. Beth MacDonald, your patience and kindness helped me through my master's project and continued through my dissertation; Dr. Jessica Shumway, your support through this journey helped me improve as a researcher, scholar, and teacher; Dr. Jody Clarke-Midura, your patience and guidance brought clarity to the gaming aspects of this dissertation; and Dr. Sarah Braden, your patience and language expertise helped improve the language aspects of this dissertation and fine-tune my ideas.

I want to thank the College of Education and Human Services and the Teacher Education and Leadership department for funding this dissertation. I am also grateful for the preservice teachers who participated in this study. Without you, this dissertation

would not have been possible.

I want to extend my sincere thanks to my family and friends: Julie and Holli, my mother and sister, who were the cheerleaders I needed when I wanted to give up; My in-laws, Ed, Jackie, and Ty, who helped me navigate childcare; Jen G., Jen J., and Tami, my best friends, who helped keep me motivated and provided their knowledge of teaching to fine-tune this dissertation.

Finally, I am deeply indebted to my husband and children. To Todd, my loving and supportive husband. Your support and patience are what helped me accomplish this goal. I could not have done this without you. I am truly grateful to have a partner who supports my passion for education. To my daughters, Maxine and Lucille, this dissertation is for you. I hope I have made you both proud. I love you both so much!

Allison L. Roxburgh

CONTENTS

	Page
ABSTRACT.....	iii
PUBLIC ABSTRACT	v
ACKNOWLEDGMENTS	vii
LIST OF TABLES.....	xi
LIST OF FIGURES	xiii
CHAPTER I: INTRODUCTION.....	1
Background of the Problem	2
Statement of the Problem.....	4
Significance of the Problem.....	5
Purpose of the Study	6
Research Questions.....	7
Summary of the Research Study Design	8
Definitions of Terms	9
CHAPTER II: LITERATURE REVIEW	11
Conceptual Framework.....	13
Awareness and Beliefs about Design Features	15
Awareness and Beliefs About Academic Language Features	23
Preservice Teachers' Beliefs about Their Preparation for Using Digital Math Games to Support Mathematics Learning for ELLs.....	31
Summary of the Important Relationships Examined in this Study.....	34
Contributions of the Current Study.....	37
CHAPTER III: METHODS.....	38
Research Design.....	38
Participants.....	39
Data Sources	41
Procedures.....	49
Data Analysis	61
Validity and Reliability.....	67

	Page
CHAPTER IV: RESULTS.....	69
Preservice Teachers’ Awareness and Beliefs about Design Features.....	70
Preservice Teachers’ Awareness and Beliefs About Academic Language Features	89
Preservice Teachers’ Beliefs about their Preparation for Using Digital Math Games to Support Mathematics Learning for ELLs.....	106
Summary of Results.....	116
CHAPTER V: DISCUSSION.....	119
Preservice Teachers’ Awareness and Beliefs About Design Features.....	120
Preservice Teachers’ Awareness and Beliefs About Academic Language Features	122
Preservice Teachers’ Beliefs About Their Preparation for Using Digital Math Games to Support Mathematics Learning for ELLs.....	124
Implications and Future Research.....	127
Limitations	130
Conclusion	130
REFERENCES	132
APPENDICES	143
Appendix A: Institutional Review Board (IRB) Approval	144
Appendix B: Preservice Teachers’ Beliefs about Preparation with Digital Math Games for ELLs Survey.....	146
Appendix C: Digital Math Game Evaluation Rubric.....	150
Appendix D: Module Reflections: Design Features and Academic Language Features.....	153
Appendix E: Interview Protocol: Preservice Teachers, Digital Math Games, and ELLs	155
Appendix F: Learning Modules Screenshots	157
CURRICULUM VITAE.....	160

LIST OF TABLES

	Page
Table 1	Summary of Participants Completed Modules 40
Table 2	Alignment of Closed and Opened Items with Design Features, Academic Language Features, and Preservice Teachers' Beliefs 43
Table 3	Summary of Data Collection Procedures..... 50
Table 4	Screenshots of Digital Math Games, Alignment to Common Core State Standards, and Design Features and Academic Language Features..... 51
Table 5	Content of the Four Modules 56
Table 6	Overview of Research Questions, Data Sources, and Data Analysis 62
Table 7	Frequencies of Themes about Most Important Design Features on Survey 73
Table 8	Frequencies of Themes about Objective and Academic Content in Digital Math Games on Evaluation Rubrics 81
Table 9	Frequencies of Themes about Design Features in Digital Math Games on Module 2 Reflection 85
Table 10	Design Feature Themes Reported by Preservice Teachers During Semistructured Interviews 88
Table 11	Frequencies of Themes about Most Important Academic Language Features 92
Table 12	Frequencies of Themes About Academic Language Development in Digital Math Games on Evaluation Rubrics 98
Table 13	Frequencies of Themes About Academic Language Features in Digital Math Games on Module 2 Reflection..... 101
Table 14	Academic Language Feature Themes Reported by Preservice Teachers During Semistructured Interviews..... 105

Table 15	Frequencies of Themes About What Teachers Should Know to Integrate Digital Math Games in Mathematics Instruction for ELLs	110
Table 16	Frequencies of Themes About Preservice Teachers' Impression of Digital Math Games on Evaluation Rubrics	111
Table 17	Beliefs About Preparation, Impressions, and Attitudes of Digital Math Games Reported by Preservice Teachers During Semistructured Interviews.....	114

LIST OF FIGURES

	Page
Figure 1 Relationships Between Preservice Teachers' Awareness and Beliefs about Design Features and Academic Language Features, and Their Beliefs about Preparation, when Preservice Teachers Choose Digital Math Games for ELLs	14
Figure 2 Technological Pedagogical Content Knowledge (TPACK) Framework....	16
Figure 3 Frequencies of Likert Scale Items about Preparation for Identifying Mathematics Content and Design Features in Digital Math Games.....	71
Figure 4 Composite Math Game Evaluation Rubric Ratings for Design Features ...	78
Figure 5 Frequencies of Likert Scale Items About Preparation for Identifying Language Demands for ELLs in Digital Math Games	90
Figure 6 Composite Math Game Evaluation Rubric Ratings for Academic Language Features	96
Figure 7 Frequencies of Likert Scale Items About Preparation for Using Digital Math Games to Support Mathematics Learning for ELLs	108

CHAPTER I

INTRODUCTION

The National Council of Teachers of Mathematics (2000) stressed the importance of technology as an essential tool in mathematics classrooms because it can impact how teachers teach mathematics and improve students' mathematics learning. Digital math games are a form of technology that can enhance mathematics learning (Falloon, 2013; Ke & Abras, 2013; Moyer-Packenham, Lommatsch, et al., 2019). Preservice teachers benefit from experiences using digital math games during their preparation programs to understand how digital games can enhance student learning (Meletiou-Mavrotheris & Prodromou, 2016; Sardone & Devlin-Scherer, 2010; Shah & Foster, 2015). It is important for preservice teachers to observe and experience effective uses of digital math games for instruction and evaluate digital games for teaching mathematics (Li, 2013). When preservice teachers have experiences with digital math games, they can critically evaluate the games because they gain awareness of specific features (e.g., feedback, content topics, rules) that support learning (Meletiou-Mavrotheris & Prodromou, 2016).

Language awareness is important when preparing preservice teachers to teach specific content areas, such as mathematics, especially language awareness for working with English language learners (ELLs; Andrews, 2007). Academic language features in mathematics include mathematical symbols, oral and written language, and visual representations (e.g., graphs and tables; Schleppegrell, 2007). When teachers are aware of these academic language features while planning mathematics instruction, they can better communicate concepts and select materials to enhance instruction (Lindahl, 2019). This

suggests that when preservice teachers are aware of academic language features, they can select digital math games as a material to enhance mathematics instruction.

Background of the Problem

Preservice teachers' beliefs can impact how they use digital math games in mathematics classrooms. Researchers have reported that preservice teachers find digital games useful when aligned with curriculum content (Li, 2013; Sardone & Devlin-Scherer, 2010). These beliefs about digital math games can influence how preservice teachers use digital math games during mathematics instruction. Preservice teachers are more likely to use digital math games when they have positive beliefs that digital math games can support student learning (Li, 2013; Sardone & Devlin-Scherer, 2010).

Preservice teachers' beliefs about teaching ELLs can also impact how they deliver mathematics instruction. When teachers believe they are better prepared in mathematics content knowledge, they also believe they are better prepared to understand how language interconnects with mathematics (McLeman & Fernandes, 2012). Teacher language awareness helps teachers better analyze materials to enhance instruction (Andrews, 2001, 2007; Lindahl, 2013, 2019). This means that teacher language awareness can help preservice teachers identify academic language features in digital math games to support mathematics learning for ELLs. Mathematical language is an important feature in digital math games (Ke, 2013; Moyer-Packenham, Litster, et al., 2019). For example, Moyer-Packenham, Litster, et al. (2019) found that when students used specific mathematics language (e.g., terminology such as "equilateral," "decimal,"

or “one-fourth”) when interacting with digital math games, students had significant learning gains from pretest to posttest. This shows that language can mediate learning mathematics in digital math games. Additionally, the use of formal and informal language in digital math games can impact mathematics understanding (Ke, 2013). Therefore, language in digital math games can impact students’ understanding of mathematics concepts. Furthermore, preservice teachers benefit from experiences with choosing and evaluating digital math games based on academic language features because the language used in the games can support students’ mathematics learning.

Design features in digital math games impact children’s mathematics learning (Falloon, 2013; Ke & Abras, 2013; Moyer-Packenham, Lommatsch, et al., 2019). Design features in a digital math game can impact students’ understanding of mathematics concepts. For example, when a design feature, like a linked representation, is in a digital math game, students link multiple mathematical representations, which leads to improved mathematics learning (Moyer-Packenham, Lommatsch, et al., 2019). Therefore, if preservice teachers are aware of design features, they can be better prepared to choose and evaluate digital math games that promote mathematics learning.

To improve awareness of design features and academic language features, preservice teachers need experiences choosing and evaluating digital math games that can support mathematics learning for ELLs (Coady et al., 2011). The experiences preservice teachers have with choosing and evaluating digital games can impact the beliefs and practices preservice teachers bring to the classroom (Belbase, 2015; Sardone & Devlin-Scherer, 2010; Shah & Foster, 2015). Thus, preservice teachers’ awareness and beliefs

about design features and academic language features can influence the way they use digital games to enhance instruction for ELLs in mathematics.

Statement of the Problem

Preservice teachers' experiences in their preparation courses can impact their beliefs about using digital math games to enhance instruction for ELLs. Providing experiences with technology in preparation courses, specifically with digital games, can better prepare preservice teachers to choose digital math games that enhance students' mathematics learning (Meletiou-Mavrotheris & Prodromou, 2016; Sardone & Devlin-Scherer, 2010; Shah & Foster, 2015). Through these experiences, preservice teachers become aware of what design features (i.e., game attributes) in digital games can promote learning. However, preservice teachers have limited experience integrating digital math games into mathematics instruction (Belbase, 2015; Niess, 2005). There is limited research on how to promote preservice teachers' awareness of design features. Therefore, there is a need to understand further what promotes preservice teachers' awareness of design features in digital math games.

Preservice teachers have reported being underprepared to teach ELLs in mainstream classrooms (Durgunoglu & Hughes, 2010; Lindahl, 2013, 2019; Reeves, 2006). To better prepare preservice teachers, Andrews (2007) and Lindahl (2013, 2019) suggest that teachers develop an awareness of language within content materials (e.g., digital math games) to improve instruction for ELLs. Mathematics has many semiotic systems (e.g., symbols, visual representations) and grammatical patterns (e.g., academic

vocabulary, dense noun phrases) that require an understanding of how different elements of language interact to make mathematical meaning (Schleppegrell, 2007). The language used in mathematics is complex and requires understanding subtle differences in the meaning of specific terms that can impact mathematics instruction and learning, such as the academic language features in digital math games. This suggests that preservice teachers could benefit from understanding how language enhances or hinders learning when students interact with digital math games. There is a body of research that examines teacher language awareness for language teachers (Lindahl, 2013, 2019). However, there is limited research on how teacher language awareness in mathematics can impact students' mathematics learning and how it can enhance mathematics instruction for ELLs.

Taken together, each of these factors may leave many preservice teachers feeling underprepared in their awareness of design features and academic language features to choose effective digital math games for ELLs. With preservice teachers feeling underprepared to teach ELLs and use digital math games in mathematics instruction, and the complex use of language in teaching mathematics, there is a need to better understand effective strategies that may support the preparation of preservice teachers in developing their awareness and beliefs.

Significance of the Problem

How preservice teachers choose and evaluate digital math games for ELLs is important because it has implications for how to better prepare preservice teachers to

choose digital math games that support mathematics learning for ELLs. Understanding how preservice teachers develop awareness and beliefs about design features and academic language features, and beliefs about using digital math games to enhance mathematics instruction for ELLs can benefit instructors who teach preparation courses. For example, suppose findings indicated preservice teachers increased their awareness of design features and academic language features by evaluating digital math games. In that case, instructors may include these types of experiences in preparation courses.

Research on design features and academic language features in digital math games has important implications for game designers. For example, if findings show there is a lack of design features and academic language features that support mathematics learning for ELLs, game designers may include these types of features in future digital math games.

Purpose of the Study

The purpose of this study was to examine how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for ELLs. To address this purpose, I developed learning modules to enhance preservice teachers' awareness of design features and academic language features in digital math games. I also examined preservice teachers' beliefs about using digital math games to support mathematics learning for ELLs.

Design features in digital math games can promote mathematics learning

(Falloon, 2013; Ke & Abras, 2013; Moyer-Packenham, Lommatsch, et al., 2019).

Because research that shows the important impacts of design features on student learning has emerged recently, there needs to be more understanding of how this new research helps prepare preservice teachers to choose and evaluate digital math games based on effective design features. Similarly, few studies examine the language awareness of preservice teachers when choosing digital math games for ELLs. Recent research findings indicate that it would be beneficial for preservice teachers to have experiences in choosing and evaluating digital math games to prepare them to choose effective games when they begin teaching in mathematics classrooms. This suggests that preparation programs have room to improve instruction for preservice teachers on how to effectively enhance mathematics instruction while using digital math games with ELLs.

There has been a movement in education to improve language awareness among students and teachers, which involves analyzing and describing language to better use academic language in educational settings (Andrews, 2007). Teacher language awareness is important for teachers to analyze content material used during instruction, such as digital math games (Lindahl, 2013, 2019). This means that preservice teachers need to be aware of complex language systems in mathematics to better choose and evaluate digital math games.

Research Questions

The overarching research question that guided this study was: How do preservice teachers develop awareness and beliefs about design features and academic language

features when choosing and evaluating digital math games for English language learners

(ELLs)? The main research questions of the study were as follows.

1. What are preservice teachers' awareness and beliefs about design features when choosing and evaluating digital math games for ELLs, and what changes, if any, are exhibited after completing the learning modules?
2. What are preservice teachers' awareness and beliefs about academic language features when choosing and evaluating digital math games for ELLs, and what changes, if any, are exhibited after completing the learning modules?
3. What are preservice teachers' beliefs about their preparation for using digital math games to support mathematics learning for ELLs, and what changes, if any, are exhibited after completing the learning modules?

Summary of the Research Study Design

In order to explore how preservice teachers chose and evaluated digital math games to support mathematics learning for ELLs, I employed a convergent mixed methods design (Creswell & Plano Clark, 2017). I used qualitative and quantitative data to analyze how preservice teachers chose and evaluated digital math games for ELLs. The qualitative data had a prominent emphasis in this study, and the quantitative data were supplemental to the qualitative data during merging and interpretation. This allowed me to understand how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for ELLs. Twenty-one elementary preservice teachers from one university participated in this study. I collected the data for this study using online methods over a 4-week time period. I used the following instruments: Preservice Teachers' Beliefs about Preparation with Digital Math Games for ELLs Survey, Digital Math Game Evaluation Rubric, Module Reflections, and semistructured interviews. My data analysis included a

multi-phase process using descriptive coding, pattern coding, frequency tables, bar graphs, a Wilcoxon signed ranked test, and a narrative comparison.

Definitions of Terms

Academic language features: “The oral and written text required to succeed in school that entails deep understanding and communication of the language of content within a classroom environment; revolves around meaningful application of specific criteria related to Linguistic Complexity in the discourse dimension, Language Forms and Conventions in the sentence dimension, and Vocabulary Usage in the word/phrase dimension within the particular context in which communication occurs” (WIDA, 2012, p. 124).

Awareness: The underlying relationships between what is being experienced and what has been experienced (e.g., awareness includes knowledge and concepts; Marton & Booth, 1997).

Design features: Game attributes that can determine learning potential in digital games (Bedwell et al., 2012); elements (e.g., feedback, hints, linked representations) that are programmed to determine how a game functions (Boyer-Thurgood, 2017).

Digital math games: Games that are designed experiences for children to learn mathematics on a digital platform (e.g., computers, tablets, smartphones; Squire, 2006).

English language learners (ELLs): “Linguistically and culturally diverse students who have been identified (by a WIDA screener and other placement criteria) as having levels of English language proficiency that require language support to achieve grade-

level content in English” (WIDA, 2012, p. 111).

Teacher beliefs: “The information, attitudes, values, expectations, theories, and assumptions about teaching and learning that teachers build over time and bring with them to the classroom” (Richards, 1998, p. 66).

Teacher language awareness: “Knowledge that teachers have of the underlying systems of the language that enables them to teach effectively” (Thornbury, 2017, p. xv).

CHAPTER II

LITERATURE REVIEW

There is a need to better understand effective strategies that prepare preservice teachers to develop an awareness of design features and academic language features when choosing and evaluating digital math games to enhance instruction for ELLs because preservice teachers feel underprepared to teach ELLs (Durgunoglu & Hughes, 2010; Lindahl, 2013, 2019; Reeves, 2006) and have limited experiences with integrating digital math games in mathematics instruction (Belbase, 2015; Niess, 2005). This study examined how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for ELLs.

This chapter reviews the theoretical underpinnings and empirical research relevant to the current study. First, this chapter presents the conceptual framework of the three premises examined in this study. The second part of the chapter examines the research literature about preservice teachers' awareness and beliefs about design features in digital math games. The third section examines research literature about preservice teachers' awareness and beliefs about academic language features in digital math games for ELLs. The fourth section examines research literature on preservice teachers' beliefs about their preparation for using digital math games for instruction and about teaching ELLs. The chapter concludes by discussing the study's contributions to the current body of research about preservice teachers' awareness and beliefs about design and academic language features when choosing and evaluating digital math games for ELLs.

This research study used the term *English language learners (ELLs)* defined as “linguistically and culturally diverse students who have been identified (by a WIDA screener and other placement criteria) as having levels of English language proficiency that require language support to achieve grade-level content in English” (WIDA, 2012, p. 111). This terminology is currently used when preparing preservice teachers for working with diverse learners. While terminology, such as multilingual, bilingual, and emergent bilingual, have gained traction in the research literature to describe linguistically diverse learners through an asset-oriented lens, the National Education Association continues to use the term ELLs in their advocacy for ELLs to receive quality education and address strategies teachers need to meet the linguistic needs of linguistically diverse students (National Education Association, 2011). This term is also used among mathematics education researchers (e.g., Aguirre & Zavala, 2012; Moschkovich, 2013; Turken & Jong, 2018), making it an appropriate term for describing the linguistically diverse students referred to in this study.

This study used the term *awareness* as the underlying relationships between what is being experienced and what has been experienced (e.g., including knowledge and concepts; Marton & Booth, 1997). Marton and Booth explain awareness as a structure impacted by a person’s understanding of a concept and how they can relate previous knowledge with current experiences. This means that awareness is not forming new knowledge but is related to the types of knowledge a person brings to an experience. Therefore, this study focuses on preservice teachers’ awareness of design features and academic language features and does not focus on measuring new knowledge that

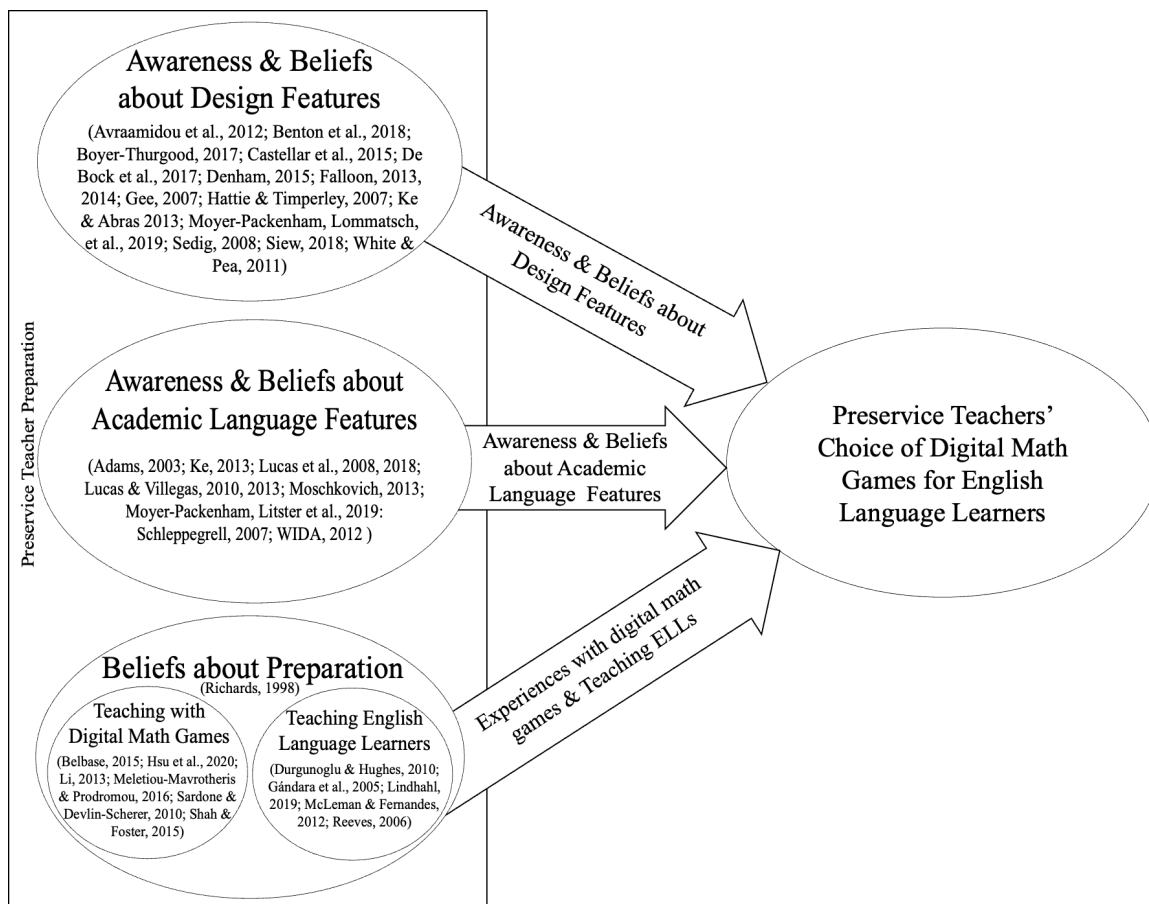
preservice teachers might gain during the study.

Conceptual Framework

This study examined how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for ELLs. Figure 1 shows the conceptual framework and how these constructs connect. The conceptual framework frames the three important premises that may impact how preservice teachers choose and evaluate digital math games to enhance mathematics instruction for ELLs. The first premise in the conceptual framework is that preservice teachers' awareness and beliefs about design features in digital math games can impact their choices of specific games selected for ELLs. The second premise is that preservice teachers' awareness and beliefs about academic language features in digital math games can impact their choices of effective digital math games for ELLs. The third premise is that preservice teachers' beliefs about using digital math games for instruction and teaching ELLs can impact their choices about whether or not to use the games in mathematics instruction. Other factors likely impact the selection of digital math games for enhancing mathematics instruction for ELLs (e.g., motivation). However, this study focuses on these three premises that form the relationships that lead to preservice teachers' selection of a digital math game for enhancing mathematics instruction for ELLs. It is important to note that I recognize that language overlaps between design features and academic language features. For example, written or auditory language can be feedback, a specific design feature in digital math games. However, the premises for

Figure 1

Relationships Between Preservice Teachers' Awareness and Beliefs about Design Features and Academic Language Features, and Their Beliefs about Preparation, when Preservice Teachers Choose Digital Math Games for ELLs



this study examined design features and academic language features separately because they have specific characteristics, as described in the sections below.

The arrows in the conceptual framework show how the three constructs may impact how preservice teachers choose digital math games for ELLs. The top arrow shows how preservice teachers' awareness and beliefs about design features can impact

how they choose digital math games for ELLs. The middle arrow shows that preservice teachers' awareness and beliefs about academic language features can impact how they choose and evaluate digital math games for ELLs. The bottom arrow shows that teacher beliefs about their preparation can influence how they choose and evaluate digital math games for ELLs by the experiences preservice teachers have with using digital math games and teaching ELLs mathematics in their preparation courses. Each element of the conceptual framework emerged from the literature, as described in detail in the following sections.

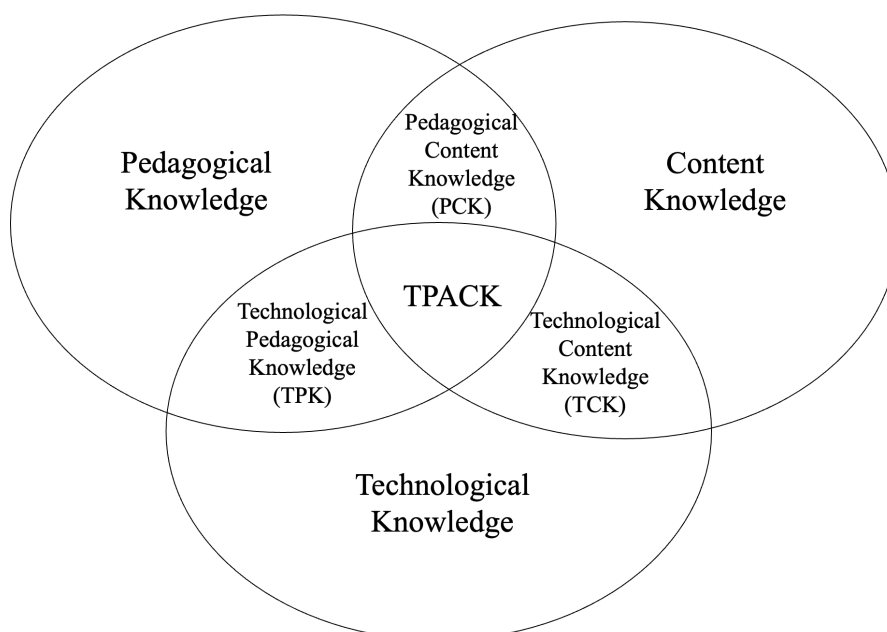
Awareness and Beliefs about Design Features

Awareness and beliefs about design features are grounded in Mishra and Koehler's (2006) theory of Technological Pedagogical Content Knowledge (TPACK), which preservice teachers may bring to this study. Figure 2 shows the TPACK framework. There are three components of TPACK: content, pedagogy, and technology.

Mishra and Koehler (2006) identified each component to show how content, pedagogy, and technology connect to teacher understanding and successful integration of technology in the classroom setting. Content refers to the content knowledge (CK) teachers have about the subject matter they teach. Pedagogy refers to the pedagogical knowledge (PK) that teachers have that provides an understanding of the learning process in the subject matter. When Content knowledge and pedagogical knowledge overlap, there is pedagogical content knowledge (PCK) which means teachers understand how to use teaching strategies to meet the needs of their students and promote a deep

Figure 2

Technological Pedagogical Content Knowledge (TPACK) Framework



Note. Adapted from Mishra and Koehler (2006).

understanding of the subject matter. Technology refers to teachers' technology knowledge (TK) about using the technology themselves. When teachers can relate technology knowledge and content knowledge, they have technological content knowledge (TCK), meaning they understand how the technology can change the subject content (e.g., provide representations that are not available without technology). Teachers have technological pedagogical knowledge (TPK) when they relate their understanding of technology and pedagogical knowledge. This means teachers understand that teaching strategies will change as they integrate a technological tool. Finally, when a teacher has an "understanding of the complex relationships between technology, content, and pedagogy, and using this understanding to develop appropriate, context-specific

strategies and representations” (Mishra & Koehler, 2006, p. 1029), then the teacher has TPACK knowledge and can integrate technology in meaningful ways to enhance learning for students.

The TPACK theory has been used to conduct research with preservice teachers to assess their knowledge of using technology for classroom instruction (Gutiérrez-Fallas & Henriques, 2021; Lachner et al., 2021; Lux et al., 2011; Schmidt et al., 2009). For example, Lux et al. created a Preservice Teacher-Technological Pedagogical Content Knowledge Survey to assess 120 preservice teachers’ perceptions and understanding of TPACK. The survey results showed that preservice teachers’ responses had lower TPK scores. Lux et al. suggested that these low response scores may be due to their lack of experience integrating technology into instruction. In another study, Lachner et al. reported that when 208 secondary preservice teachers participated in a study, the experiment group ($N = 88$) outperformed the control group ($N = 120$) in TPACK knowledge and had higher self-efficacy in using technology to enhance instruction after participants interacted with TPACK learning modules. These findings are important to the current study because it shows that the experiences preservice teachers have with choosing and evaluating digital math games may increase their awareness of design features, leading to better approaches for integrating digital math games for instruction.

TPACK was used as an interpretive lens to examine how 13 preservice teachers evaluated multiple digital math games using two different rubrics and then to understand how preservice teachers planned, taught, and reflected on a mathematics lesson using the games they evaluated with the rubrics (Meletiou-Mavrotheris & Prodromou, 2016).

Results of this study showed that the prior training and awareness helped preservice teachers better understand how to use TPACK to choose digital math games and effectively integrate them into mathematics lessons. This finding is important to the current study because it demonstrates that preservice teachers' prior experiences with evaluating digital games, and their experiences using TPACK in their methods courses, can strengthen their awareness of design features and academic language features to choose and evaluate digital math games effectively and to ensure that preservice teachers are better able to integrate digital math games in mathematics lessons successfully.

TPACK is a broad framework that focuses on general technology, which has led to a framework to include specificity on Technological Pedagogical Content Knowledge for games (TPACK-G; Hsu et al., 2013, 2017, 2020). TPACK-G includes teachers' game knowledge (GK), which is the knowledge of playing games; teachers' game pedagogical knowledge (GPK), which is about how to appropriately use teaching methods to integrate games in instruction; teachers' game content knowledge (GCK), which focuses on how games represent content; and teachers' game pedagogical content knowledge (GPCK), which includes how teachers use pedagogy and knowledge of games to integrate digital games into instruction appropriately.

The TPACK-G framework research has focused on in-service teachers in the elementary setting (Hsu et al., 2013, 2017, 2020). For example, Hsu et al. (2020) reported that 376 in-service elementary school teachers completed a survey about their TPACK-G knowledge. This study reported that novice teachers were significantly more positive toward their perceptions of TPACK-G knowledge than veteran teachers. The authors of

this study suggested that novice teachers had more preparation for integrating technology during their preparation program, which could explain the difference in novice teachers' beliefs compared to teachers who had been teaching longer and did not receive such preparation. The TPACK-G literature is important to the current study because it provides a framework that suggests that positive beliefs can impact preservice teachers' confidence in integrating games into mathematics instruction for ELLs. The findings of this research are also important to the current study because they suggest that preservice teachers' experiences in their preparation may contribute to such beliefs.

Squire (2006) explained that educational games are “designed experiences” for learning. This study defined digital math games as designed experiences for children to learn mathematics on a digital platform (e.g., computers, tablets, smartphones). Digital math games are designed experiences that include design features, defined as game attributes that can determine learning potential in digital games (Bedwell et al., 2012). Design features elements (e.g., feedback, hints, linked representations) are programmed into the games that determine how the game functions (Boyer-Thurgood, 2017). Current research has examined how design features (e.g., characteristics) can enhance content understanding (Callaghan & Reich, 2018; Gresalfi et al., 2018; Moyer-Packenham, Lommatsch, et al., 2019). It is important to note that language features in a digital game overlap with the other design features in the digital game, making it difficult to separate the two elements. For example, language can provide hints for students to complete a task within a digital math game accurately. The characteristics of specific academic language features in this study focus on the specific academic mathematical language used in

digital math games, as described in a later section of this chapter.

Research by Moyer-Packenham, Lommatsch, et al. (2019) identified eight design features that promote mathematical understanding after 193 elementary-aged children played 12 digital math games. These features include accuracy feedback, progressive levels, multiple attempts, hints, focused constraint, game efficiency, linked representations, and linked physical actions. Another study with 100 children ages 4-8 reported that features such as incentives (e.g., coins or points for correct answers), application themes (e.g., characters), and open-ended tasks promoted children's engagement with the mathematics in the games (Watts et al., 2016). These findings suggest it is important to be aware of design features in digital math games when examining how a game aligns with mathematics learning outcomes. Based on these findings, this research relates to the current study by positing that preservice teachers should be aware of design features when choosing and evaluating digital math games.

Design features in digital math games can help or hinder children's mathematics learning (Falloon, 2013; Ke & Abras, 2013; Moyer-Packenham et al., 2020; Moyer-Packenham, Lommatsch, et al., 2019). For example, Ke and Abras reported that middle school-aged children in an algebra class interacted with digital math games, and certain features (e.g., clear learning goals, rewards, open-ended challenges) improved engagement for learning the concepts in the game. Similarly, Falloon reported that when games had certain features (e.g., scaffolding, corrective feedback, the balance of education and entertainment), students maintained thoughtful engagement throughout their gameplay. Moyer-Packenham et al. (2020) conducted a study with 193 elementary-

aged students, where students identified design features that helped or hindered their learning in the digital math game. A design feature a student reported as hindering their learning was a linked physical action because the student found it difficult to move the object on the screen to complete the mathematics task. This suggests that features in digital math games can promote or hinder mathematics understanding by engaging students in playing digital math games, leading to impacts on learning. Therefore, preservice teachers need awareness of how features can promote or hinder engagement to enhance mathematics learning in digital math games.

Feedback is an important design feature to be aware of when examining digital math games. Boyer-Thurgood (2017) defined feedback features as “clues the app provides following a user response that let the user know about the accuracy of their response or how to proceed” (p. 77). Using this definition, she identified six types of feedback features (e.g., auditory, visual, text, immediate, delayed, and requested) that can influence learning in digital math games. Falloon (2014) reported on children’s use of feedback features in 45 apps and found that when feedback features only had visual or audio support (i.e., points, score, or character actions), they were less effective than corrective feedback (i.e., tutorials). In other studies, the timing of feedback (immediate or delayed) influenced a child’s success in a given task (Clariana et al., 2000; Hattie & Timperley, 2007; Sedig & Liang, 2006; Shute, 2008). For example, immediate feedback was best at a process level, while delayed feedback was more effective at a task level (Hattie & Timperley, 2007). These findings relate to the current study by showing that feedback features are important to be aware of when choosing digital math games

because they can impact mathematics learning outcomes. Thus, preservice teachers need to be aware of feedback as an important design feature that can impact learning. The body of research on design features is important to the current study by informing which design features preservice teachers should be aware of when choosing and evaluating digital math games for ELLs and which features the design of the modules should include in this study.

Using representations in a digital math game in the game's design features can promote mathematics understanding. Representations are signs, objects, or characters representing something (Goldin, 2003). Research shows that the effective use of mathematical representations in a digital math game can impact student learning outcomes (Castellar et al., 2015; Denham, 2015; Sedig, 2008; Siew, 2018). When students link representations in digital math games or physical actions with digital math games, their understanding of mathematics improves (Moyer-Packenham, Lommatsch, et al., 2019). For example, Avraamidou et al. (2012) reported that the physical actions of manipulating objects on a computer screen to build a house led to children abstracting mathematics knowledge about area and perimeter because the children were using these movements to explain why they were putting two blocks on one side to make both sides equal area. In another study, T. White and Pea (2011) found that when four middle school students used a program that provided multiple representations (e.g., graphs, tables, and text), they could make connections among the representations that promoted understanding of functions. Teachers need to be aware of the representations in digital math games that children can interact with to make connections among representations

and between their physical actions with those representations.

Awareness and Beliefs About Academic Language Features

Second language acquisition (SLA) theories focus on how a second language is learned and informs research on the importance of teacher language awareness (Gass et al., 2013; Hummel, 2014). SLA examines patterns among linguistic characteristics, structures of language, and social interactions and how these patterns relate to challenges language learners may face when acquiring a new language (Ellis, 2015). Many SLA theories have informed language education initiatives over the past 50 years. Of particular relevance to this study, is Krashen's (1982) notion of comprehensible input. Krashen hypothesized that language learners acquire a new language when exposed to input slightly above their current level of understanding. The input is the language that learners interact with when learning (e.g., auditory language, written language). This input can be modified for students to understand what is being said (Krashen, 1982). For example, a teacher can manipulate the input language learners are exposed to by choosing appropriate materials or adjusting language (e.g., adding pictures or using simple sentences) to make the input comprehensible (Gass et al., 2013). The affective filter students may have (e.g., motivation, anxiety, self-confidence) can impact input (Krashen, 1982). This means that the social contexts in which language learners receive linguistic input impacts how that input is received and used in language acquisition. Language learners can acquire a second language when they have comprehensible input and supportive affective influences (Krashen, 1982). The teacher's role is to ensure language

learners receive comprehensible input within a social context that reduces anxiety because the input is important to learning a second language (Gass et al., 2013).

Researchers have criticized Krashen's (1982) Comprehensible Input Hypothesis because it assumes that language is acquired by simply understanding the input language learners receive in a second language (Ellis, 2015); however, input alone does not lead to acquiring a second language (Echevarria et al., 1999, 2010, 2017; Gass et al., 2013; Swain, 1985). For example, Long's (1983) Interaction Hypothesis explains that learners acquire a second language by modifying input by negotiating meaning as they interact in a conversation. Another relevant SLA theory is Swain's (1985) Output Hypothesis which explains that output is an important aspect of acquiring a second language because learners must produce comprehensible, accurate, and socially acceptable output. When language learners produce output in social contexts, they adjust their grammatical form and can receive feedback on their output that can help develop grammatical competence.

Krashen (1982) also needed to provide specifics on how to make input comprehensible (Lichtman & VanPatten, 2021; Long, 1983; Swain, 1985). This has led to modifications of Krashen's claims about input. For example, Long suggested specific ways to modify the input to make it comprehensible for language learners. Such as using language structures students are already familiar with, providing context and using students' common knowledge, and adjusting the conversation input level. Another input form involves feedback about incorrect utterances (White, 1987). The feedback language learners receive as they interact with language in a specific context improves their language ability, leading the student to focus more on the target language output they are

producing (Gass et al., 2013).

Although the comprehensible input hypothesis is criticized because input is not the only causal variable in SLA, the idea of input is acknowledged as important in SLA research and teachers use various approaches to try to create comprehensible input as a strategy to teach language learners (Lichtman & VanPatten, 2021). For example, Echevarria et al. (1999, 2010, 2017) developed the Sheltered Instruction Observational Protocol (SIOP) to help teachers integrate content and language instruction for ELLs. Comprehensible input is one of the eight main components within the SIOP model. Comprehensible input includes the variety of ways the teacher makes a lesson accessible for ELLs. Such as the way the teacher speaks (e.g., enunciation), how they model tasks (e.g., model academic language), and how they use multimodal strategies to improve comprehension during a lesson (e.g., interactive whiteboards). Technology can also help make input accessible to ELLs, such as digital math games. This supports the need for preservice teachers to be aware of academic language features in digital math games to help support mathematics learning for ELLs. Therefore, this study focuses on aspects of input by examining how preservice teachers develop an awareness of academic language features when choosing and evaluating digital math games as a form of input for ELLs.

Linguistic input, output, and feedback are important in facilitating SLA, and teachers working with language learners need to know how to modify these classroom language dimensions to meet the needs of their students. Teacher Language Awareness (TLA) builds on this foundational work of SLA by focusing on “the knowledge that teachers have of the underlying systems of the language that enables them to teach

effectively” (Thornbury, 2017, p. xv). This language awareness includes teacher knowledge about content and language proficiency, specifically their understanding of a language’s underlying organization (e.g., semantics, word meanings) of language (Andrews, 2007). There are three domains within TLA: User Domain, Analyst Domain, and Teacher Domain. The user Domain includes a teacher’s awareness of their language and their diverse learners’ language. The Analyst Domain includes the teacher’s understanding of language (e.g., rules and systems). The Teacher Domain involves how the teacher plans lessons to support diverse learners. These domains are connected and help teachers better instruct ELLs. For example, if teachers are aware of the input (e.g., the language they expose ELLs to), they can filter for language demands ELLs will encounter (Andrews, 2001). This shows that it is important for preservice teachers to be aware of the input they will provide through the language they use, and the language used in supplemental materials (e.g., language in digital math games). For the purpose of this study, the Analysis Domain supports the need for preservice teachers to be aware of academic language features in digital math games so they can choose games that support mathematics learning for ELLs.

There is limited research on how to prepare preservice content teachers to use TLA in their instruction (Lindahl, 2019). There have been studies with in-service content teachers and using professional development to prepare teachers to use TLA in their instructional practices (Hansen-Thomas et al., 2018; Metz, 2018). For example, Hansen-Thomas et al. (2018) used language objectives to help teachers use their language awareness to plan content lessons for ELLs. The findings of this study suggest that

development programs need to start with what teachers already know about language and build on that knowledge to help teachers develop a better understanding of specific language structures that will strengthen their language awareness when planning instruction for ELLs.

Current research suggests that preservice teachers have a low ability to identify language demands and language structures that can impact ELLs (Lindahl, 2013, 2019). For example, Lindahl (2019) found a theme among 116 preservice teachers showing they feel underprepared in their TLA to meet the needs of ELLs even though they had received some form of coursework in working with ELLs. Lindahl reported that preservice teachers felt frustrated with their lack of language awareness, making it difficult to create language objectives for content lessons. This lack of language awareness can hinder instruction for ELLs because preservice teachers cannot identify language demands that may impact ELLs' understanding of content. This suggests that preservice teachers need more instruction in methods courses about TLA and how to use it when choosing instructional materials for ELLs.

Academic language is viewed as the “language of school” that differs in complexity and cognitive demand compared to the language often used outside of school (Schleppegrell, 2004). The language used in academic settings also has a different level of cultural demand placed on students as they navigate the content knowledge and the interaction with peers and teachers with different backgrounds (Lindahl & Watkins, 2014). This means that language used in academic settings has unique demands that teachers need to understand to communicate successfully with students, structure

classroom interactions among students, and teach content concepts.

Halliday (1978) describes mathematics as a specific register that uses language differently from everyday language and other content areas. The functional language within the mathematics register communicates meaning for mathematical purposes. Mathematics language forms and vocabulary are complex and include representations (e.g., symbols, words, pictures), technical vocabulary, and grammatical patterns (e.g., sentence length, dense noun phrases; Adams, 2003; Lucas & Villegas, 2010, 2013; Moschkovich, 2013; Schleppegrell, 2007). In other words, the language used in mathematics differs from the language used in other content areas and outside of school.

For the purpose of this study, *academic language feature* was defined using WIDA's (2012) definition,

The oral and written text required to succeed in school that entails deep understanding and communication of the language of content within a classroom environment; revolves around meaningful application of specific criteria related to Linguistic Complexity in the discourse dimension, Language Forms and Conventions in the sentence dimension, and Vocabulary Usage in the word/phrase dimension within the particular context in which communication occurs. (p. 124)

The use of the term *academic language* throughout this dissertation does not imply that this work advocates for a specific type of language that should be used in digital math games. Rather, this work aims to bring awareness to how interpretable the language in digital math games is for language learners. The term was also used due to the limited time preservice teachers interacted with the learning modules. Preservice teachers in this study used the WIDA standards when learning about teaching linguistically diverse students in their preparation courses. Therefore, it was possible for preservice teachers to be familiar with this term. This term was intended to increase preservice teachers'

awareness by helping preservice teachers focus on the specific mathematics language forms and vocabulary used in the digital math games and to evaluate how these features related to the comprehensibility of input for ELLs.

WIDA (2012) outlined specific academic language features within three different dimensions of sociocultural contexts for language in school. These included the discourse dimension that focuses on linguistic complexities (e.g., amount of speech, speech density); the sentence dimension that focuses on the language forms and conventions (e.g., language form and purpose); and the word/phrase dimension that focuses on vocabulary usage (e.g., specific content language, multiple meanings of words and phrases). Similarly, Lindahl and Watkins (2014) outlined academic language demands that teachers should consider when identifying the language in content areas and writing a language objective that aligns with content objectives. These language demands include specific content vocabulary, functional terms (e.g., transitions, opinions), grammar, the structure of words, comprehension strategies, and writing conventions. Lindal and Watkins explain that teachers can better plan effective instruction focusing on content and language development when they have a foundation of language demands. This is important to the current study because it shows the importance of preservice teachers being aware of specific academic language features (e.g., amount of speech, speech density, formal and informal language, multiple meanings of words and phrases) which could help or hinder the comprehensibility of digital math games for ELLs.

Although a body of research focuses on preparing teachers to use their language awareness to enhance instruction, few studies have specifically examined the language

demands in digital math games. With the limited body of research that has examined language in digital math games, mathematical language is an important feature in digital math games (Bedwell et al., 2012; Ke, 2013; Moyer-Packenham, Litster, et al., 2019). For example, Moyer-Packenham, Litster, et al. reported that when 193 children in grades 3-6 interacted with digital math games, there were significant changes from pretest to posttest when students used specific mathematical language in connection with mathematical representations (e.g., symbols, images, gestures). This study demonstrated that when students orally described their mathematics understanding in connection with the written mathematics language (e.g., equilateral triangle) in digital math games, students had a more explicit awareness of the mathematics in the digital math games. This suggests that specific mathematics vocabulary in the input of digital math games can impact students' awareness of specific mathematics terms and shape how students talk about the mathematics in the game. This is important to the current study because it posits that preservice teachers should be aware of specific academic language features, such as formal mathematics vocabulary, to help ELLs develop mathematics language as they interact with digital math games.

The use of formal and informal language in digital math games relates to mathematics understanding (Ke, 2013). Ke reported that most tutoring games (87%) use formal language, while fewer games use informal language. For example, games that used formal language focused on symbols, while other games used informal language to describe a concept, such as describing the area as the inside of a shape. This suggests that the use of informal language helps access the formal knowledge used in the games.

Ganesh and Middleton (2006) argue that using digital math games allows ELLs to develop competencies in English and mathematics when they translate among different representations (e.g., written texts to symbols). This shows that the language used in digital math games can impact mathematical understanding. These findings relate to the current study because they show how the balance of informal and formal language and translating among representations (e.g., symbols, visuals) in a game can make it more comprehensible for ELLs. In order to strategically select such games for use with ELL students, preservice teachers need to cultivate language awareness and specifically develop an understanding of the academic language features of mathematics.

Preservice Teachers' Beliefs about Their Preparation for Using Digital Math Games to Support Mathematics Learning for ELLs

The third premise of this study examines preservice teachers' beliefs about their preparation for using digital math games in mathematics instruction and their preparation for teaching ELLs. A preservice teacher's beliefs may impact how they choose digital math games for ELLs. Richards (1998) defined teacher beliefs as "The information, attitudes, values, expectations, theories, and assumptions about teaching and learning that teachers build over time and bring with them to the classroom" (p. 66). Preservice teachers' experiences in life, including personal experiences, learning experiences, and teaching experiences, form beliefs (Richardson, 1996). Preservice teachers' beliefs can change through their experiences in their preparation courses by reflecting on these experiences (McLeman & Fernandes, 2012; Richardson, 1996). Understanding how

beliefs form and how they can change is important to the current study because the experiences provided in this study can help preservice teachers form or change their current beliefs about choosing and evaluating digital math games to enhance instruction for ELLs.

Beliefs about Teaching Mathematics with Digital Math Games

Preservice teachers' beliefs can be impacted by the opportunities they have to learn about digital games in content pedagogy courses (e.g., math methods courses) (Meletiou-Mavrotheris & Prodromou, 2016; R uth et al., 2022; Sardone & Devlin-Scherer, 2009, 2010; Shah & Foster, 2015). For example, Shah and Foster (2015) reported that before an intervention with 14 preservice teachers using educational games, they believed that games were engaging for students. After the intervention of teaching with digital games, preservice teachers believed that the digital games could promote skills and problem-solving abilities, which positively impacted their desire to use digital math games in future instruction. In another study, 13 preservice teachers initially believed that games are important to integrate into instruction (Meletiou-Mavrotheris & Prodromou, 2016). After the experience with evaluating digital math games, their beliefs became more sophisticated because they were aware of specific features of the games (e.g., feedback, rules, topics) to support the effectiveness of using digital math games to enhance instruction. This suggests that when preservice teachers become aware of specific design features in digital games, their beliefs become more sophisticated in using digital math games for mathematics instruction. Similarly, when 25 preservice secondary

teachers participated in a course that allowed them to explore digital educational games by choosing, reviewing, and teaching an educational game to a student, it positively influenced their beliefs about using educational games for instruction (Sardone & Devlin-Scherer, 2010). These findings are important to the current study because they highlight the importance of examining teachers' beliefs and how they may change when using digital games in content preparation courses.

Beliefs about Preparation for Teaching ELLs

Teachers have reported that they are underprepared to effectively teach ELLs (Clark & Andreasen, 2021; Durgunoglu & Hughes, 2010; Gándara et al., 2005; Lindahl, 2013, 2019; Reeves, 2006). The experiences preservice teachers have in their preparation courses can impact their beliefs about teaching ELLs and change deficit beliefs to more positive ones (Huerta et al., 2022; McLeman & Fernandes, 2012). For example, when teachers had greater preparation for teaching ELLs, they reported higher confidence in their ability to work with ELLs (Gándara et al., 2005).

The level of language knowledge preservice teachers have about language demands in content areas also impacts their beliefs about teaching ELLs (Lindahl, 2013, 2019). For example, Huerta et al. (2022) reported that when preservice teachers ($N = 136$) and in-service teachers ($N = 59$) completed a survey about their attitudes toward linguistic diversity and teaching ELLs, they had limited language knowledge about integrating language instruction into content areas instruction. This was true among preservice teachers who believed direct translation from English to students' first language was the best way to support ELLs. Similarly, Lindahl (2019) reported that 116

preservice teachers lacked explicit knowledge of a language (e.g., forms and functions of language, identifying language demands). The low level of language knowledge frustrated preservice teachers, leading to a lack of confidence in their teaching. Lindahl suggests that preservice teachers be provided experiences with language awareness tasks that focus on specific language demands and that these tasks be embedded in content preparation courses to help change deficit beliefs and better prepare teachers to meet the needs of ELLs. In another study, findings indicated that when preservice teachers had experiences with studying language issues related to ELLs, they had positive beliefs about teaching ELLs in content areas, suggesting that the experiences preservice teachers have with studying language issues can impact their beliefs about ELLs in the classroom (McLeman & Fernandes, 2012). The results of these studies are important to the current study because they show that preservice teachers' experiences during their preparation programs may impact their beliefs about teaching ELLs.

Summary of the Important Relationships Examined in this Study

ELLs perform significantly lower in mathematics than their English-proficient peers (McFarland et al., 2019), and preservice teachers need to feel prepared to teach ELLs (Durgunoglu & Hughes, 2010; McLeman & Fernandes, 2012). Therefore, it is important to understand what prepares preservice teachers to meet ELLs' needs successfully because the technology used with ELLs can promote learning in mathematics (Ganesh & Middleton, 2006; López, 2010). Ganesh and Middleton explain that technology can help ELLs because "It is through such technology-based experiences,

by translating among forms of representations (e.g., from written text to symbols to graphs to oral exposition) that students develop both competences in the English of math instruction and also competence in mathematics.” (p. 104). López (2010) found that when integrating digital learning formats into three third-grade classrooms, ELLs had significant learning gains compared to their non-English language learning peers. These findings suggest that technology, such as digital math games, can promote mathematics learning for ELLs. Therefore, preservice teachers should be equipped with analytical skills to identify relevant design features and academic language features for the input a digital math game provides for ELLs and to make judgments of the comprehensibility of the specific language demands ELLs may have when learning mathematics concepts.

Current research on digital math games reports improved learning outcomes (Gresalfi et al., 2018; Moyer-Packenham, Lommatsch, et al., 2019; O’Rourke et al., 2017). For example, students’ mental math skills can improve when interacting with digital math games (Gresalfi et al., 2018; O’Rourke et al., 2017). Students also enjoy learning mathematics more when interacting with digital math games (Moyer-Packenham, Lommatsch, et al., 2019; O’Rourke et al., 2017). These results suggest that digital math games positively impact students’ mathematics learning.

Methods courses must prepare preservice teachers to integrate technology in a way that models how they can use technology in their future classrooms (Franklin, 2011; Gibson, 2002; Meletiou-Mavrotheris & Prodromou, 2016; Niess, 2005). When 700 K-8 teachers completed a survey, only 8% said they learned to use digital games in their preservice teacher preparation (Takeuchi & Vaala, 2014). This suggests that there is

limited preparation for digital game integration in education programs. Grandgenett (2008) stated, “An effective teacher education program can indeed have a significant impact on later teacher and student achievement” (p. 159). Effective education programs can also provide experiences with integrating technology that help preservice teachers have more positive beliefs about integrating technology and using it effectively in instruction (Belbase, 2015; Gibson, 2002; Li, 2013; Sardone & Devlin-Scherer, 2009, 2010). For example, when preservice teachers are immersed in using digital games to learn, they gain a deeper understanding of how to use digital games to enhance instruction and have more positive beliefs about using digital games (Sardone & Devlin-Scherer, 2009).

It is also important for preservice teachers to be better prepared to teach ELLs (Aguirre & Zavala, 2012; Durgunoglu & Hughes, 2010; Lucas et al., 2008, 2018; McLeman & Fernandes, 2012; Von Esch & Kavanagh, 2018). Preservice teachers’ preparation can impact their self-efficacy with teaching ELLs and how they meet their needs (Durgunoglu & Hughes, 2010). For example, preservice teachers’ preparation for analyzing linguistic features (e.g., vocabulary, sentence length) relates to their ability to anticipate ELLs’ needs to complete a task (Lucas et al., 2008). In other studies, preservice teachers who focused on vocabulary by providing non-examples or synonyms and simplified sentences were able to help ELLs be successful in completing mathematics problems (I & Araujo, 2019; Kruz et al., 2017; Turken & Jong, 2018). For example, preservice teachers simplified sentences by changing numeric words to symbols or by changing words (e.g., emperor penguins to birds) helped improve understanding because

it lightened the language demand but did not change the cognitive demand of the mathematics (Kruz et al., 2017). These results show that when preservice teachers are aware of language, they can meet the needs of ELLs. The literature on preparing preservice teachers by integrating technology and working with ELLs is important to the current study because it is through preparation experiences (e.g., awareness of design features and academic language features) that preservice teachers can effectively choose and integrate digital math games into mathematics instruction for ELLs.

Contributions of the Current Study

A body of research examines how to prepare preservice teachers to use digital games to enhance instruction for students. However, there needs to be more research that focuses on how to prepare preservice teachers to choose effective digital math games for ELLs. Therefore, this study examined how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for ELLs. This research provides further insights into how preservice teachers can increase their awareness of design features and academic language features and how this awareness can impact their beliefs about using digital math games to enhance mathematics instruction for ELLs. This is significant because digital math games are used more often in education. Teachers and researchers need to understand how preservice teachers develop awareness and beliefs about design features and academic language features to choose effective digital math games that will support mathematics learning for ELLs.

CHAPTER III

METHODS

The purpose of this study was to examine how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for ELLs. This chapter outlines the research questions, research design, setting and participants, data sources, procedures, and data analysis and addresses the validity and reliability of this study. The overarching research question for this study was: How do preservice teachers develop awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for ELLs? The main research questions of the study were as follows.

1. What are preservice teachers' awareness and beliefs about design features when choosing and evaluating digital math games for ELLs, and what changes, if any, are exhibited after completing the learning modules?
2. What are preservice teachers' awareness and beliefs about academic language features when choosing and evaluating digital math games for ELLs, and what changes, if any, are exhibited after completing the learning modules??
3. What are preservice teachers' beliefs about their preparation for using digital math games to support mathematics learning for ELLs, and what changes, if any, are exhibited after completing the learning modules?

Research Design

This study employed a convergent mixed methods design (Creswell & Plano Clark, 2017). Creswell and Plano Clark describe a convergent mixed method design as analyzing qualitative and quantitative data separately and merging them for interpretation to understand how the data types relate and provide a combined understanding of the

results. There was a “QUAL + quan = converge results” notion of mixed methods in this study, meaning that qualitative data had more emphasis during data collection and analysis (Creswell & Plano Clark, 2017, p. 63). The plus sign between QUAL and quan shows that the methods occurred concurrently, and the equal sign shows the comparison of the qualitative and quantitative results. This study used the Teachers’ Beliefs about Preparation with Digital Math Games for ELLs Survey with a questionnaire variant that included both qualitative and quantitative items. Using the qualitative and quantitative items on the survey allowed the quantitative findings to supplement the qualitative findings (Tashakkori & Teddlie, 2010), allowing me to better understand how preservice teachers developed awareness and beliefs about design features and academic language features. I also used the Digital Math Game Evaluation Rubric to gather qualitative and quantitative data on how preservice teachers used their awareness of design features and academic language features to evaluate digital math games for ELLs. Module Reflections were an additional source to gather qualitative data on how preservice teachers reflected on their awareness of design features and academic language features after watching module lecture videos. Finally, I conducted semistructured interviews with all participants to better corroborate and explain the survey and rubric data.

Participants

There were 40 elementary preservice teachers from one university in the western U.S. who signed the consent form to participate in this study. Prior to recruitment, I obtained the appropriate Institutional Review Board (IRB) approval (see

Appendix A). There were 21 participants who completed all of the required materials. The consent form explained that when participants withdrew or were terminated from the study, their data would be deleted and not used. The termination occurred when participants did not respond to three reminder emails. In the final reminder email, I informed participants that if they did not complete the materials by the intended date, their participation would be terminated. Table 1 summarizes the completed modules for each participant.

Table 1

Summary of Participants Completed Modules (N = 40)

Participants									
Signed consent		Module 1		Module 2		Module 3		Module 4	
<i>N</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
40	100	31	77.5	28	70.0	25	62.5	21	52.5

The 21 participants with complete data sets were between the ages of 20 and 26. More than half (67%) of the participants were in their final semester of coursework before their student teaching experience. A majority of the participants identified themselves as female (90%), with 10% identifying themselves as males. Most participants were Caucasian (95%), and 5% were Hispanic/Latinx/Spanish. In addition, 24% spoke a second language. When asked what grade levels they preferred to teach, over half (57%) preferred teaching the upper elementary grades (e.g., grades 3-5).

Creswell and Poth (2017) explain that qualitative studies tend to have fewer participants ranging from 5-50 participants because the study focuses on the participants'

views and meanings. Since this study's emphasis was qualitative, and because there were multiple data sources, 21 participants were a sufficient size to achieve the study's goals and answer the research questions. This population was also appropriate because the elementary preservice teachers had similar knowledge foundations of teaching mathematics, diverse learners, and integrating technology into mathematics instruction.

This study used a nonprobabilistic sampling method (Creswell & Plano Clark, 2017; Terrell, 2015). This sampling method was used because it was convenient during the COVID-19 pandemic outbreak and provided a population that could be studied using virtual data collection methods. I understood that this population only represented some preservice teacher who completed the university requirements to become practicing teachers (Creswell & Plano Clark, 2017; Terrell, 2015).

Data Sources

The qualitative and quantitative data sources included: Preservice Teachers' Beliefs about Preparation with Digital Math Games for ELLs Survey, Digital Math Game Evaluation Rubric, Module Reflections, and semistructured interviews. The Preservice Teachers' Beliefs about Preparation with Digital Math Games for ELLs Survey was completed twice as Pre-Survey Items and Post-Survey Items. The Pre-Survey Items included collecting demographic information about participants. The Post-Survey Items were the Pre-Survey Items in a randomized order. The Digital Math Game Evaluation Rubric was completed twice as a Pre-Evaluation Rubric and a Post-Evaluation Rubric. The Evaluation Rubric was the same for both the pre-and post-evaluations.

I created the Preservice Teachers' Beliefs about Preparation with Digital Math Games for ELLs Survey, the Digital Math Game Evaluation Rubric, and Module Reflections to understand the three constructs used in this study to examine how preservice teachers develop awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for ELLs. Table 2 shows an overview of the open-ended and closed-ended items in the survey, evaluation rubric, and module reflections and how they align with preservice teachers' awareness and beliefs about design features and academic language features. Column 1 provides the construct that was measured. The second column explains the purpose of the construct. Columns 3-5 show open-ended and close-ended responses by listing the number of items from the data sources (see Appendix B, C, and D). The last column provides an example from the instrument to reference how the statement aligns with the construct.

The Preservice Teachers' Belief Survey was piloted with 22 preservice teachers who volunteered to provide feedback on how long it took to complete the survey and on the clarity of items. Volunteers completed the survey during a math methods course using Google Forms. This allowed me to revise the items based on the volunteer's feedback. The revisions included rewording to clarify some of the items and to delete redundant items because overall feedback suggested the time it took to complete the survey needed to be shorter. I also piloted the semistructured interview questions with two in-service elementary teachers who volunteered to provide feedback on the clarity of the questions. The teachers met with me using the online platform Zoom to provide feedback. I revised the wording of some of the questions for clarity based on the teachers' feedback.

Table 2*Alignment of Closed and Opened Items with Design Features, Academic Language Features, and Preservice Teachers' Beliefs*

Construct	Purpose	Items on survey	Items on evaluation rubric	Items on the module reflection	Example
Design features	To understand preservice teachers' awareness and beliefs about design features in digital math games	Part 1: Closed-ended responses 6, 7, 8, 10 Part 2: Open-ended responses 2	Part 1: Game Overview 1, 2	Module 2: 2, 3, 4, 5	I can identify whether the targeted mathematics concepts are displayed in digital math games (Hsu et al., 2013, 2017, 2020).
Academic language features	To understand preservice teachers' awareness and beliefs about academic language features in digital math games	Part 1: Closed-ended responses 11, 12 Part 2: Open-ended responses 3	Part 1: Game Overview 4	Module 3: 2, 3, 4, 5	I understand the language demands in mathematics that may impact learning for English language learners (Durgunoglu & Hughes, 2010).
Preservice teachers' beliefs Teaching with digital math games Teaching ELLs	To understand preservice teachers' beliefs about their preparation for using digital math games and teaching ELLs	Part 1: Closed-ended responses 1, 2, 3, 4, 5, 9 Part 2: Open-ended responses 1	Part 1: Game Overview 3		Using digital math games in mathematics lessons can improve students' understanding of mathematics (McGinnis et al., 2002).

Qualitative Data Sources

The qualitative data sources were three open-ended response items on the Preservice Teachers' Beliefs about Preparation with Digital Math Games for ELLs Survey (Part 2), four open-ended responses on the Digital Math Game Evaluation Rubric (Part 1), eight open-ended responses on the Module Reflections, and preservice teachers' responses to semistructured interview questions.

The open-ended response items on Preservice Teachers' Beliefs about Preparation with Digital Math Games for ELLs Survey (Part 2) captured insights that validated the close-ended items of the survey (Part 1) by providing details about preservice teachers' thoughts (Creswell & Plano Clark, 2017). This part of the survey was important because closed-ended responses (Part 1) only captured Likert scale ratings, while the open-ended responses (Part 2) provided more detail about preservice teachers' awareness and beliefs about design features and academic language features.

The open-ended response items on the Preservice Digital Math Game Evaluation Rubric (Part 1) provided insights to validate the close-ended items of the evaluation rubric (Parts 2 and 3) by providing details about preservice teachers' awareness and beliefs about design features and academic language features (Creswell & Plano Clark, 2017). The statements were chosen based on research about evaluating educational games. For example, Bedwell et al. (2012) used the statement "Choose the three gaming attributes most important to you" and listed gaming attributes (e.g., fantasy, mystery, challenge) where participants could choose three. This study adapted this wording for the statements, "What are three gaming features most important to you?" and "What

academic language features in digital math games are important to learning mathematics?” I then listed the features used in this study and asked participants to explain why their chosen features were important. This part of the evaluation rubric was important because closed-ended responses (Parts 2 and 3) only captured scale ratings, while the open-ended responses (Part 1) provided more detail about how preservice teachers evaluated the features in the digital math games.

After completing the lecture videos, the qualitative data sources on the Module Reflections (see Appendix D) provided insights into preservice teachers’ awareness and beliefs about design features and academic language features. These qualitative responses provided insights that validated the qualitative and quantitative results from the survey and the evaluation rubric (Creswell & Plano Clark, 2017). Therefore, reflections were appropriate to use to better understand how preservice teachers’ awareness and beliefs about design features and academic language features may have impacted how they chose and evaluated the digital math games for ELLs.

During the study, I conducted semistructured interviews with all preservice teacher participants ($N = 21$). I used an interview protocol (see Appendix E) to ask specific questions about preservice teachers’ awareness and beliefs about design features and academic language features and their beliefs about their preparation for using digital math games to support mathematics learning for ELLs. These questions were adapted from current research on preservice teachers’ preparation for using digital games and teaching ELLs in mathematics. For example, Aguirre and Zavala (2012) used the question, “What role do you think language (home and math); culture and

family/community play in learning and teaching mathematics?” in a survey in their study. This study adapted this wording as, “Have your views about the role of *academic language features* in digital math games changed since you initially chose and evaluated the digital math games? If so, how?” Semistructured interviews allowed me to probe for more explanations from participants (Creswell & Plano Clark, 2017). It also allowed me to ask the participants to explain their thinking about how they chose and evaluated the digital math games based on design features and academic language features to support ELLs’ mathematics understanding. I recorded the interviews on the digital platform Zoom which allowed me to watch the interviews multiple times to validate the findings (Saldaña, 2016). I also transcribed the interviews for analysis.

Quantitative Data Sources

The two quantitative data sources were the 12 closed-ended responses on the Preservice Teachers’ Beliefs about Preparation with Digital Math Games for ELLs Survey (Part 1) and the nine design feature ratings and nine academic language feature ratings on the Digital Math Game Evaluation Rubric (Parts 2 and 3). I created this survey based on the existing literature on digital math games and teacher beliefs about ELLs. For example, Hsu et al. (2013, 2017, 2020) used the statement, “I can identify whether the core concepts of the subject matter knowledge are displayed in the digital games” in their online surveys. I adapted this as, “I can identify whether the targeted mathematics concepts are displayed in digital math games.” The Preservice Teachers’ Beliefs about Preparation with Digital Math Games for ELLs Survey (Part 1) was a closed-ended survey that included items that had Likert scale ratings to examine preservice teachers’

beliefs about design features, academic language features, and preparation for using digital math games to support ELLs' mathematics understanding (see Appendix B). Preservice teachers used the Likert scale (1 strongly disagree to 6 strongly agree) to rate a variety of statements (e.g., "Using digital math games in mathematics lessons can improve students' understanding of mathematics"). Using an even number of scales was appropriate because participants were familiar with the subjects in the statements (South et al., 2022). The close-ended survey items were appropriate to address the research questions in this study to understand preservice teachers' views and opinions as an entire population (Creswell & Plano Clark, 2017; Terrell, 2015).

On the Digital Math Game Evaluation Rubric (Parts 2 and 3), participants used a scale (1-3 points) to evaluate digital math games for Design Features (Part 2) and Academic Language Features (Part 3) (see Appendix C). Rubrics have been used in multiple studies to evaluate educational games for learning and help researchers and teachers choose digital games to enhance learning (Capraro et al., 2015; Gavriushenko et al., 2015; Namukasa et al., 2016; Petri & Gresse von Wangenheim, 2016). The use of evaluation rubrics and a scoring scale for this study was intended to help preservice teachers increase their awareness of design features and academic language features by evaluating each feature in the digital math games.

I created the evaluation rubrics based on the literature for design features that identified specific features that supported learning (Avraamidou et al., 2012; Bedwell et al., 2012; Benton et al., 2018; Boyer-Thurgood, 2017; Castellar et al., 2015; De Bock et al., 2017; Denham, 2015; Falloon, 2013, 2014; Gee, 2007; Goldin, 2003; Hattie &

Timperley, 2007; Ke & Abras 2013; McGinnis et al. 2002; Moyer-Packenham, Lommatsch et al., 2019; Sedig, 2008; Siew, 2018; Watts et al., 2016; White & Pea, 2011). For example, numerous researchers have identified *multiple attempts* as an important feature in digital games because having more than one chance to engage with the content helps students better understand the content in the digital game (Benton et al., 2018; Gee, 2007; Moyer-Packenham, Lommatsch, et al., 2019). I also used current literature for the language demands in content areas to identify specific academic language features that related to comprehensible input in mathematics teaching materials (Adams, 2003; Bedwell et al., 2012; Ganesh & Middleton, 2006; Ke, 2013; Lucas & Villegas, 2010, 2013; Moschkovich, 2013; Moyer-Packenham, Litster, et al., 2019; Schleppegrell, 2007; WIDA, 2012). For example, *multiple meanings of words and phrases* was an important academic language feature identified by researchers that could impact how a student comprehends mathematics (Adams, 2003; Schleppegrell, 2007; WIDA, 2012). For instance, the word volume can mean noise level (everyday language) or the amount of space of an object (mathematics language; Adams, 2003).

Use of first language was identified in the rubrics as an academic language feature because it can be a resource ELLs use to help learn academic content (Lucas & Villegas, 2010, 2013; Lucas et al., 2008; Moschkovich, 2013). However, none of the digital math games in this study had the option to use a language other than English. This was still used on the evaluation rubric to help increase preservice teachers' awareness that digital math games could have a feature where ELLs could use their first language, which can be a resource for ELLs to learn mathematics content.

I created three different evaluation categories for each feature with, “1” being a low score, “2” being a limited rating, and a “3” being a high score. For example, for *multiple attempts*, I identified a “1” as “One attempt is provided for students to experiment with mathematical concepts”; a “2” as “Limited attempts are provided for students to experiment with mathematical concepts”; and a “3” as “Multiple or unlimited attempts are provided for students to experiment with mathematical concepts.” For the *amount of speech*, I identified a “1” as “The game uses a large amount of language (written or auditory) that students have to process in order to participate in the game;” a “2” as “The game uses a moderate amount of language (written or auditory) that students have to process in order to participate in the game;” and a “3” as “The game uses a low amount of language (written or auditory) that students have to process in order to participate in the game.” The relationship between design features and teacher language awareness is an important factor to use in selecting of digital math games to support ELLs’ mathematics understanding.

Procedures

This section explains the study procedures, including the selection of the digital math games, and the creation of the modules. The implementation procedures are explained by discussing participant recruitment; how participants completed the Preservice Teachers’ Beliefs Survey, the Evaluation Rubrics, and the Module Reflections; and how I conducted the semistructured interviews. Table 3 shows a summary of the data collection procedures.

Table 3*Summary of Data Collection Procedures*

Prior to data collection	Obtained IRB approval, created modules and chose 12 digital math games
Week 1	Recruitment of participants and sought consent
Week 2	Participants completed Module 1 Participants completed: <ul style="list-style-type: none"> • PRESERVIVE TEACHERS' BELIEF SURVEY (Pre-Survey Items) • EVALUATION RUBRIC (Pre-Evaluation Rubric)
Week 3	Participants completed Module 2 Participants completed: <ul style="list-style-type: none"> • MODULE 2 REFLECTION: DESIGN FEATURES
Week 4	Participants completed Module 3 Participants completed: <ul style="list-style-type: none"> • MODULE 3 REFLECTION: ACADEMIC LANGUAGE FEATURES
Week 5	Participants completed Module 4 Participants completed: <ul style="list-style-type: none"> • PREASERVIVE TEACHERS' BELIEFS SURVEY (Post-Survey Items) • EVALUATION RUBRIC (Post-Evaluation Rubric)
Week 6-7	Participants were interviewed


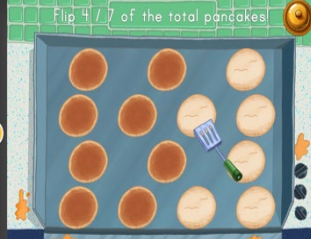
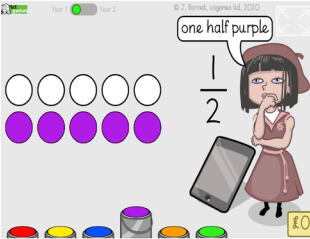



Selection of Digital Math Games

This study used a selection of 12 fraction games. The digital math games were chosen from online websites and digital game app stores (e.g., Apple App Store, Google Play Apps) and were free of charge. The keywords “fraction games,” “equivalent fraction games,” and “number line fraction games” were used to search for the games. I used this number of games to provide choices for the preservice teachers and to ensure that the number would be manageable for participants when they chose and evaluated three digital math games. One digital math game was not chosen by any of the preservice teachers. Table 4 shows the 11 digital math games preservice teachers used in this study, the fraction Common Core State Standard (Common Core State Standards, 2010)

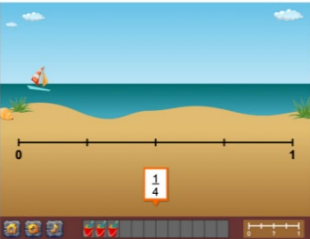
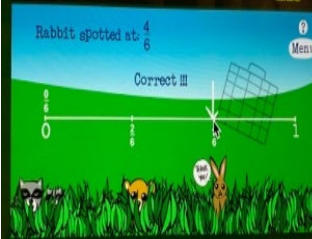
Table 4

Screenshots of Digital Math Games, Alignment to Common Core State Standards, and Design Features and Academic Language Features

CCSS.MATH.CONTENT.3.NF.A.1: Understand a fraction $1/b$ as the quantity formed by 1 part when a whole is partitioned into b equal parts; understand a fraction a/b as the quantity formed by a parts of size $1/b$.

<p>Fargo and Denny Part I</p> 	<p>Flipping Pancake Fractions</p> 	<p>Fraction Fresco</p> 
<p>DF: AF, MA, ML, LR ALF: SY, VS</p>	<p>MA, HT, LP AP, AS, SY</p>	<p>MA, LR SY, SS</p>
<p>Pizza Toppings/Representing Fractions Visually</p> 	<p>Smart Pirates Simple Fractions</p> 	<p>Seashell Fractions</p> 
<p>DF: AF, GE, LR ALF: AP, AS, SY, VS, RT, MM, SS</p>	<p>AF, HT, LP AP, AS, SY, SS</p>	<p>HT, MM, AP, AS, MM, SS</p>

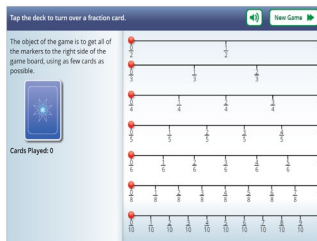
CCSS.MATH.CONTENT.3.NF.A.2.A: Represent a fraction $1/b$ on a number line diagram by defining the interval from 0 to 1 as the whole and partitioning it into b equal parts. Recognize that each part has size $1/b$ and that the endpoint of the part based at 0 locates the number $1/b$ on the number line.

<p>Beach Surprise</p> 	<p>Fraction Number Animal Rescue</p> 
<p>DF: AF, MM, LR ALF: AP, AS, SY, VS, SS</p>	<p>AF, HT, LP AP, AS, SY, RT, SD</p>

(table continues)

CCSS.MATH.CONTENT.3.NF.A.3.B: Recognize and generate simple equivalent fractions, e.g., $1/2 = 2/4$, $4/6 = 2/3$. Explain why the fractions are equivalent, e.g., by using a visual fraction model.

NCTM Fraction-Game



Triplets



DF: HT, GE, ML

HT, ML, LR

ALF: SY, RT

AS, VS

CCSS.MATH.CONTENT.3.NF.A.3.D: Compare two fractions with the same numerator or the same denominator by reasoning about their size. Recognize that comparisons are valid only when the two fractions refer to the same whole. Record the results of comparisons with the symbols $>$, $=$, or $<$, and justify the conclusions, e.g., by using a visual fraction model.

Galactic Space Fractions



DF: MM, HT, ML, LR

ALF: AP, SY, VS, SD

Note. DF= design features; ALF= academic language features; AF= accuracy feedback; MA= multiple attempts; HT= hints/tutorial; FC= focused constraint; PL= progressive levels; GE= game efficiency; ML= mathematics learning; LR= linked representations; LP= linked physical actions; AP= appropriate level of language; AS= amount of speech; SY= symbols; VS= visual support; RT=references require sentences to be translated into symbolic representation; SD= speech density of formal and informal language; MM= multiple meaning of words or phrases; SS= simple sentences; UL= use of first language.

alignment, and the design features and academic language features present in the digital math games.

The games aligned with third-grade Common Core State Standards for fractions (Common Core State Standards, 2010) to ensure that they matched the content that the preservice teachers used to teach mathematics in an elementary school setting. The digital math games were also interactive and chosen based on their inclusion of virtual

manipulatives, defined by Moyer-Packenham and Bolyard (2016) as

an interactive, technology-enabled visual representation of a dynamic mathematical object, including all of the programmable features that allow it to be manipulated, that presents opportunities for constructing mathematical knowledge. (p. 13)

This means that the games had to include interaction with mathematical objects in the game more than simply clicking or typing in an answer. For example, in the game “Smart Pirate Simple Fractions,” interaction with mathematical objects involved dragging fractional pieces and clicking correct fractions that represent the pieces left.

The digital math games were also chosen based on the design features, and academic language features present in the games. I evaluated each digital math game using the Evaluation Rubric. This study selected digital math games if multiple design features were present and if multiple academic language features supported the comprehensibility of the written or auditory language in the games. This would allow preservice teachers to interact with digital math games that had multiple features that could support mathematics learning for ELLs. For example, the game “Fargo and Denny Part 1” was chosen because it had the design features: accuracy feedback (AF), multiple attempts (MA), mathematics learning that focused on complex problem solving (ML), and linked representations (LR), as well as the academic language features symbols (SY) and visual support (VS) that helped make the mathematics language comprehensible for ELLs (see Table 4).

Recruitment and Consent

Recruitment of participants were from two elementary mathematics method

courses offered at a local university across multiple semesters (e.g., Spring 2021, Fall 2021, Spring 2022). The courses had about 20-50 students enrolled each semester. I explained the study to preservice teachers in each class in a video format. The video explained the purpose of the study, the procedures, and that participants would receive a compensation of a \$40 Amazon e-gift card to those that completed all data sources needed for this study. I then sent three follow-up emails to the students enrolled in the courses. Next, participants completed a consent form permitting data collection for research purposes. This form permitted survey and evaluation rubric responses, module reflections, and the recording of the semistructured interviews. Once I received consent, I added the participants to the Canvas page with the four learning modules.

Module Content and Data Collection

I created four learning modules with content about design features and academic language features in digital math games. These modules were based on the literature, aligned with the conceptual framework (see Figure 1) from Chapter II, and developed before recruitment of preservice teachers. The use of modules was appropriate because research has reported that mini-workshop experiences (e.g., e-learning experiences) (Sardone & Devlin-Scherer, 2009, 2010) that provide specific experiences with digital math games (Belbase, 2015; Handal et al., 2016; Li, 2013) and language demands for ELLs (Durgunoglu & Hughes, 2010; Kruz et al., 2017; McLeman & Fernandes, 2012) can improve preservice teachers abilities to choose and evaluate digital math games for ELLs. It is important to note that the modules and the evaluation rubrics did not distinguish among ELL students different WIDA proficiency levels because of the total

time preservice teachers had to interact with the learning module. Thus, the intention of the learning modules was to be an introduction to help preservice teachers increase their awareness of design features and academic language features.

The modules were delivered through Canvas, an online platform that allowed participants to access and turn in materials. Participants completed the modules in sequence and could not access a subsequent module until the module requirements that preceded it was complete. For example, participants had to complete Module 1 requirements before they could access Module 2. This ensured that all materials were completed appropriately (e.g., pre- survey completed before participants could access lecture videos). These modules included content and all the data collection tools the participants completed in the study (e.g., surveys and evaluation rubrics). All modules were completed within a four-week time period. Participants were given one week to complete each module to ensure that students had ample time to participate in the study in addition to their regular university coursework. Table 5 summarizes the content in each module.

Module 1 Procedures

During Module 1, participants virtually completed the Preservice Teachers' Beliefs Survey (Pre-Survey Items) and chose three digital math games based on a description of a fictional group of students in a third-grade mathematics classroom (e.g., "In your class, there are five English language learners. Two of your English language learning students are towards the end of Level 3 and can understand how ideas are connected through a few cohesive devices [e.g., pronouns], understand expanded noun

Table 5*Content of the Four Modules*

Modules	Content
1	<p>CONTENT: Choose and evaluate three digital math games</p> <ul style="list-style-type: none"> Participants chose three digital math games based on the needs of their fictional class description <p>DATA COLLECTION:</p> <ul style="list-style-type: none"> Participants completed PRESERVICE TEACHERS' BELIEFS SURVEY (Pre-Survey Items) Participants evaluated three digital math games with the EVALUATION RUBRIC (Pre-Evaluation Rubric)
2	<p>CONTENT: Lecture video on design features</p> <ul style="list-style-type: none"> Participants watched a lecture video that defined and provided examples of design features in digital math games Participants used the evaluation rubric as they watched the video and evaluated a digital math game in the video <p>DATA COLLECTION:</p> <ul style="list-style-type: none"> Participants completed MODULE 2 REFLECTION
3	<p>CONTENT: Lecture video on language awareness</p> <ul style="list-style-type: none"> Participants watched a lecture video that defined and provided examples of academic language features in digital math games Participants used the evaluation rubric as they watched the video and evaluated a digital math game in the video <p>DATA COLLECTION:</p> <ul style="list-style-type: none"> Participants completed MODULE 3 REFLECTION
4	<p>CONTENT: Beliefs about choosing and evaluating three digital math games</p> <ul style="list-style-type: none"> Participants reevaluated the three digital math games from Module 1 Participants emailed me to set up a semistructured interview <p>DATA COLLECTION:</p> <ul style="list-style-type: none"> Participants completed PRESERVCE TEACHERS' BELIEFS SURVEY (Post-Survey Items) Participants completed EVALUATION RUBRIC (Post-Evaluation Rubric)

groups with classifiers, and can relate simple sentences. Three of your English language learning students are towards the end of Level 4 and can understand multiple cohesive devices [e.g., synonyms, antonyms], understand prepositional phrases, and relate multiple simple sentences”). Participants evaluated the three digital math games they chose using the Evaluation Rubric (Pre-Evaluation Rubric). Preservice teachers chose the digital math games from a list of 12 digital math games that I provided as links on the Canvas page. Participants had one week to complete Module 1 on their personal computers. Module 1 took participants approximately 45-60 minutes to complete. An email was sent to participants once they were added to the Canvas page, and reminder emails were sent out weekly to remind participants when modules needed to be completed.

Module 2 Procedures

Participants accessed Module 2 once they completed Module 1. The Canvas page was designed for the modules to open after the previous module requirements were complete. Module 2 provided a video I created in lecture format (see Appendix F). To help preservice teachers increase their awareness of design features in digital math games, the modules included a definition for each design feature and provided examples of screenshots from digital math games that were not on the list of fraction games used in this study. For example, I defined *accuracy feedback* in the video as “Accuracy feedback is how the game provides feedback on accuracy or correct answers by providing a visual, auditory or numerical feedback.” This definition aligns with Moyer-Packenham, Lommatsch, et al. (2019), identifying accuracy feedback as the feedback on student accuracy by providing a visual (e.g., pictures), auditory (e.g., sounds), or numerical (e.g.,

accumulating coins) form of feedback. The video then provided an image of a digital math game not used in this study that showed the design feature. For example, the video showed a clip of the game *Chicken Coop Painter*, which was not a fraction game used in this study. In the video, I provided a guided experience where preservice teachers evaluated each design feature using the Evaluation Rubric. I provided a short pause in the video for preservice teachers to evaluate a design feature. Then I explained the evaluation score that I had given the feature on the rubric and why that feature was given that evaluation score. For example, accuracy feedback was given a “3” evaluation score in the *Chicken Coop Painter* demonstration because the game provided hatched or unhatched eggs for completed levels and showed check marks or Xs to show correct answers and an explanation of how to solve the fractions in the game. This type of task can help increase preservice teachers’ awareness of design features because it provides a meaningful experience (Sardone & Devlin-Scherer, 2009) that makes preservice teachers consider what makes a digital math game effective.

Participants completed the Module 2 Reflection based on the content of design features in the video, which was in a quiz format on Canvas. Reflections can help form or change beliefs about design features in digital math games (McLeman & Fernandes, 2012; Richardson, 1996), which is why it was appropriate to have preservice teachers write a reflection about design features shown in the video. Participants had one week to complete Module 2 on their personal computers. Module 2 took approximately 30 minutes to complete.

Module 3 Procedures

Participants accessed Module 3 once they completed Module 2. Module 3 provided a video in a lecture format (see Appendix F). The video defined and provided examples of academic language features in a digital math game. To help increase preservice teachers' awareness of academic language features, I defined each academic language feature based on the current literature. I provided examples of screenshots from digital math games that were not on the list of fraction games used in this study. For example, I defined *speech density* in the video as "Speech density examines the balance of the formal and informal language in the game. If there is too much formal language, students get lost in translating the meaning. If there is too much informal language students may be unable to relate it to the formal mathematics." This definition aligns with the findings reported by Ke (2013) and Ke and Abras (2013) that using formal and informal language relates to mathematics learning and that too much informal language can hinder students' mathematics understanding. I then provided an image of a digital math game not used in this study that showed the academic language feature. The video showed a clip of the game Chicken Coop Painter, which was not a fraction game used in this study. I provided a guided experience where preservice teachers evaluated each academic language feature using the Evaluation Rubric. I provided a short pause in the video for preservice teachers to evaluate an academic language feature and then explained the evaluation score that I had given on the rubric and why that feature was given that evaluation score. For example, speech density was given a "1" evaluation score in the Chicken Coop Painter demonstration because the game only used symbolic

representations without language support for students to understand how to multiply fractions to find the correct number of boxes to paint. This type of task can help increase preservice teachers' awareness of academic language features because it provides a meaningful experience (Sardone & Devlin-Scherer, 2009) that makes preservice teachers consider how language can impact the comprehensibility of digital math games.

Participants completed the Module 3 Reflection based on the content of academic language features in the video, which was in a quiz format on Canvas. This reflection could help form or change beliefs about academic language features in digital math games (McLeman & Fernandes, 2012; Richardson, 1996), which is why it was appropriate to have preservice teachers reflect on the academic language features discussed in the video. Participants had one week to complete Module 3 on their personal computers. Module 3 took approximately 30 minutes to complete.

Module 4 Procedures

Participants accessed Module 4 once they completed Module 3. During Module 4, participants virtually completed the Preservice Teachers' Beliefs Survey (Post-Survey Items) and reevaluated the three digital math games they chose in Module 1 using the Evaluation Rubric (Post-Evaluation Rubric). Module 4 instructed participants to email me to schedule a semistructured interview. Participants had one week to complete Module 4 on their personal computers. Module 4 took approximately 45-60 minutes to complete.

Semistructured Interviews

After the modules were completed, I conducted semistructured interviews with each participant. Preservice teachers answered interview questions to provide greater detail about their responses on the survey. The interviews were recorded on a digital platform (e.g., Zoom). Participants emailed me to set up a time to meet over the digital platform. The interviews lasted approximately 20 minutes.

Data Analysis

The data analysis for this study examined how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for English language learners (ELLs). I analyzed four data sources for this study: (1) Preservice Teachers' Beliefs about Preparation with Digital Math Games for ELLs Survey (Pre- and Post-Survey Items); (2) Digital Math Game Evaluation Rubric (Pre- and Post-Evaluation Rubrics); (3) Module Reflections; and (4) semistructured interview transcripts. Data analysis occurred in a multi-phase process that included descriptive coding, pattern coding, frequency tables, bar graphs of frequencies, a Wilcoxon signed ranked test, and a narrative comparison. Table 6 provides an overview of the research questions, data sources, and data analysis procedures. The sections below describe the analysis procedures for each phase.

The first step in data analysis was data preparation. Creswell and Plano Clark (2017) outline ways to prepare the data, which include assigning numeric values to each response, transcribing the data, and checking the data for accuracy. Therefore, I assigned

Table 6*Overview of Research Questions, Data Sources, and Data Analysis*

Research question	Data sources	Data analysis
1 What are preservice teachers' awareness and beliefs about design features when choosing and evaluating digital math games for ELLs, and what changes, if any, are exhibited after completing the learning modules?	Teachers' Beliefs Survey (Pre-and Post-Survey Items) ¹ Math Game Evaluation Rubric (Pre-and Post-Evaluation Rubric) ² Module Reflections ⁶ Semistructured interview transcripts ³	Descriptive and pattern coding ⁴ Frequency tables ⁵ Bar Graphs ⁸ Wilcoxon signed ranked test ⁵ Narrative Comparison ⁷
2 What are preservice teachers' awareness and beliefs about academic language features when choosing and evaluating digital math games for ELLs, and what changes, if any, are exhibited after completing the learning modules?	Teachers' Beliefs Survey (Pre-and Post-Survey Items) ¹ Math Game Evaluation Rubric (Pre-and Post-Evaluation Rubric) ² Module Reflections ⁶ Semistructured interview transcripts ³	Descriptive and pattern coding ⁴ Frequency tables ⁵ Bar Graphs ⁸ Wilcoxon signed ranked test ⁵ Narrative Comparison ⁷
3 What are preservice teachers' beliefs about their preparation with using digital math games to support mathematics learning for ELLs, and what changes, if any, are exhibited after completing the learning modules??	Teachers' Beliefs Survey (Pre- and Post-Survey Items) ¹ Semistructured interview transcripts ³	Descriptive and pattern coding ⁴ Frequency tables ⁵ Bar Graphs ⁸ Wilcoxon signed ranked test ⁵ Narrative Comparison ⁷

¹ Adapted from Bedwell et al., 2012; Durgunoglu & Hughes, 2010; Hsu et al., 2013, 2017, 2020; Lucas & Villegas, 2010, 2013; McGinnis et al. 2002; Reeves, 2006; Sardone & Devlin-Scherer, 2009, 2010; Shah & Foster, 2015.

² Adapted from Adams, 2003; Avraamidou et al., 2012; Boyer-Thurgood, 2017; Castellar et al., 2015; De Bock et al., 2017; Denham, 2015; Falloon, 2013, 2014; Hattie & Timperley, 2007; Ke, 2013; Ke & Abras 2013; Lucas et al., 2008, 2018; Lucas & Villegas, 2010, 2013; Moschkovich, 2013; Moyer-Packenham, Litster, et al., 2019; Moyer-Packenham, Lommatsch, et al., 2019; Schleppegrell, 2007; Sedig, 2008; Siew, 2018; White & Pea, 2011; WIDA, 2012.

³ Adapted from Aguirre & Zavala, 2012; Bedwell et al., 2012; Franklin, 2011; Gibson, 2002; Shah & Foster, 2015.

⁴ Saldaña, 2016; Tashakkori & Teddlie, 2010.

⁵ Boone & Boone, 2012.

⁶ Adapted from Aguirre & Zavala, 2012; Sardone & Devlin-Scherer, 2009.

⁷ Creswell & Plano Clark, 2017.

⁸ Cooksey, 2020; Robbins & Heiberger, 2011.

numbers to each participant, transcribed the semistructured interviews, and checked the data for accuracy. I then compiled participants' responses into files with assigned numeric values and deleted all identifiers. I used a transcription software (e.g., Otter.ai) to create documents of the narrative information from the semistructured interviews. Finally, I checked the data by looking for data entry errors and transcript accuracy.

Data Analysis Phases

This study had a four-phase process to answer the research questions. The first phase included descriptive and pattern coding (Saldaña, 2016; Tashakkori & Teddlie, 2010). This coding used the open responses on the Preservice Teachers' Beliefs about Preparation with Digital Math Games for ELLs Survey (Pre-and Post-Survey Items), the Digital Math Game Evaluation Rubric (Pre- and Post-Evaluation Rubric), Module Reflections, and semistructured interview responses. The second phase included computing frequencies of responses and creating bar graphs to visualize and summarize the frequency tables. The third phase involved computing a Wilcoxon signed ranked test to compare changes on the Preservice Teachers' Beliefs Survey (Pre- and Post-Survey Items) and changes on the Digital Math Game Evaluation Rubric (Pre- and Post-Evaluation Rubric). The fourth phase used a mixed methods comparison technique, called a narrative comparison, to determine how the data converged or diverged. The sections below describe this four-phase analysis process.

Phase I: Descriptive and Pattern Coding

The data analysis for the research questions used the same coding process. First, I

used descriptive coding for the open-ended responses on the Preservice Teachers' Beliefs about Preparation with Digital Math Games for ELLs Survey (Pre- and Post-Survey Items), the Digital Math Game Evaluation Rubric (Pre- and Post-Evaluation Rubric), Module Reflections, and semistructured interviews (Creswell & Plano Clark, 2017; Saldaña, 2016; Tashakkori & Teddlie, 2010). Saldaña (2016) defines descriptive coding as “summarizing in a word or short phrase—most often a noun—the basic topic of a passage of qualitative data” (p. 102). This type of coding helps identify subtopics that can be combined during a second coding phase to show themes that emerge from the qualitative data (Saldaña, 2016). These codes summarized initial topics that emerged from responses to identify preservice teachers' beliefs and awareness of design and academic language features in digital math games. Descriptive coding has been used in prior research about preservice teachers (Meletiou-Mavrotheris & Prodromou, 2016; Sardone & Devlin-Scherer, 2009, 2010) and applies to a wide variety of data forms (Saldaña, 2016). Therefore, it was appropriate to use in this study as the first coding phase to gain a basic understanding of the initial topics from the qualitative responses.

Next, I used pattern coding to identify common themes by grouping similar topics from the first phase of descriptive coding (Saldaña, 2016). These codes were more advanced than descriptive coding in identifying themes by providing a meaningful unit of analysis when grouping similar ideas (Saldaña, 2016). Pattern coding helped better understand the themes that emerged about preservice teachers' awareness and beliefs about design features and academic language features in digital math games. Pattern coding has been used in prior research about preservice teachers to better understand

themes that emerge from qualitative data (Li, 2013; Meletiou-Mavrotheris & Prodromou, 2016). Thus, pattern coding was appropriate to use in this study as a second phase of coding to identify the themes.

Phase II: Frequency Tables

The second part of the data analysis for the research questions included computing frequencies and creating bar graphs. I computed frequencies using the open-ended responses on the Preservice Teachers' Beliefs Survey (Pre- and Post-Survey Items) and the Digital Math Game Evaluation Rubric (Pre-and Post-Evaluation Rubric). To compute the frequencies from the qualitative pattern coding, I transformed the qualitative data by "quantitizing" the data to be presented in the frequency tables (Saldaña, 2016). I counted the frequencies of the common themes that emerged during pattern coding and reported these in a frequency table. I also computed frequencies using the close-ended responses from the Preservice Teachers' Beliefs Survey (Pre-and Post-Survey Items) and Digital Math Game Evaluation Rubric (Pre-and Post-Evaluation Rubric) and reported them in the frequency table. Frequency tables were appropriate for showing variability among ordinal data (Boone & Boone, 2012). The frequency tables allowed me to understand the qualitative and quantitative data as an overview of preservice teachers' awareness and beliefs of design features and academic language features.

Once I computed the frequencies, I used a stacked bar graph to summarize preservice teachers' Likert scale frequencies from the Preservice Teachers' Beliefs Survey (Pre- and Post-Survey Items) to show how they diverged from the "agree" portion of the Likert scale. Researchers have recommended a stacked bar graph to summarize

frequencies and show how frequency percentages relate to the “agree” or “disagree” portion of a Likert scale (Cooksey, 2020; Robbins & Heiberger, 2011; South et al., 2022). Similarly, a bar graph helped summarize preservice teachers’ composite ratings on the Evaluation rubric. Bar graphs are appropriate when summarizing frequencies to show relationships and important attributes of the data (Cooksey, 2020). I used the bar graph to show the relationship between changes in preservice teachers’ frequencies of ratings from pre- to post-evaluation rubrics.

Phase III: Wilcoxon Signed Ranked Test

To compare changes on the Preservice Teachers’ Beliefs Survey (Pre- and Post-Survey Items) and the Digital Math Game Evaluation Rubric (Pre- and Post-Evaluation Rubrics), I used a non-parametric test, a Wilcoxon signed ranked test, to compare medians of individual items on a Likert scale and composite ratings on the evaluation rubrics (Boone & Boone, 2012; Cooksey, 2020). The Likert scale items, and rubric evaluations used in this study were ordinal measurement scales because I transformed the qualitative data into frequency counts, which means that normal distribution cannot be assumed, making the Wilcoxon signed ranked test appropriate to analyze changes in pre- and post-survey responses (Boone & Boone, 2012; Clason & Dormody, 1994; Cooksey, 2020). By computing a Wilcoxon signed ranked test, I could see how preservice teachers’ awareness and beliefs about design features and academic language features changed after completing the modules.

Phase IV: Narrative Comparison

During the final analysis phase, I used a mixed methods comparison technique called a narrative comparison to merge the data sources for interpretation and answer the overarching research question. This process began with a presentation of the qualitative data examples followed by the quantitative data to discuss how the frequencies and changes in the pre- and post-versions of the survey and evaluation rubric related to the qualitative examples (Creswell & Plano Clark, 2017). The discussion was constructed by examining how data converged or diverged by observing the data analyses and writing memos of observations when examining the data. The observations of the data analyses helped validate and confirm the results.

Validity and Reliability

This section addresses the validity and reliability of this study. To ensure the mixed analysis was valid, I used multiple data sources (e.g., belief survey, evaluation rubric, module reflections, and semistructured interviews) to triangulate the evidence (Creswell & Plano Clark, 2017). Terrell (2015) explained the importance of ensuring the item validity of instrument questions (e.g., surveys) and stressed the need to consider item validity in research studies. To address this need, items and content in this study were based on the current literature that pertained to the purpose of this study and that aligned with the research questions. For example, survey items were adapted from Hsu et al. (2013, 2017, 2020) survey in multiple studies.

I piloted the survey items with a small group of preservice teachers who

volunteered to provide feedback on clarity and how long it took to complete the items. Survey items were revised based on this feedback to make items reliable. Using an interview protocol ensured that interviews were reliable because each participant was asked the same questions but allowed for flexibility in follow-up questions based on participant responses (Saldaña, 2016). The semistructured interview questions helped further understand the responses from the survey questions by asking participants to elaborate on their beliefs and if they changed from the beginning of the study (Terrell, 2015). I piloted the semistructured interview questions with two in-service teachers that volunteered to provide feedback on the clarity of questions. The semistructured interview questions were revised based on this feedback to ensure questions were reliable.

CHAPTER IV

RESULTS

The purpose of this study was to examine how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for ELLs. This study used qualitative and quantitative data sources to answer the research questions. The overarching research question in this study was: How do preservice teachers develop awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for English language learners (ELLs)? The main research questions of the study were as follows.

1. What are preservice teachers' awareness and beliefs about design features when choosing and evaluating digital math games for ELLs, and what changes, if any, are exhibited after completing the learning modules?
2. What are preservice teachers' awareness and beliefs about academic language features when choosing and evaluating digital math games for ELLs, and what changes, if any, are exhibited after completing the learning modules??
3. What are preservice teachers' beliefs about their preparation for using digital math games to support mathematics learning for ELLs, and what changes, if any, are exhibited after completing the learning modules?

This chapter presents the results from the mixed methods analyses. The research questions were answered by reporting frequencies of “quantitized” qualitative data from the Teachers' Belief Survey (Pre- and Post-Survey Items), Math Game Evaluation Rubric (Pre- and Post-Evaluation Rubric), and Module Reflections (Saldaña, 2016). The first section examines preservice teachers' awareness and beliefs about design features when choosing and evaluating digital math games for ELLs. The second section reports

preservice teachers' awareness and beliefs about academic language features in digital math games. The third section examines preservice teachers' beliefs about their preparation for using digital math games to support mathematics learning for ELLs. The chapter concludes with a summary of the results.

Preservice Teachers' Awareness and Beliefs about Design Features

This section reflects preservice teachers' awareness and beliefs about design features in digital math games and the changes exhibited after completing the learning module about design features. Results indicate that preservice teachers felt better prepared to integrate digital math games into mathematics instruction for ELLs because they had an increased awareness of the design features in the digital games after completing the learning modules.

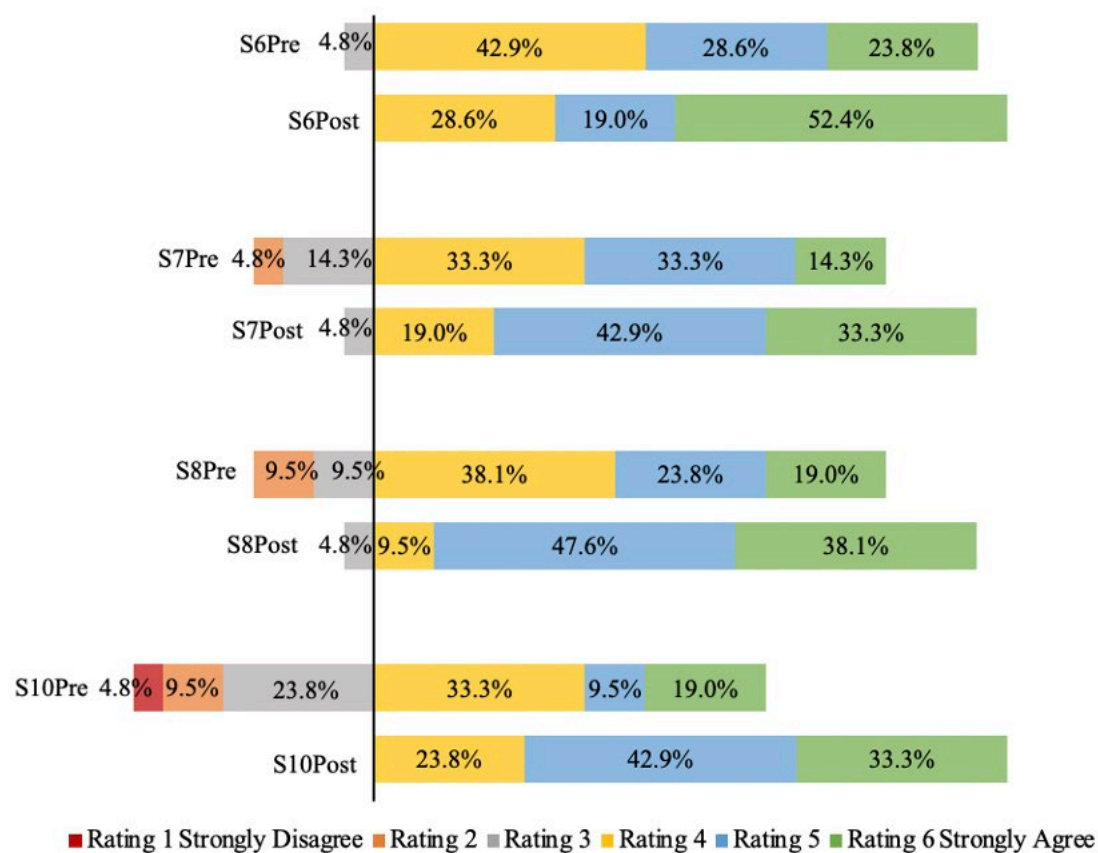
Design Features Reported on Survey Likert Items

Figure 3 shows frequencies of preservice teachers' beliefs about identifying mathematics content and design features in digital math games reported on the Teachers' Beliefs Pre- and Post-Survey Likert scale items. The black vertical line shows how preservice teachers' reported beliefs diverge from the "disagree" (i.e., rating of 1, 2, or 3) and "agree" (i.e., rating of 4, 5, or 6) portion of the Likert scale. The red (i.e., 1), orange (i.e., 2), and gray (i.e., 3) bars represent the "disagree" portion of the scale, and the yellow (i.e., 4), blue (i.e., 5), and green (i.e., 6) bars represent the "agree" portion of the Likert scale. For example, when preservice teachers rated the statement, "I can identify the knowledge related to mathematics in digital math games" (S6) on the pre-survey,

there were 5% of preservice teachers that rated this as a “3” (i.e., gray bar), while 43% rated it as a “4” (i.e., yellow bar), 29% rated it as a “5” (i.e., blue bar), and 24% rated it as a “6” (i.e., green bar). Similarly, 100% of preservice teachers agreed with this statement, as shown by the yellow (i.e., 4), blue (i.e., 5), and green (i.e., 6) bars on the right side of the black vertical line on the post-survey.

Figure 3

Frequencies of Likert Scale Items about Preparation for Identifying Mathematics Content and Design Features in Digital Math Games (N = 21)



Note. S6= I can identify the knowledge related to the mathematics in digital math games; S7= I can tell when the digital math games represent the targeted mathematics knowledge; S8= I can identify whether the targeted mathematics concepts are displayed in digital math games; S10= I can identify design features in digital math games that can support learning; Pre= pre-survey frequency percentages; post= post-survey frequency percentages.

Figure 3 indicates that preservice teachers showed a shift in frequencies that favored the “agree” portion for all four statements about “preparation for identifying math content” from pre-survey (62%-95%) to post-survey (95%-100%). This indicates that preservice teachers felt better prepared to identify mathematics content and design features in digital math games after completing the learning modules. For example, when preservice teachers rated, “I can tell when the digital math games represent the targeted mathematics knowledge” (S7) and “I can identify whether the targeted mathematics concepts are displayed in digital math games” (S8), there was an increase of frequency toward the “agree” portion of the Likert scale from pre-survey (80%-81%) to post-survey (95%). Additionally, preservice teachers reported the biggest shift in frequency towards the “agree” portion of the Likert scale when they rated the statement “I can identify design features in digital math games that can support learning” (S10), from pre-survey (62%) to post-survey (100%). These survey items (i.e., 6, 7, 8, and 10) focus on preservice teachers’ preparation for identifying the math content in the digital games.

Important Design Features Reported by Preservice Teachers

Table 7 shows the frequencies of themes reported by preservice teachers about the important design features in digital math games (from the Teachers’ Beliefs Pre- and Post-Survey). Progressive levels, accuracy feedback, and multiple attempts were identified as the most important design features on both the pre- and post-survey. This suggests preservice teachers were most aware of these three design features in the digital math games.

Table 7

Frequencies of Themes about Most Important Design Features on Survey (N = 21)

Design features	Frequency			
	Pre-response		Post-response	
	<i>n</i>	%	<i>n</i>	%
Progressive levels	17	81.0	12	57.1
Accuracy Feedback	15	71.4	14	66.7
Multiple attempts	15	71.4	14	66.7
Hints/Tutorials	7	33.3	8	38.1
Linked physical action	4	19.0	2	9.5
Game efficiency	2	9.5	6	28.6
Linked representation	2	9.5	8	38.1
Focused Constraint	1	4.8	4	19.0

As Table 7 indicates, more than half of preservice teachers described progressive levels as important on the Teachers' Beliefs Pre-Survey (81%) and Post-Survey (57%). For example, one preservice teacher wrote, "Progressive levels can push students to what they are capable of or what they have the potential of learning. Students will have a feeling of accomplishment and satisfaction if they can move up levels. They are used to a progression in levels in the computer and video games they are used to." Another preservice teacher explained, "Progressive Levels so that it can get harder and introduce more complex ideas." Similarly, a preservice teacher wrote, "Progressive levels so they can be challenged at the appropriate level." This shows that preservice teachers were aware of progressive levels promoting mathematics learning by providing levels that challenge players as they master a concept.

Similarly, high percentages of preservice teachers chose accuracy feedback and

multiple attempts as important on the pre-survey (71%) and post-survey (67%). For example, one preservice teacher described accuracy feedback as important: “Kids learn from their mistakes, and if they get feedback on their mistakes, then they can learn from it.” Another preservice teacher stated: “Accuracy feedback is important because students won't learn if they don't know if they are correctly solving problems. They need to know what to change and fix to improve.” Multiple attempts were described as important when one preservice teacher wrote, “Multiple attempts is important because students will get really frustrated if they get it wrong and don't get another chance. Also, more chances will give students longer time to learn how to solve the problem correctly. I don't think it's about when a student answers correctly but if they are able to.” Another preservice teacher wrote, “I don't think learning is just a one-time trial, and I think the game should give them multiple attempts to try again.” This shows that preservice teachers were aware of accuracy feedback and multiple attempts as important design features supporting their perspective on how students learn mathematics.

Preservice teachers reported the lowest frequency of awareness for focused constraint (5%), game efficiency (10%), and linked representations (10%) on the Teacher Belief Pre-Survey. However, there was an increase in the percentage of preservice teachers that reported these design features as important from pre-survey (5%-10%) to post-survey (19%-38%). For example, there was an increase in the percentage of preservice teachers from pre-survey (5%) to post-survey (19%) for focused constraint. Preservice teachers' statements showed more awareness on the post-survey by specifically explaining how focused constraint allows students to focus on one area of

mathematics instead of being described on the pre-survey as helping the game stay on topic (e.g., “I think it’s important for the lesson to stay on topic”). For example, one preservice teacher wrote on the post-survey, “I believe that focused constraint makes it, so students are able to have more practice working with certain ideas, being able to feel more comfortable with them, rather than trying to deal with too much at once.”

Preservice teachers reported increased awareness of game efficiency from pre-survey (10%) to post-survey (29%). For example, preservice teachers’ explanations lacked awareness on the pre-survey because they focused on wasting class time (e.g., “I don’t want students wasting precious classroom time on a game that is not supporting our learning goals”). The explanations about game efficiency showed a lack of awareness of what this feature entails in a digital math game because game efficiency is how features promote efficiency in completing the game task, not the efficiency of class time (Moyer-Packenham, Lommatsch, et al., 2019). For example, in the game *Pizza Toppings Representing Fractions Visually*, players can drag the toppings to cover the pieces, or click on the slices, and the toppings are placed for them. This game feature makes the player more efficient because they can quickly place toppings on the slices to represent a fraction of the pizza. However, preservice teachers’ explanations on the post-survey showed more awareness of game efficiency because they focused on the game helping students be efficient in the task and focus on the mathematics instead of effective use of class time. For example, one preservice teacher wrote, “Game efficiency is important because if students have to spend more time on the menial aspects of the game as opposed to the actual mathematics themselves, that will take away from learning.

Students should be able to conveniently demonstrate their understanding of the concept.”

Another preservice teacher wrote, “I believe that game efficiency is important because when a game is efficient, students are less focused on trying to figure out how the game works and spend more time learning from the game.”

Preservice teachers reported the biggest increase in frequency for linked representation from pre-survey (10%) to post-survey (38%). For example, preservice teachers’ statements on the pre-survey indicated a lack of awareness (e.g., “This is important because we want students to be able to understand what is happening by creating models and representations they can model and play with.”). However, preservice teachers showed an increase in awareness on the post-survey when they wrote, “We want everything in the math game to link to mathematical concepts that we are targeting. We want the games to be creating multiple forms of representations and understanding for our students,” and “Being able to link different representations of mathematical concepts, such as words, symbols, and visual models or objects helps students develop a deeper understanding of math concepts.” The increase in reported frequencies and the awareness in the statements suggest that when preservice teachers defined linked representation in the learning module and evaluated this feature in digital math games, they had an increase in their awareness of when this design feature was present and supported mathematics learning in digital math games.

Preservice teachers reported low frequency for linked physical action on the Teacher Belief Pre-Survey (19%) and Post-Survey (10%). However, the statements describing this feature on the post-survey showed more awareness than the pre-survey

(e.g., “I also think that physical action is important so that students get up a MOVE!”) because they focused on how the physical action in the game related to the mathematics. For example, one preservice teacher wrote on the post-survey, “Linked Physical action - this allows students to physically interact with a content, further helping to solidify the learning.” Another preservice teacher wrote, “Link physical action: inviting the students to physically move objects or see visual changes is a great way for students to understand the math they are completing.” Preservice teachers’ increased awareness could explain the decrease in frequency from pre-survey (19%) to post-survey (10%) because this awareness could have led them to believe that other design features in digital math games were more important than linked physical action.

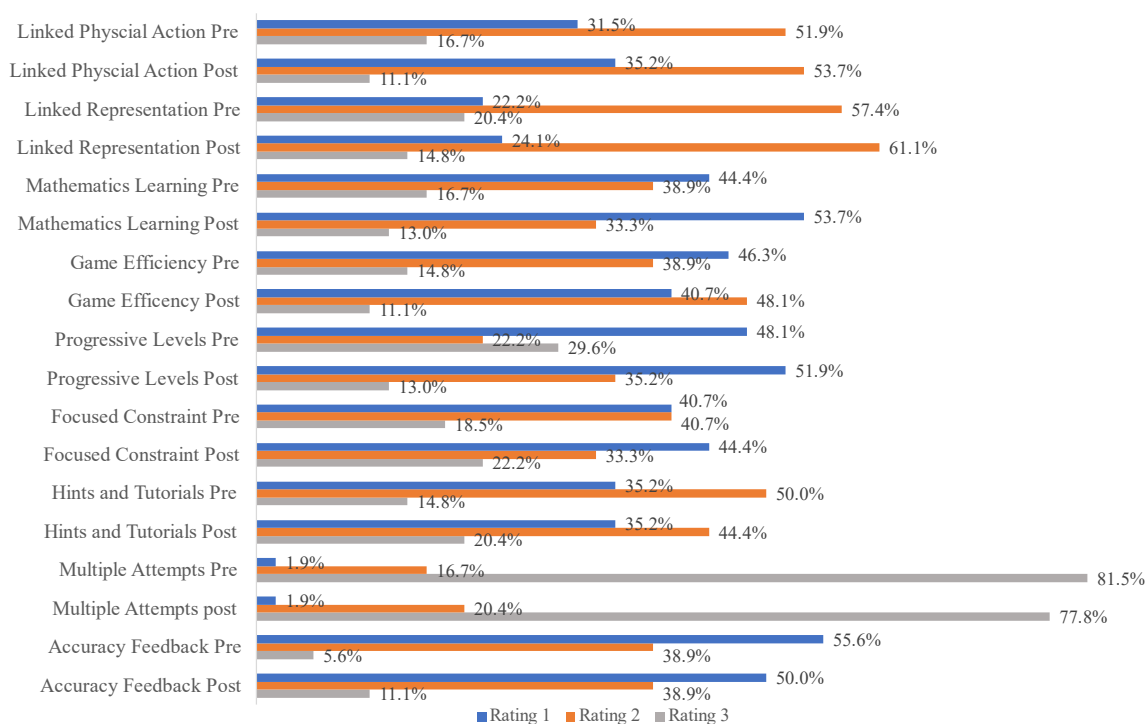
Design Features Reported on the Math Game Evaluation Rubric

Figure 4 shows the frequencies of preservice teachers’ composite ratings from the closed responses on the Math Game Evaluation Rubric Pre- and Post-Evaluation items about design features. Preservice teachers rated each design feature as they played a digital math game. The evaluation rubric had a scale of 1-3, where “1” was a low rating (i.e., design feature was not in the game or it did not support learning) and “3” was a high rating (i.e., design feature was present and supported learning). The bars in the figure represent the ratings “1” (i.e., blue bar), “2” (i.e., orange bar), and “3” (i.e., gray bar) and are show the evaluations for the pre- and post-evaluation rubrics (i.e., Linked Physical Action pre, Linked Physical Action post). For example, for accuracy feedback, 56% of preservice teachers rated this as a “1” (i.e., blue bar) on the pre-evaluation, and 50% rated

this as a “1” on the post-evaluation. Thirty-nine percent of preservice teachers rated accuracy feedback as a “2” (i.e., orange bar) for both the pre- and post-evaluation. The gray bar shows the ratings of a “3” on the pre-evaluation (6%) and post-evaluation (11%) for accuracy feedback.

Figure 4

Composite Math Game Evaluation Rubric Ratings for Design Features (N = 18)



Note. Percentages reflect the composite scores of design feature ratings on evaluation rubrics across all digital math games; 1= low rating; 2= limited rating; 3= high rating; Pre= pre-evaluation scores; Post= post-evaluation scores.

The highest-rated design feature by preservice teachers was multiple attempts, with a high rating (i.e., 3) indicating the design feature was present and supported learning across all digital math games on the pre- and post-evaluation rubrics. This was

the only design feature with a high percentage of preservice teachers (78%-82%) with a “3” rating, suggesting that preservice teachers were most aware of multiple attempts while evaluating the digital math games. This shows that preservice teachers could identify when a digital math game provided multiple attempts to the player.

Preservice teachers rated hints and tutorials, linked representation, and linked physical action as a limited rating across all digital math games in this study, with 44%-61% of preservice teachers rating these as a “2” on the pre-and post-evaluation rubric. This suggests that preservice teachers were aware of these design features because they could identify their presence in the digital math games.

Preservice teachers rated most design features lower than a “3” rating on the rubric across all digital math games on the pre- and post-evaluation. For example, preservice teachers rated accuracy feedback, progressive levels, and math learning low across all digital math games. Each of these design features had higher frequency (44%-56%) ratings as a “1” on the pre-and post-evaluation rubrics. This suggests that preservice teachers were aware that these design features were not present in the digital math games. This is also supported by high percentages of preservice teachers’ awareness of accuracy feedback and progressive levels when reported as important design features (see Table 7).

Preservice teachers’ frequencies for the ratings of focused constraint and game efficiency had changes in ratings from pre- and post-evaluation. For example, 40% of preservice teachers rated focused constraint as limited (i.e., either a “1” or a “2”) on the pre-evaluation rubric. However, on the post-evaluation rubric, this design feature was

rated by more preservice teachers as a “1” (44%). This was the only design feature with an overall shift to a “1” rating. This suggests that preservice teachers increased their awareness of this design feature from pre- to post-evaluation rubric because they may have been able to better identify when this design feature was not present in the digital math games after completing the learning module about design features.

Forty-six percent of preservice teachers rated game efficiency as a “1” on the pre-evaluation rubric. However, 48% rated game efficiency as a “2” on the post-evaluation rubric. This was the only design feature to have an overall shift from a “1” rating to a “2.” This shift may indicate that preservice teachers became more aware of game efficiency after completing the learning modules because they could better identify when a digital math game had features that helped make the game more efficient.

Design Feature Themes Reported by Preservice Teachers on Game Evaluation Rubric

Table 8 shows the frequencies of preservice teachers’ themes about the objectives, academic content, and skills in digital math games (from the Math Game Evaluation Rubric). Themes emerged from the statements preservice teachers used to identify the fraction content and objectives in the digital math games. Overall, frequencies show that preservice teachers were aware of fraction content and skills in the digital math games because each participant could identify the fraction content and skills in the games.

As Table 8 shows, when preservice teachers were asked, “What is the objective of the game?” three main themes emerged (based on the Math Game Evaluation Rubric): (1) Game objective with general fraction terms (e.g., represent a fraction, make fractions);

Table 8

Frequencies of Themes about Objective and Academic Content in Digital Math Games on Evaluation Rubrics (N = 18)

Themes	Frequency											
	Game 1				Game 2				Game 3			
	Pre		Post		Pre		Post		Pre		Post	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Objective unrelated	5	27.8	2	11.1	4	22.2	3	16.7	4	22.2	3	16.7
Objective general fraction	7	38.9	10	55.6	8	44.4	8	44.4	7	38.9	11	61.1
Objective specific fraction	6	33.3	6	33.3	6	33.3	7	28.9	7	28.9	4	22.2
General Fraction knowledge	9	50.0	6	33.3	8	44.4	6	33.3	8	44.4	5	27.8
Represent fractions	7	38.9	7	38.9	5	27.8	6	33.3	4	22.2	5	27.8
Fraction Relationships	2	11.1	5	27.8	5	27.8	6	33.3	6	33.3	8	44.4

Note. N reflects the number of participants who completed the pre-evaluation rubric and post-evaluation rubric for the same digital math games.

(2) game objective with specific fraction terms (e.g., equivalent fractions, represent a fraction, part-whole relationships); and (3) game objective with no mathematics terms or mathematics terms other than fractions. Results showed an increase in preservice teachers' use of general fraction terms from pre- (39%- 44%) to post-evaluation (44%- 61%). For example, one preservice teacher used general fraction terms when they wrote, "Represent fractions." Another preservice teacher wrote, "Cover a fraction (Fraction would be given) of the pizza with toppings." This shows that preservice teachers could identify general fraction objectives (e.g., represent fractions, make fractions) in the digital math games. This also aligns with the preservice teachers' Likert scale ratings in Figure 3, where high percentages of preservice teachers "agreed" with the statements about identifying mathematics in digital math games.

Preservice teachers used specific fraction terms to describe the objective on the pre-evaluation (33%-39%) and post-evaluation (22%-39%). For example, one preservice teacher used specific fraction terms to describe the objective as “The objective is to visually show fractions and match the fraction with the picture. Then you order them from least to greatest and help the rocket fly.” Another preservice teacher described the objective with specific fraction terms when they wrote, “The students will understand fractions as they flip the correct equivalent number of pancakes shown in fraction form on the order.” Thus, the preservice teachers in this study may have had limited awareness of specific fraction objectives (e.g., equivalent fractions, ordering fractions) in the digital math games because less than half of them identified specific fraction objectives when evaluating the digital math games.

There was a decrease in the percentage of preservice teachers that used no mathematics terms or mathematics other than fractions when identifying the mathematics objective in digital math games from the pre-evaluation (22%- 28%) to post-evaluation (11%-17%; e.g., “To help the animals along the journey”). This indicates that preservice teachers became more aware of the mathematics objectives, specifically the general fraction objectives (e.g., represent a fraction, make fractions), in the digital math games after completing the learning modules.

When preservice teachers were asked, “What academic content and skills are in the digital math games?” three main themes emerged: (1) general fraction knowledge (e.g., visualizing fractions and parts of a whole); (2) representing fractions; and (3) relationships among fractions. Evidence of general fraction knowledge decreased in

frequency in the writings of preservice teachers from pre-evaluation (44%-50%) to post-evaluation (28%-33%). For example, one preservice teacher wrote: “Players will learn to differentiate between objects that are divided into equal parts and objects that have not been. They will learn to count the number of pieces of equivalent parts to determine how many parts make up a whole.” This suggests that preservice teachers wrote fewer general statements and became more aware of specific content and skills in digital math games.

Preservice teachers used specific fraction knowledge when they described the content and skills as representing fractions (e.g., “learning how to create a fraction”) and relationships among fractions (e.g., “understanding the relationship between a model of a fraction and the written form of a fraction). There was a slight increase in the percentage of preservice teachers that used terminology for representing fractions from the pre-evaluation (22%-39%) to post-evaluation (28%-39%). For example, one preservice teacher wrote: “The dots are a visual representation of equal parts of the fraction. The student learns to match the chips or dots to the appropriate fraction.”

Preservice teachers’ comments for identifying relationships among fractions showed the biggest increase in frequency from pre-evaluation (11%-33%) to post-evaluation (28%-44%). For example, one preservice teacher wrote, “This game promotes deep thinking about the relationship of fractions and how they compare in size to other fractions” Similarly, another preservice teacher wrote, “You can learn least from greatest and how fractions compare to one another with the same denominator.” The frequency changes for representing fractions and recognizing relationships among fractions suggest that preservice teachers became more skilled at using specific terminology to describe the

mathematics content because there were increases in those frequencies (e.g., equivalent fractions, comparing fractions, simplifying fractions).

Design Feature Themes Reported on Module 2 Reflections

Table 9 shows the frequencies of themes reported by preservice teachers from the Module 2 Reflection that preservice teachers completed after watching a video about design features. Overall, the themes indicated that preservice teachers believe design features can promote mathematics learning in digital math games. For example, when asked to define design features, 62% of preservice teachers specifically stated that design features could promote learning (e.g., “Different aspects of the game such as pushing buttons or and the things displayed on the screen to play the game, and how the game can help students to learn”).

When asked, “What role do you think design features play in helping ELLs learn mathematics in digital math games,” most preservice teachers (86%) indicated that design features impact mathematics learning. For example, one preservice teacher wrote, “I think all 9 of the features can play a helpful role in making the games more accessible to students who are English Language Learners.” Another preservice teacher wrote, “I think that the design features of games are key to ELLs having a positive learning experience versus a confusing, frustrating one.”

When asked, “How do you think design features helped promote mathematics learning in the digital math game shown in the video,” 81% of preservice teachers indicated that design features were helpful to learning fractions in the game. For example,

Table 9

Frequencies of Themes about Design Features in Digital Math Games on Module 2 Reflection (N = 21)

Theme	Frequency	
	<i>n</i>	%
How would you define design features?		
Aspects, attributes, characteristics, elements	15	71.4
Promote learning	13	61.9
How the game runs	12	57.1
How do you think design features helped promote mathematics learning in the digital math game shown in the video?		
Design features helped learn fractions	17	81.0
Hints/tutorials	13	61.9
Accuracy feedback	7	33.3
Game efficiency	6	28.6
Progressive levels	5	23.8
Multiple attempts	3	14.3
Liked physical action	2	9.5
Mathematics learning	1	4.8
Linked representation	1	4.8
Focused constraint	1	4.8
What was your impression of the design features in the digital math game shown in the video?		
Positive	17	81.0
Negative	4	19.0
What role do you think design features play in helping ELLs learn mathematics in digital math games?		
Impact on learning	18	85.7
Multiple attempts	4	19.0
Hints/tutorials	4	19.0
Game efficiency	3	14.3
Accuracy feedback	2	9.5
Progressive levels	1	4.8
Mathematics learning	1	4.8
Linked representation	1	4.8
No impact	1	4.8
Liked physical action	0	0.0
Focused constraint	0	0.0

Note. Bolded numbers represent percentages 50% or above.

one preservice teacher wrote,

Overall, the design features were very helpful in providing math learning and interaction in this game. Most of the design features scored highly, indicating that more needs are being met.

Another preservice teacher wrote,

I think that when they are all used together to assist the child in learning, the child gains the most out of the game at that point. I feel like they all promote different areas of mathematical concepts that are needed in our mathematical learning progression.

This shows that preservice teachers were aware that design features could impact mathematics learning in digital math games.

Preservice teachers described specific design features that they believed to promote learning on the Module 2 Reflection. For example, one preservice teacher wrote,

The multiple attempts feature would help them to keep trying (especially if they are still trying to figure it out) and not get as frustrated like they might if it just moved on.

Another preservice teacher wrote,

The player is provided with a tutorial before they start the game, which automatically helps the player understand the rules and procedures for the game. The student can then focus on learning the math objective regarding unit fractions. Also, there are helpful hints in the game that can redirect the player during the rounds.

This shows that preservice teachers could describe specific ways that the design features in the game promoted mathematics learning.

When asked, “What was your impression of the design features in the digital math game shown in the video,” 81% of preservice teachers reported positive impressions of design features. For example, one preservice teacher wrote,

I liked the visual representation of paint buckets for fractions. It was visually

appealing to look at with the different colors. It was also really user-friendly to use based off of what the video showed.

Another preservice teacher wrote,

I thought the math game did a good job of providing many of the design features to make it a good learning experience for students.

Similarly, one preservice teacher wrote,

Overall, the design features were effective in providing a stimulating mathematical learning experience.

This suggests that preservice teachers viewed the design features positively and perceived that they enhanced the experience and effectiveness of the digital games.

Wilcoxon Signed-Rank Test and Preservice Teachers' Self-Reported Changes in Awareness of Design Features During Semistructured Interviews

The Wilcoxon Signed-Rank test indicated that post-survey ranks were statistically higher than pre-survey ranks for all Likert scale items about mathematics content and design features in digital math games: I can identify the knowledge related to the mathematics in digital math games ($Z = -1.964, p = .050$); I can tell when the digital math games represent the targeted mathematics knowledge ($Z = -2.559, p = .010$); I can identify whether the targeted mathematics concepts are displayed in digital math games ($Z = -3.038, p = .002$); I can identify design features in digital math games that can support learning ($Z = -2.854, p = .004$). This shows that preservice teachers felt better prepared to identify the mathematics content and design features in a digital math game, which could be explained by the modules about design features that preservice teachers completed in this study. These significant changes align with the themes from the

preservice teacher interviews (see Table 10). For instance, 71% of preservice teachers indicated that their ideas of the role of design features in digital math games changed from the beginning of this study. One preservice teacher said,

Because I don't know if I really knew too much about the design features or like, what would like help students like influence, like how they would learn better.

Similarly, another preservice teacher said,

Because I understand, like, what the features are that I was looking at, because when I started, I was just playing a math game to like, play the math game. And then, um, but now I like to see like, oh, like, this concept here, like, that is gonna help the students.

Another preservice teacher said,

I think there's knowing what to look for, like, now I know those design features that help you to be more successful, and so you can so I don't know, I just think I know what to look for. And they're very helpful now. So, my views have changed positively. I know what design features to look at in games.

Table 10

Design Feature Themes Reported by Preservice Teachers During Semistructured Interviews (N = 21)

Theme	Frequency	
	<i>n</i>	%
Changes in important design features		
Changed	9	42.9
Did not change	7	33.3
Unsure	5	23.8
Changes in the role of design features		
Changed	15	71.4
Little or no change	6	28.6

In contrast, the Wilcoxon Signed-Rank test indicated there were no significant changes in post-rubric ranks compared to pre-rubric ranks for any of the design features:

Accuracy feedback ($Z = -1.177, p = .239$); multiple attempts ($Z = -.462, p = .644$); hints/tutorials ($Z = -.626, p = .532$); focused constraint ($Z = -.013, p = .990$); progressive levels ($Z = -2.524, p = .012$); game efficiency ($Z = -.150, p = .881$); mathematics learning ($Z = -1.152, p = .249$); linked representation ($Z = -.758, p = .433$); linked physical action ($Z = -.842, p = .400$). Although there were no significant changes, 43% of preservice teachers indicated that the design features they found important at the beginning of this study changed by the end. For example, one preservice teacher said, “I think they changed for sure because I didn't understand some of the design features at first. I like just used context clues and guessed. But I think the fact that now knowing what each of them meant and seeing them in an example helped change my idea of what was most important in a video game. So yeah, I think they definitely did change.” Similarly, another preservice teacher said, “I think I just learned so much more about each feature, and different things became important looking at it through the eyes of an ELL student.” Preservice teachers reported that they became more aware of the role of design features in digital math games.

Preservice Teachers' Awareness and Beliefs About Academic Language Features

This section reflects preservice teachers' awareness and beliefs about academic language features in digital math games and describes the changes after completing the learning module about academic language features. Results indicate that preservice teachers felt better prepared to integrate digital math games into mathematics instruction

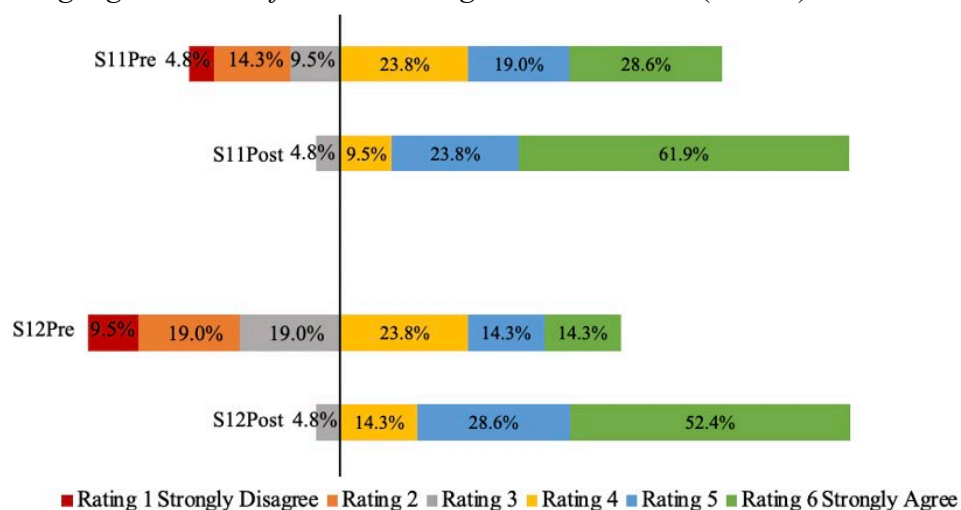
for ELLs because they had an increased awareness of academic language features such as the amount of speech, multiple meanings of words and phrases, and speech density.

Academic Language Features Reported on Survey Likert Items

Figure 5 shows the frequencies of preservice teachers' responses to beliefs about identifying language demands in digital math games reported on the Teachers' Beliefs Pre- and Post-Survey. The black vertical line shows how preservice teachers' reported beliefs diverge from the "disagree" (i.e., rating of 1, 2, or 3) and "agree" (i.e., rating of 4, 5, or 6) portion of the Likert scale. The red (i.e., 1), orange (i.e., 2), and gray (i.e., 3) bars represent the "disagree" portion of the scale, and the yellow (i.e., 4), blue (i.e., 5), and green (i.e., 6) bars represent the "agree" portion of the Likert scale. For example, when

Figure 5

Frequencies of Likert Scale Items About Preparation for Identifying Language Demands for ELLs in Digital Math Games (N = 21)



Note. S11= I understand the language demands in mathematics that may impact learning for English language learners; S12= I can identify language demands in digital math games that may impact learning for English language learners. Pre= pre-survey frequency percentages; post= post-survey frequency percentages.

preservice teachers rated the statement, “I understand the language demands in mathematics that may impact learning for English language learners” (S11) on the pre-survey, 5% of preservice teachers rated this as a “1” (i.e., red bar), 14% rated this as a “2” (i.e., orange bar) and 10% rated this as a “3” (i.e., gray bar). This shows that 29% of preservice teachers favored the “disagree” portion of the scale (i.e., the left side of the black vertical line). However, frequencies of responses show 95% of preservice teachers shifted their ratings toward the “agree” portion on the post-survey, as shown by the yellow, blue, and green bars on the right side of the black vertical line.

Preservice teachers showed a shift in responses toward the “agree” portion from pre-survey (52%-71%) to post-survey (95%-100%) for both statements. More than half (52%-62%) of preservice teachers rated these statements as “strongly agree” (i.e., Rating 6) on the post-survey. This indicates that learning more about language features in digital math games may have shifted preservice teachers’ feelings about preparation to identify language demands.

Important Academic Language Features Reported by Preservice Teachers

Table 11 shows the frequencies of themes reported by preservice teachers about important academic language features in digital math games on the Teachers’ Beliefs Pre- and Post-Survey. When asked, “What academic language features in digital math games are important to learning mathematics?” preservice teachers showed an increase in percentage for five academic language features (speech density, multiple meaning of words and phrases, amount of speech, symbols, and use of first language), from the pre-

survey to post-survey. Additionally, 50% or more of preservice teachers identified each academic language feature as important in digital math games. This suggests that preservice teachers became more aware of academic language features in digital math games after completing the learning modules.

Table 11

Frequencies of Themes about Most Important Academic Language Features (N = 21)

	Frequency			
	Pre-response		Post-response	
Academic language features	<i>n</i>	%	<i>n</i>	%
Visual support	17	81.0	15	71.4
Appropriate level	14	66.7	14	66.7
Simple sentences	13	61.9	13	61.9
Use of first language	8	38.1	14	66.7
Symbols	6	28.6	15	71.4
Multiple meanings of words/phrases	4	19.0	12	57.1
Amount of speech	3	14.3	13	61.9
Speech density	2	9.5	12	57.1

Preservice teachers reported similar frequencies of responses for visual support, appropriate level, and simple sentences as important features to learning mathematics in digital math games on the pre-survey (61-81%) and post-survey (61%-71%). For example, preservice teachers reported visual support as important on the pre-survey (81%) and post-survey (71%). One preservice teacher wrote, “I believe that visual support is important because it can help students to understand the problem on their own and not feel like they always have to rely on someone else to help them.” Visual support was also as described as being important to making connections between visual support

and words in the statements, “They are able to place a picture or a visual with what is being said” and “students can associate the visuals with words and have two ways to understand what they need to do.” This indicates that preservice teachers were aware of visual support in digital math games.

Sixty-seven percent of preservice teachers reported appropriate levels as an important academic language feature on both the pre-survey and post-survey. One preservice teacher explained appropriate levels as important: “If the game isn't appropriate for the age-group/content then it isn't going to be as beneficial.” Another preservice teacher wrote, “This is so important for the digital math game to be an effective learning tool. It has to be appropriate for the students’ abilities, and the content needs to be appropriate.” Although preservice teachers did not specifically indicate how the appropriate language related to the hypothetical ELL students’ language proficiencies from Module 1, these statements indicated that preservice teachers were aware that there needs to be alignment between the language input offered in digital math games and the language proficiency of students.

Similarly, 62% of preservice teachers reported simple sentences as important on the pre-and post-survey with the statements, “Sometime simple is better. It can make it easier for the students to understand what is being said.” and “Simple sentences because the simpler the sentences, the easier it is for all to understand.” This shows that preservice teachers were aware that simple sentences could help make language input in digital math games comprehensible for ELLs.

Preservice teachers reported less frequently about speech density (10%), amount

of speech (14%), and multiple meanings of words/phrases (19%) on the Teachers' Beliefs Pre-Survey. However, more than half (57%-62%) of preservice teachers reported these as important academic language features on the post-survey. For example, some preservice teachers' explanations showed a lack of awareness with statements like, "Speech density is important because it needs to be a good level for the intended audience" and "The speech density of learning games should progress slowly in order for students to grasp everything. It can be "jam packed," however, if this is the case there should be many levels with a new term on each level." However, 57% of preservice teachers identified speech density as important on the post-survey with explanations that indicated increased awareness, such as, "Speech density should be kept simple with a good mix of formal and informal language" and "This is important for our ELL students too because if their Lexile levels are low and we are using high-level content vocabulary, this could trip them up during their game."

There was an increase in preservice teachers that reported the amount of speech as important from the pre-survey (14%) to the post-survey (62%; e.g., "The amount of speech featured in digital games will determine how often the students are reading and applying mathematics in their game"). Similarly, preservice teachers reported higher frequencies for multiple meanings of words/phrases as important from pre-survey (19%) to post-survey (57%). For example, one preservice teacher wrote, "While it is important to focus on math, it's vital to have multiple meanings of words and phrases in these games so the students are using their prior knowledge and context clues to figure it all out." Another preservice teacher wrote, "Since math and the English language are not

always consistent in what it's meaning, it's important for students to learn that there are multiple meanings. Games can help students recognize different situations where the words and phrases would change, which will allow the students flexibility in their understanding.”

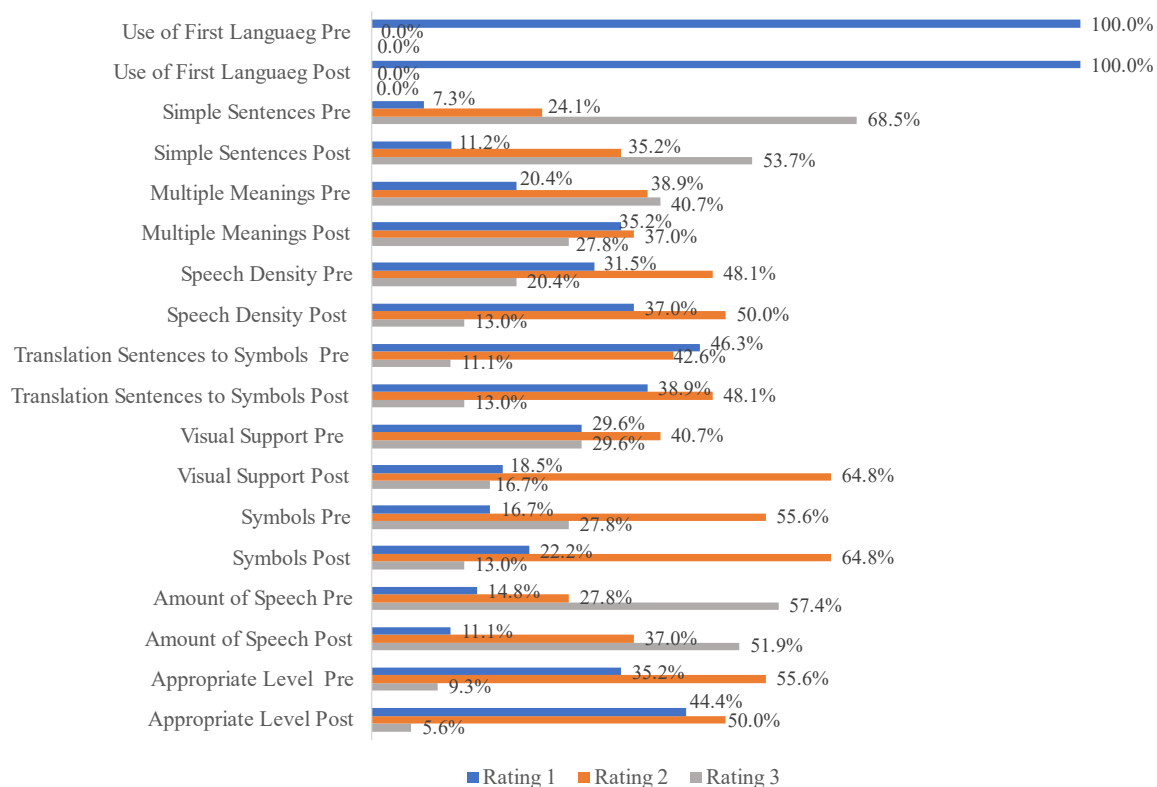
There was also an increase in the percentage of preservice teachers from the pre-survey (29%) to the post-survey (71%) in the identification of symbols. For example, one preservice teacher wrote, “By using it [symbols] correctly, the student is able to connect the visual of symbols in math to the words used to explain it.” Another preservice teacher wrote, “Symbols should be used in conjunction with words and visuals so the students can make sense of what the symbols represent.” Use of first language also had an increase in frequencies from pre-survey (38%) to post-survey (67%; e.g., “When there is an option for the game to be played in the students' first language, the language barrier is torn down and the student can focus on the mathematical concepts”). The increase in frequencies for five of the academic language features (speech density, multiple meaning of words and phrases, amount of speech, symbols, and use of first language) shows a strong indication that preservice teachers became more aware of the academic language features in the digital math games after completing the learning module about academic language features.

Academic Language Features Reported on the Math Game Evaluation Rubric

Figure 6 shows the percentage of preservice teachers' composite ratings for academic language features from the closed responses on the Math Game Evaluation

Figure 6

Composite Math Game Evaluation Rubric Ratings for Academic Language Features (N = 18)



Note. Percentages reflect the composite scores of academic language feature ratings on evaluation rubrics across all digital math games. Rating 1= low rating; 3= high rating; Pre= pre-evaluation scores; Post= post-evaluation scores.

Rubric. Preservice teachers rated each academic language feature as they played a digital math game. The evaluation rubric used a scale of 1-3, where “1” was a low rating (i.e., academic language feature was not in the game or it did not support learning) for the academic language feature and 3 was a high rating (i.e., academic language feature was present and supported learning). The bars in the figure represent the ratings “1” (i.e., blue bar), “2” (i.e., orange bar), and “3” (i.e., gray bar) and show the evaluations for the pre- and post-evaluation rubrics (i.e., AL pre, AL post). For example, a high percentage of

preservice teachers rated most academic language features lower than a “3” rating on the rubric across all digital math games, as shown by the blue (i.e., “1”) and orange bars (i.e., “2”) having higher frequencies than the gray bar (i.e., “3”). For instance, the use of first language was the only academic language feature that had all preservice teachers (100%) rate this as a “1” on both pre- and post-evaluation rubrics, as shown by the blue bar. This indicates that preservice teachers were aware of this academic language feature because they could easily identify that the use of first language was not in the digital math games. This suggests that defining each academic language feature and having a guided experience with evaluating a digital math game supports preservice teachers in identifying academic language features that can help make input from digital math games comprehensible for ELLs.

Figure 6 shows, that more than half of preservice teachers (52%-69%) rated the amount of speech and simple sentences as a “3” across all digital math games on the pre-survey and post-survey. Preservice teachers were aware of these academic language features because they could identify them in the games. This aligns with the increased percentages of preservice teachers who identified these academic language features as important (see Table 11). Preservice teachers rated appropriate level, symbols, visual support, and speech density of formal and informal language as a limited rating across all digital math games, with 41%-65% of preservice teachers rating each of these academic language features as a “2” on the pre-and post-evaluation rubrics.

There was an increase in the number of preservice teachers that rated visual support as a “2” on the rubric between the pre-evaluation (40%) to post-evaluation

(65%), indicating an increased awareness after completing the learning modules. More than half of preservice teachers rated this feature as being in the game (e.g., a 2 rating) on the post-evaluation. This aligns with the high percentages of preservice teachers identifying this as an important academic language feature (see Table 11).

Academic Language Features Themes Reported by Preservice Teachers on the Math Game Evaluation Rubric

Table 12 shows the frequencies of themes reported by preservice teachers about language development in digital math games on the Math Game Evaluation Rubric.

When preservice teachers were asked, “How does the digital math game use language to support academic language development for ELLs?” three main themes emerged: (1) Simple or supportive language, (2) complex or not supportive language, and (3) visual

Table 12

Frequencies of Themes About Academic Language Development in Digital Math Games on Evaluation Rubrics (N=18)

Themes	Frequency											
	Game 1 (N = 18)				Game 2 (N = 18)				Game 3 (N = 18)			
	Pre		Post		Pre		Post		Pre		Post	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Simple language and supportive	9	50.0	10	55.6	4	22.2	4	22.2	6	33.3	8	44.4
Complex language and not supportive	7	38.9	5	27.8	12	66.7	11	61.1	8	44.4	8	44.4
Visual support	2	11.1	3	16.7	2	11.1	3	16.7	4	22.2	2	11.1

Note. N reflects the number of participants who completed the pre-evaluation rubric and post-evaluation rubric for the same digital math games.

support. Overall, frequencies show that preservice teachers were aware of the use of simple or complex language in digital math games.

Preservice teachers reported similar frequencies on the pre-evaluation rubric and post-evaluation rubric for simple and complex language. For instance, similar percentages of preservice teachers identified a game as using simple and supportive language on the pre-evaluation rubric (22%-50%) and post-evaluation rubric (22%-55%). Preservice teachers identified this as a theme when they used statements like, “This game supports academic language development for English language learners by providing them with simple academic language such as smallest to largest, arrange, specified, etc. This game also gives students the opportunity to have more exposure to simple sentences.” Preservice teachers reported similar percentages for identifying complex and not supportive language on the pre-evaluation rubric (39%-67%) and post-evaluation rubric (28%-61%). For example, one preservice teacher wrote, “The sentences were a little more complex and using different type of vocabulary than usual for math.” Another preservice teacher wrote, “There is close to no language academic support for ELLs. The only language used is to give instructions.” This shows that preservice teachers were aware of language demands in digital math games because they could identify if the games used simple or complex language. This aligns with the increase in Likert scale ratings, where teachers felt better prepared to identify the language demands in digital math games (see Figure 5).

Preservice teachers showed a decrease in reported frequency for visual support from the pre-evaluation (22%-55%) to the post-evaluation (11%-17%). Preservice

teachers' statements were more precise about how the visuals and language related to support academic language development for ELLs. For example, on the pre-survey, preservice teachers' statements were vague in how visuals and language related to academic language development. Such as "Visuals would help students know what to do" and "Visual cues and simple sentence." However, on the post-survey, preservice teachers used statements such as, "This allows the ELLs to hear and read the instructions and to connect written fractions to a picture" and "The words used to correct or show how to get the correct answer are used along with an arrow to point the direction to move on the number line." These statements show more awareness of how the visuals and language are related to supporting the mathematics language development for ELLs.

Academic Language Feature Themes Reported on Module 3 Reflections

Table 13 shows the frequencies of themes reported by preservice teachers from the Module 3 Reflection that preservice teachers completed after watching a video about academic language features. The themes indicated that preservice teachers believed academic language features could promote mathematics learning in digital math games for ELLs by helping make language comprehensible. For example, when asked, "What role do you think academic language features play in helping ELLs learn mathematics in digital math games?" 81% of preservice teachers stated that academic language features could promote learning. For example, one preservice teacher wrote, "I think academic language features play a vital role in helping ELLs learn mathematics in digital math games because depending on how well the features are executed and used, the ELLs can

Table 13

Frequencies of Themes About Academic Language Features in Digital Math Games on Module 2 Reflection (N = 21)

Theme	Frequency	
	<i>n</i>	%
How would you define academic language features?		
Aspects, attributes, characteristics, elements	19	90.5
Promote understanding	6	28.6
Context	2	9.5
How do you think academic language features helped promote mathematics learning in the digital math game shown in the video?		
Promotes learning	13	61.9
Symbols	8	38.1
Hindered Learning	7	33.3
Visual support	4	19.0
Amount of speech	4	19.0
Multiple meanings words and phrases	3	14.3
Use of first language	3	14.3
Appropriate level	2	9.5
References translated to symbolic	1	4.8
Speech density	1	4.8
Simple sentences	1	4.8
What was your impression of the academic language features in the digital math games shown in the video?		
Negative	15	71.4
Positive	6	28.6
What role do you think academic language features play in helping ELLs learn mathematics in digital math games?		
Impact on learning	17	81.0
Appropriate level	8	38.1
Simple sentences	7	33.3
Multiple meanings words and phrases	5	23.8
Visual support	5	23.8
Amount of speech	4	19.0
References translated to symbolic	4	19.0
Symbols	2	9.5
Use of first language	1	4.8
Speech density	0	0.0

Note. Bolded numbers represent percentages 50% or above.

have an easier or much harder time trying to play the game.” Another preservice teacher wrote, “They seem to play a very large role. Because language will be an ELL’s most difficult obstacle, any features that help reduce the severity of that obstacle will help. Manipulating or evaluating academic language features are ways game designers and teachers can make or select games that reduce the cognitive strain imposed on ELLs.”

When asked, “How do you think academic language features helped promote mathematics learning in the digital math game shown in the video?” 62% of preservice teachers indicated that academic language features could impact mathematics learning. For example, one preservice teacher wrote, “Academic language features seemed to assist students in truly grasping the concept of the math being illustrated in the game. By using the features effectively, the students can understand the math and connect the math language to the concept of it.” Another preservice teacher wrote, “Academic language features help to promote mathematics learning by connecting visual to academic sentences.” There were 33% of preservice teachers who indicated these features could hinder learning (e.g., “I don't think the language features did a good enough job to teach the concepts behind the tasks. The features instead made the game into more suitable for practice rather than for learning”).

When asked, “How would you define academic language features,” 29% of preservice teachers indicated that academic language features are a way to help make language comprehensible for ELLs and promote mathematics understanding. For example, one preservice teacher wrote, “I would say it is the way language is used in the game to either improve or confuse the students’ learning ability.” Another preservice

teacher wrote, “Things to help us see what kinds of things the games can be useful for and to see the different ways they make practice into understanding.” This shows that preservice teachers were aware of academic language features being important in digital math games because they identified how language helped or hindered learning.

Preservice teachers also described specific academic language features that they believed promoted learning. For instance, 38% of preservice teachers wrote that appropriate level plays a role in helping ELLs learn mathematics when they wrote, “Appropriate level of language for age group helps ELLs not be unnecessarily overwhelmed by language that is too difficult for them to understand whether or not they are an ELL” and “If the ELL students are just trying to decode the instructions, it is not helping them with their math skills. The language, mathematical representation, and explanations need to be appropriate.” Similarly, 38% of preservice teachers identified symbols as an academic language feature that can promote mathematics learning. For example, one preservice teacher wrote, “One of the academic language features that I think helped promote mathematics learning was the symbols.” Another preservice teacher wrote, “Symbols can help promote mathematics learning like the example in the video.” This shows that preservice teachers were aware of academic language features in the game and how they impacted learning.

When asked, “What was your impression of the design features in the digital math game shown in the video,” 71% had negative impressions of the academic language features in digital math games. For example, one preservice teacher wrote, “They were lacking in many areas. There were opportunities for this game to have an improved

amount of speech as well as visual supports.” Another preservice teacher wrote, “I think the academic language features in this game could have been improved. I think they tried to keep it simple with the academic language, but in doing so they lack support in the mathematical concepts. There was only one form of visual support, the painted array. The academic language that is provided is not quite appropriate for the intended audience and there could be more ways to support the translation of sentences into symbolic representations.” This indicates that many preservice teachers viewed the digital math game as lacking language features that could promote learning.

Wilcoxon Signed-Rank Test and Preservice Teachers’ Self-Reported Changes in Awareness of Academic Language Features During Semistructured Interviews

The Wilcoxon Signed-Rank test indicated that post-survey ranks were statistically higher than pre-survey ranks for all Likert scale items about identifying language demands in digital math games: I understand the language demands in mathematics that may support learning for English language learners ($Z = -2.642, p = .008$); I can identify language demands in digital math games that may impact learning for English language learners ($Z = -2.833, p = .005$). After completing the academic language features module, preservice teachers felt better prepared to identify the language demands in a digital math game. These significant changes align with the themes that emerged from the interviews with preservice teachers (see Table 14). For instance, all (100%) preservice teachers indicated that their ideas about the role of academic language features in digital math games changed from the beginning of this study. For example, one preservice teacher said,

Yes, I feel like it did. Because at the beginning, when I was trying to evaluate, like, based off the language of it, I felt like, I didn't exactly know what I was looking for. But then once I was learning, I was able to evaluate and see the games actually did have that.

Another preservice teacher said,

Yeah, no, it definitely did. Because I remember when we started and I like saw the survey, and I was like, I don't know if I've ever, like kind of, like, I got what they like kind of were just from like previous, like education and educational terms, but it was never like I dived in. So, I kind of just like took a guess of what each one meant. And then once I learned like, a little bit more in depth what each one meant. It was it was kind of like, I got a I got a better idea of like, how to evaluate if that makes sense.

Another preservice teacher said,

Like the way that I feel a game should be set up like game efficiency and like, appropriate language, and like the amount of language given, so it's as streamlined as possible and accessible to both English language learners and native English speakers.

Table 14

Academic Language Feature Themes Reported by Preservice Teachers During Semistructured Interviews (N = 21)

Theme	Frequency	
	<i>n</i>	%
Changes in important academic language features		
Changed	12	57.1
Did not change	8	38.1
Unsure	1	4.8
Changes in the role of academic language features		
Changed	21	100.0
Little or no change	0	0.0

In contrast, the Wilcoxon Signed-Rank test indicated there were no significant changes in post-rubric ranks compared to pre-rubric ranks for any of the academic

language features: Appropriate level ($Z = -1.308, p = .191$); the amount of speech ($Z = -.175, p = .861$); symbols ($Z = -1.864, p = .062$); visual support ($Z = -.122, p = .903$); references translated into symbolic representation ($Z = -.842, p = .400$); speech density ($Z = -1.051, p = .293$); multiple meanings ($Z = -2.062, p = .039$); simple sentences ($Z = -.895, p = .058$); use of first language ($Z = .000, p = 1.00$). Although there were no significant changes, 57% of preservice teachers indicated that the academic language features they found important at the beginning of this study changed by the end. For example, one preservice teacher said,

I didn't really understand everything, or like I didn't understand how they pertained to a math game, I may have understood the general term, but I didn't understand why it would be important in a math game. They definitely did change at the end because I was able to see, oh, that's how it was beneficial in this math game.

Another said,

I feel like once I got more information about what each of them meant and how to identify them in the games, then I was able to have a better opinion on which ones were most influential to the kids.

Preservice teachers increased their awareness of academic language features after completing the learning modules. This aligns with the high percentage of preservice teachers that indicated all nine academic language features were important on the post-survey (see Table 11).

Preservice Teachers' Beliefs about their Preparation for Using Digital Math Games to Support Mathematics Learning for ELLs

This section reflects preservice teachers' beliefs about their preparation for using

digital math games to support mathematics learning for ELLs and changes exhibited after completing the learning module about design features and academic language features. Results indicate that preservice teachers felt more positive about their preparation for integrating digital math games into mathematics instruction for ELLs after interacting with the learning modules.

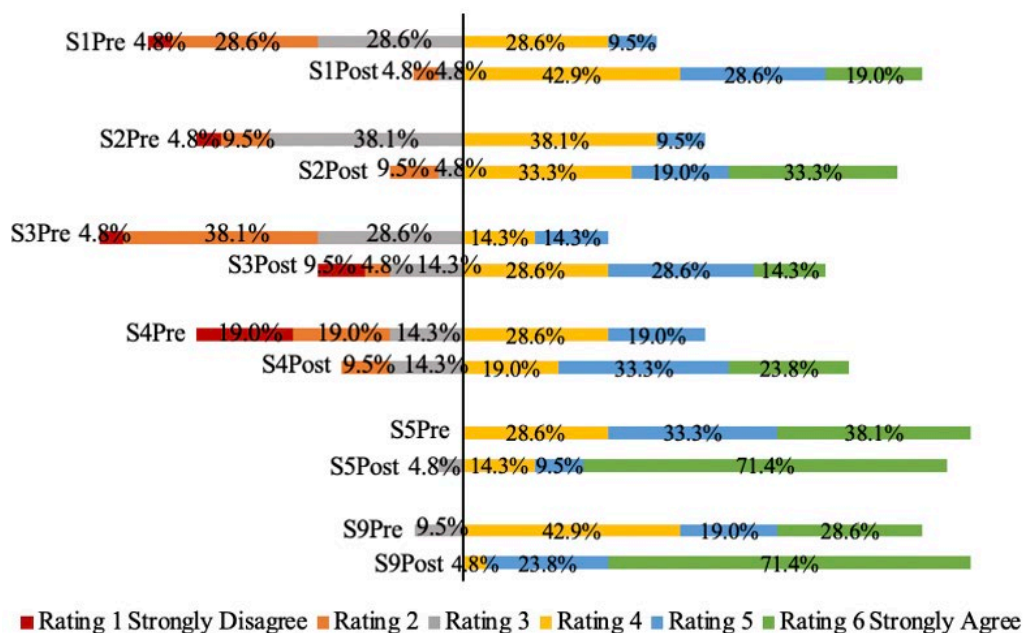
Preservice Teachers' Beliefs about Preparation Reported on Likert Scale Items

Figure 7 shows frequencies for preservice teachers' beliefs about their preparation for using digital math games to support mathematics learning for ELLs reported from the Teachers' Beliefs Survey. The vertical black line shows how preservice teachers' reported beliefs diverge from the "disagree" (i.e., rating of 1, 2, or 3) and "agree" (i.e., rating of 4, 5, or 6) portion of the Likert scale. The red (i.e., 1), orange (i.e., 2), and gray (e.g., 3) bars represent the "disagree" portion of the Likert scale, and the yellow (i.e., 4), blue (i.e., 5), and green (i.e., 6) bars represent the "agree" portion of the Likert scale. When preservice teachers rated the following statements: "Using digital math games in mathematics lessons can improve students' understanding of mathematics" (S5) and "Game features in digital math games can help students learn mathematics content" (S9), they rated these statements towards the "agree" portion of the Likert scale on the pre-and post-survey (95%-100%), as shown by the yellow, blue, and green bars on the right of the black vertical line. Additionally, there was an increase in the percentage of preservice teachers that rated these statements as "strongly agree" (i.e., 6 Rating) on the pre-survey (29%-38%) and post-survey (71%), as shown by the green bars. This suggests that

preservice teachers believed that digital math games could promote mathematics learning.

Figure 7

Frequencies of Likert Scale Items About Preparation for Using Digital Math Games to Support Mathematics Learning for ELLs (N = 21)



Note. S1 = I feel confident in choosing linguistically appropriate learning experiences for English language learners in mathematics; S2 = I feel prepared to choose learning experiences that meet the needs of English language learners in mathematics; S3 = I have adequate training to work with English language learners; S4 = I have adequate training to integrate digital math games into mathematics instruction; S5 = Using digital math games in mathematics lessons can improve students' understanding of mathematics; S9 = Game features in digital math games can help students learn mathematics content; Pre = pre-survey frequency percentages; post = post-survey frequency percentages.

Preservice teachers may feel underprepared to teach mathematics to ELLs because more than half (52%-71%) of the preservice teachers rated these statements towards the “disagree” portion of the Likert scale (i.e., 1, 2, or 3) on the pre-survey. In contrast, more than half (71%-100%) of preservice teachers shifted their ratings to the “agree” portion (i.e., 4, 5, or 6) on the post-survey. This indicates that preservice teachers

felt better prepared after completing the learning modules. For example, preservice teachers reported the biggest shift in frequencies toward the “agree” portion of the Likert scale when they rated the statements “I feel confident in choosing linguistically appropriate learning experiences for English language learners in mathematics” (S1) and “I have adequate training to work with English language learners” (S3) from pre-survey (29%-38%) to post-survey (71%-90%). Similarly, when asked to rate “I feel prepared to choose learning experiences that meet the needs of English language learners in mathematics” (S2) and “I have adequate training to integrate digital math games into mathematics instruction” (S4), there was an increase in the percentage of preservice teachers’ that favored the “agree” portion of the Likert scale from pre-survey (48%) to post-survey (76%-86%).

Teacher Knowledge Reported by Preservice Teachers

Table 15 shows the frequencies of themes reported by preservice teachers about what teachers should know to integrate digital math games in mathematics instruction for ELLs. Three main themes emerged: (1) student knowledge, (2) teacher game knowledge, and (3) teaching strategies.

Teacher game knowledge was a theme that emerged with the biggest increase in frequencies from pre-survey (29%) to post-survey (95%). For example, one preservice teacher wrote, “What sort of games there are, where to find them, and how to make them meaningful for learning.” A preservice teacher also described teacher game knowledge as important when they wrote, “Teachers need to know how to identify quality math games

Table 15

Frequencies of Themes About What Teachers Should Know to Integrate Digital Math Games in Mathematics Instruction for ELLs (N = 21)

Themes of what teachers should know	Frequency			
	Pre-response		Post-response	
	<i>n</i>	%	<i>n</i>	%
Teacher game knowledge	6	28.6	20	95.2
Student knowledge	11	52.4	5	23.8
Teaching strategies	10	47.6	4	19.0

that are digital.” Another preservice teacher wrote, “They need to understand academic language features and design features.” The increase in frequencies suggests preservice teachers became more aware of teacher game knowledge (e.g., design features and academic language features) being important for integrating digital math games into mathematics instruction for ELLs.

Preservice teachers showed a decrease in frequency for student knowledge from the pre-survey (52%) to post-survey (24%). One preservice teacher wrote, “One thing that teachers need to know is their students’ English level is at, especially with English math language. Another thing that teachers need to know is how much the students knows in their math skills.” Another preservice teacher wrote, “Teachers need to be aware of the skills, strategies, and vocab that the students already know. Once they realize the background knowledge of the ELL students, they can start to build off that.” Similarly, teaching strategies had a decrease in frequencies from pre-survey (48%) to post-survey (19%; e.g., “Teachers need to have a general understanding of teaching techniques that can specifically help English language learners”). The decrease in

frequencies for these themes may suggest that preservice teachers became more aware of other knowledge (e.g., design features, academic language features) that teachers need to know to integrate digital math games effectively.

Beliefs about Digital Math Games Reported on the Math Game Evaluation Rubric

Table 16 shows the frequencies of themes reported by preservice teachers about their impressions of digital math games from the Math Game Evaluation Rubric. When asked, “What was your overall impression of the game?” preservice teachers’ reported a positive impression (61%-78%). One preservice teacher wrote, “I thought it was really fun to play! I also understood it fairly easily. There were some math games that were harder to play.” Similarly, another preservice teacher liked it because “I thought it was a fun and creative game. It started out with small steps and works up to higher level of fractions.”

Table 16

Frequencies of Themes About Preservice Teachers’ Impression of Digital Math Games on Evaluation Rubrics (N = 18)

Themes (impressions of game)	Frequency											
	Game 1				Game 2				Game 3			
	Pre		Post		Pre		Post		Pre		Post	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Liked it, impressed, fun, engaging	14	77.8	10	55.6	11	61.1	8	44.4	13	72.2	9	50.0
Did not like it, not engaging, confusing	4	22.2	8	44.4	7	38.9	10	55.6	5	27.8	9	50.0

Note. N reflects the number of participants who completed the pre-evaluation rubric and post-evaluation rubric for the same digital math games.

In contrast, a lower percentage (22%-39%) of preservice teachers that wrote negative impressions of the digital math games. For example, one preservice teacher wrote, "It was difficult! I wanted to keep playing to figure out a strategy. This being said, I think it is too advanced for 3rd grade." Another preservice teacher wrote, "I wasn't a big fan of it. The directions at the bottom weren't super clear and you didn't know what you were doing." Most preservice teachers had positive impressions of using digital math games to enhance mathematics instruction for English language learners.

However, there was a decrease in the percentage of preservice teachers who reported positive impressions from pre-evaluation (61%-78%) to post-evaluation (44%-56%), which in turn, showed an increase in negative impressions from the pre-evaluation (22%-39%) to the post-evaluation (44%-56%). This suggests that preservice teachers' impressions of digital math games became more negative towards the end of the study. This could be explained by preservice teachers becoming more aware of design features and academic language features because their explanations about their impressions specifically identified ineffective features in the games. For example, one preservice teacher had a positive impression and wrote, "I think that this was one of my favorites that I looked at. One feature that I liked about this game was that the level progressed. This allows the students to be challenged more and more as they start to gain more of an understanding of the concept. Another thing that I liked was that it gave hints and feedback for when the students got something wrong." Another preservice teacher wrote, "This game is great! It gives multiple attempts, is very user-friendly, straight forward and uses calming beach sounds." One preservice teacher disliked a game and wrote, "The

game does not offer any hints or tutorials, which is so frustrating!” Another preservice teacher wrote, “This game does not offer accuracy feedback. If the player is incorrect about the number of pancakes flipped, the pancakes are flipped back to their cooking side and the player has to start from scratch again. This does not teach or explain why the player was incorrect, which would cause great frustrations.”

Preservice teachers also explained that their impressions changed from pre-evaluation to post-evaluation. For example, one preservice teacher wrote, “Playing this game a second time, I do not think this is a very high-quality math game. There is hardly any feedback, hints, and the explanations are poor. I would not recommend this game.” Similarly, another preservice teacher wrote, “I don't think that it is as effective as before.” The changes in frequencies and preservice teachers' use of specific features when explaining their impressions indicate that they had more awareness of design feature and academic language features in digital math games after completing the learning modules.

Wilcoxon Signed-Rank test and Preservice Teachers' Self-Reported Changes in Beliefs about Their Preparation During Semistructured Interviews

The Wilcoxon Signed-Rank test indicated that post-survey ranks were statistically higher than pre-survey ranks for 5 of the 6 Likert scale items about preservice teacher beliefs about their preparation for using digital math games to enhance learning for ELLs: I feel confident in choosing linguistically appropriate learning experiences for English language learners in mathematics ($Z = -3.447, p = .001$); I feel prepared to choose learning experiences that meet the needs of English language learners in mathematics ($Z = -3.010, p = .003$); I have adequate training to work with English language learners (Z

= -2.937, $p = .003$); I have adequate training to integrate digital math games into mathematics instruction ($Z = -2.979, p = .003$); Game features in digital math games can help students learn mathematics content ($Z = -3.169, p = .002$). In contrast, the post-survey ranks were not significantly higher than pre-survey ranks for Using digital math games in mathematics lessons can improve students' understanding of mathematics ($Z = 1.627, p = .103$). This suggests that preservice teachers had more positive beliefs about their preparation for integrating digital math games in mathematics instruction for ELLs by the end of this study. This aligns with the themes that emerged from the semistructured interviews about preservice teachers' beliefs about their preparation, impressions, and attitudes about digital math games (see Table 17).

Table 17

Beliefs About Preparation, Impressions, and Attitudes of Digital Math Games Reported by Preservice Teachers During Semistructured Interviews (N = 21)

Theme	Frequency	
	<i>n</i>	%
Preparation for digital math game integration		
Did not prepare	17	81.0
Prepared	4	19.0
Changes about impressions of digital math games		
Changed	16	76.2
Did not change	5	23.8
Changes in attitude about using digital math games		
Changed	19	90.5
Did not change	2	9.5

Note. Bolded numbers indicate percentages 50% or more.

When asked, “Do you feel that your teaching preparation courses have prepared you to integrate digital math games into mathematics instruction for English language

learners? If so, how? If not, why,” 81% of preservice teachers reported that they did not feel prepared. For example, one preservice teacher said,

No, I definitely think that I learned a lot more during this course. So, before this course, no, I don't think that I was able to, like, learn a lot of like the supplemental strategies that was taught in this course as well as like, I'm not only like the digital math games, but also prepared me for like, other like science, digital games, or like things like that and other subjects. I just think that sometimes the professor's found it like difficult to add in, you know, to like, teach us how to, like test the effectiveness and assess the effectiveness of the games.

Another preservice teacher said,

No, not really. Um, I think like, I feel like the courses that I've taken have been very broad and like, they give very specific like, like, they give good ideas and things like that. But I don't feel like when I started going through, like playing those math games, and then like, learning about the things that you were talking about, like academic language, and math language, I was just like, oh, like, I would never have thought about thinking about any of these things for a math game, or just like a game to implement into schools.

Preservice teachers indicated that their impressions (76%) and attitudes (91%) changed about digital math games by the end of the study. For example, one preservice teacher explained their impressions changed when they said,

So, I think that it definitely did. It kind of made me realize some of the games I thought weren't as beneficial, were actually like, okay, that's not the worst game you could pick. And then it also just like opened my eyes to like the reciprocal of that of like, oh, that I thought that was a good game, but that actually has like, no design features or anything that would like benefit a kid.

Similarly, another preservice teacher said,

I'm, like, at the very beginning of doing this module, I didn't feel like it was a good one. But then after learning about like, the design features in the academic language features, it helped me see like how it could be beneficial on some parts, but also, it like didn't have like progressive levels and like not a lot of like, teaching helped like the students understand.

When describing their change in attitudes towards using digital math games, one

preservice teacher said,

Yeah, I think, um, I guess I just never have thought of using math games, just because, as I stated earlier, it never really came up in my education. But I think that like, through this, I've found like an efficient way of choosing like good games for that group of students. So, it's definitely inclined me way more to use math games, for sure.

Another preservice teacher said,

Yes. It's made me realize that math games can really help the students and that, if they're not created wisely, they can really hinder the students and frustrate them. At least, I believe it could. So yeah, I think they're, they're a good way to make it make math more accessible to English language learners.

This shows that preservice teachers had positive changes in their beliefs about their preparation for integrating digital math games into mathematics instruction for ELLs by the end of this study.

Summary of Results

Results showed preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for ELLs after interacting with learning modules where preservice teachers defined design features and academic language features, then used these features to evaluate a digital math game in a guided experience. Preservice teachers had increased awareness of design features by the end of this study. This is indicative of the significant changes in the post-survey ranks. This shows that preservice teachers felt better prepared to identify mathematics content and design features in digital math games. This is also evident in the evaluation rubric results, where there were high percentages of preservice teachers that could identify the specific mathematics concepts and the mathematical

terminology in digital math games because each participant identified a general or specific fraction concept. Results indicate that a high percentage of preservice teachers were most aware of the following design features: progressive levels, accuracy feedback, and multiple attempts. Preservice teachers self-reported on the Module 2 reflection and the semistructured interviews that they better understood design features and how these features supported learning by the end of this study. This indicates that preservice teachers felt better prepared to choose and evaluate digital math games because they were more aware of design features that promoted mathematics learning.

Preservice teachers also reported an increase in their awareness of academic language features. The significant changes in post-survey ranks compared to pre-survey ranks show that preservice teachers felt better prepared to identify language demands in digital math games. This was also evident by the high percentage of preservice teachers that identified language as simple or complex when evaluating digital math games. Similarly, many preservice teachers identified all nine academic language features as important features in digital math games. Preservice teachers also self-reported on the Module 3 reflection and the semistructured interviews that they understood academic language features better and how these features supported learning in digital math games. Therefore, preservice teachers were more aware of academic language features in digital math games by the end of this study.

Preservice teachers' beliefs became more positive about their preparation for using digital math games to support mathematics learning for ELLs. The significant changes in post-survey ranks compared to pre-survey ranks show that preservice teachers

felt better prepared to choose digital math games to support mathematics learning for ELLs. Preservice teachers also self-reported during the semistructured interviews that their beliefs became more positive about using digital math games in mathematics instruction by the end of the study. Thus, preservice teachers had more positive beliefs about their preparation for integrating digital math games into mathematics instruction for ELLs by the end of this study.

CHAPTER V

DISCUSSION

The purpose of this study was to examine how preservice teachers developed awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for English language learners (ELLs). The overarching research question for this study was: How do preservice teachers develop awareness and beliefs about design features and academic language features when choosing and evaluating digital math games for English language learners (ELLs)? The main research questions of the study were as follows.

1. What are preservice teachers' awareness and beliefs about design features when choosing and evaluating digital math games for ELLs, and what changes, if any, are exhibited after completing the learning modules?
2. What are preservice teachers' awareness and beliefs about academic language features when choosing and evaluating digital math games for ELLs, and what changes, if any, are exhibited after completing the learning modules??
3. What are preservice teachers' beliefs about their preparation for using digital math games to support mathematics learning for ELLs, and what changes, if any, are exhibited after completing the learning modules?

This research study focused on three premises (i.e., preservice teachers' awareness and beliefs about design features, awareness and beliefs about academic language features, and their beliefs about using digital math games for instruction) that can impact preservice teachers' preparation for choosing and evaluating digital math games to enhance mathematics instruction for ELLs. This chapter interprets the results of this study and situates it in the existing literature. The first three sections of the chapter discuss the results, based on changes between pre- and post-assessments of preservice

teachers' awareness and beliefs about design features and academic language features, and beliefs about their preparation for using digital math games to support mathematics learning for ELLs. The final sections discuss the implications, limitations, and suggestions for future research based on the findings.

Preservice Teachers' Awareness and Beliefs About Design Features

The first premise examined how preservice teachers' awareness and beliefs about design features can impact how preservice teachers choose and evaluate digital math games for ELLs. Results indicated that preservice teachers felt better prepared to integrate digital math games into mathematics instruction for ELLs after they completed the four modules because they had an increased awareness of design features. This was evident in both the qualitative and quantitative findings, where preservice teachers reported changes in their awareness of design features. For instance, an example from the qualitative data were statements during the semistructured interviews such as, "I think I just learned so much more about each feature, and different things became important looking at it through the eyes of an ELL student" and "But I think the fact that now knowing what each of them meant and seeing them in an example helped change my idea of what was most important in a video game." An example of this from the quantitative data was the significant changes in post-survey ranks on the Wilcoxon Signed-Rank test for the Likert scale items about design features.

Preservice teachers conveyed that their awareness of design features increased through preservice teachers the semistructured interview responses (e.g., "My views have

changed positively. I know what design features to look at in games.”) and the increased awareness of explanations for important design features from pre-survey (e.g., “I also think that physical action is important so that students get up a MOVE!”) to post-survey (e.g., “Link physical action: inviting the students to physically move objects or see visual changes is a great way for students to understand the math they are completing”). As a result, preservice teachers felt better prepared to choose and evaluate digital math games for ELLs. Preservice teachers reported that their ideas about the role of design features changed from the beginning of the study. For example, they change from an engaging role (e.g., “Because I understand, like, what the features are that I was looking at, because when I started, I was just playing a math game to like, play the math game”) to a learning role where they promote mathematics learning (e.g., “I think that the design features of games are key to ELLs having a positive learning experience versus a confusing, frustrating one”). After completing the learning modules about design features and academic language features, preservice teachers were more aware of design features. This result aligns with Meletiou-Mavrotheris and Prodromou’s (2016) research, which noted that prior training and awareness of the TPACK framework helped 13 preservice teachers choose and use digital math games effectively in mathematics lessons. Since design features are part of technology knowledge (TK) in the TPACK framework, preparation courses need to provide experiences that help preservice teachers increase their awareness of design features in digital math games to choose and effectively implement digital math games into mathematics instruction for ELLs.

Other research that aligns with the current findings has shown that teacher game

content knowledge is important to effectively integrate digital games into instruction (Hsu et al., 2013, 2017, 2020). Results in this dissertation study indicated that preservice teachers had fraction game content knowledge, as evidenced by their ability to identify the fraction content and skills in the digital math games. This demonstrates that preservice teachers' awareness of the mathematics in digital math games is important to effectively choose and evaluate the games.

Overall, Preservice teachers reported positive impressions of design features in digital math games. They indicated that design features could promote mathematics learning. For example, they stated,

I think that when they are all used together to assist the child in learning, the child gains the most out of the game at that point. I feel like they all promote different areas of mathematical concepts that are needed in our mathematical learning progression.

Prior researchers have reported that design features can enhance mathematics learning in digital math games (Callaghan & Reich, 2018; Gresalfi et al., 2018; Moyer-Packenham, Lommatsch, et al., 2019). This shows the important role of preservice teachers learning about design features in their preparation courses to identify games that use these features to enhance mathematics learning.

Preservice Teachers' Awareness and Beliefs About Academic

Language Features

The second premise of this study examined how preservice teachers' awareness and beliefs about academic language features can impact how preservice teachers choose and evaluate digital math games. Both qualitative and quantitative indicated that

preservice teachers had an increased awareness of academic language features and felt better prepared to integrate digital math games into mathematics instruction for ELLs by the end of this study. For instance, examples of this from the qualitative data were the statements preservice teachers used during the semistructured interviews (e.g., “I feel like once I got more information about what each of them meant and how to identify them in the games, then I was able to have a better opinion on which ones were most influential to the kids”). An example of this from the quantitative data was the significant changes in post-survey ranks on the Wilcoxon Signed-Rank test for the Likert scale items about academic language features.

Prior research by Lindahl (2013, 2019) has noted that preservice teachers have low abilities to identify language demands and structures that can impact ELLs. Lindahl’s findings aligned with preservice teachers’ beliefs at the beginning of this study when they reported feeling underprepared to identify language demands in digital math games. However, preservice teachers’ awareness of academic language features increased after they completed the learning modules. For example, preservice teachers were able to better identify the simple and complex language in the digital math games. Preservice teachers also reported that their ideas of the role of academic language features changed by the end of the study based on their comments during the semistructured interview (e.g., “I felt like, I didn't exactly know what I was looking for. But then once I was learning, I was able to evaluate and see the games actually did have that”). As a result, preservice teachers felt better prepared to choose digital math games to support mathematics learning for ELLs. This result has implications for preservice teachers’

preparation programs. It indicates the important role that experiences with identifying language demands can play in helping preservice teachers to better identify features in digital math games that can help make input comprehensible for ELLs. This can potentially increase preservice teachers' awareness of language demands and positively impact their beliefs about their preparation.

Research has reported that mathematical language can be an important feature in digital math games (Bedwell et al., 2012; Ke, 2013; Moyer-Packenham, Litster, et al., 2019). The findings on the importance of mathematical language in digital math games align with this study because preservice teachers indicated their awareness that academic language features can promote mathematics learning in digital math games. For example, in the current study, preservice teachers reported negative impressions of academic language features in digital math games. However, preservice teachers conveyed that the academic language features need improvements to better support the mathematics in the games. This indicates that preservice teachers were aware of academic language features and how academic language features to support students' mathematics learning. Thus, attention to academic language features can help preservice teachers choose and evaluate digital math games that better align with the language needs of ELL learners.

Preservice Teachers' Beliefs About Their Preparation for Using Digital Math Games to Support Mathematics Learning for ELLs

The third premise in this study examined how preservice teachers' beliefs about their preparation for using digital math games for instruction and teaching ELLs can

impact how they choose and evaluate digital math games. The findings suggest that preservice teachers had more positive beliefs about their preparation for choosing and evaluating digital math games for ELLs by the end of this study. For instance, examples of this from the qualitative data were the statements during the semistructured interviews, such as, “Yes. It's made me realize that math games can really help the students and that, if they're not created wisely, they can really hinder the students and frustrate them” and “Yeah, I think, um, I guess I just never have thought of using math games...it's definitely inclined me way more to use math games, for sure.” An example of this from the quantitative data was the high percentage of preservice teachers that indicated their attitudes about using digital math games changed by the end of the study.

There were significant changes in preservice teachers' beliefs about their preparation for choosing and evaluating digital math games for ELLs based on the results of the Wilcoxon Signed-Ranked test. As noted by several research studies (Meletiou-Mavrotheris & Prodromou, 2016; Sardone & Devlin-Scherer, 2009, 2010; Shah & Foster, 2015), when preservice teachers have opportunities to learn about digital games in content courses, their beliefs can be impacted. For example, Meletiou-Mavrotheris and Prodromou reported that 13 preservice teachers' beliefs became more sophisticated after evaluating digital math games because they were aware of specific features of the games (e.g., feedback, rules, topics). Therefore, content courses that include experiences for preservice teachers to choose and evaluate digital math games, like the learning modules in this study, offer the potential to increase awareness of game features that promote mathematics learning.

Preservice teachers indicated that their beliefs about the effectiveness of the games changed after completing the learning modules. This indicates that preservice teachers became more aware of design features and academic language features after completing the learning modules in this study. Research has reported that preservice teachers' experiences in their preparation programs can impact their beliefs about using digital math games (Belbase, 2015; Gibson, 2002; Li, 2013; Sardone & Devlin-Scherer, 2009, 2010). This aligns with this study's findings that the learning modules about design features and academic language features have some measure of influence on preservice teachers' beliefs in this study, based on the experiences they had with identifying features and evaluating a digital math game during the learning modules. Therefore, meaningful experiences in preservice teachers' preparation courses focusing on design features and academic language features can potentially develop preservice teachers' skills in choosing digital math games that promote mathematics learning for ELLs.

Results indicated that preservice teachers' beliefs about using digital math games became more positive by the end of the study. Preservice teachers reported that they felt they could better choose digital math games, making them more willing to integrate them into mathematics instruction. This indicates that the experiences preservice teachers have with digital math games during their preparation can have a positive impact. This finding also aligns with previous research (Gutiérrez-Fallas & Henriques, 2021; Sardone & Devlin-Scherer, 2010; Shah & Foster, 2015). For example, Gutiérrez-Fallas and Henriques reported that when 12 preservice teachers in a secondary preparation course interacted with technology, it improved their attitude about integrating technology into

mathematics instruction. The results in this study support this claim because after preservice teachers interacted with technology (e.g., digital math games), their beliefs became more positive about using digital math games in mathematics instruction. Similarly, Shah and Foster reported that 14 preservice teachers' beliefs were positively impacted by interacting with digital math games, which increased their desire to use them in future instruction. Thus, preparation courses that integrate experiences similar to the learning modules in this study offer the opportunity to better prepare preservice teachers to develop positive beliefs about integrating digital math games into mathematics instruction.

Preservice teachers reported teacher game knowledge as important for teachers to integrate digital math games into mathematics instruction, specifically knowledge of design features and academic language features. This shows that preservice teachers were aware of the importance of design features and academic language features in digital math games. Preservice teachers need this knowledge when choosing and evaluating digital math games for ELLs. As noted by several researchers, teacher game knowledge is important to integrate digital math games into instruction effectively (Hsu et al., 2013, 2017, 2020). Therefore, teacher preparation programs should integrate learning about design features and academic language features to develop preservice teachers' skills in choosing and evaluating digital math games.

Implications and Future Research

This study makes several contributions to the field and provides important

implications for game designers, researchers, and preservice teacher preparation programs. First, this study highlights important design features and academic language features that game designers should be aware of that impact the learner's interactions with digital math games. For example, game designers should consider how academic language features in digital math games help players develop mathematics language. Game designers should also consider providing options for different languages because the digital math games in this study only used English. This option could be a resource ELLs use to better understand mathematics in digital math games (Lucas et al., 2008; Lucas & Villegas, 2010; 2013; Moschkovich, 2013).

This study provides a model for how preservice teachers can increase their awareness of design features and academic language features, which may impact their beliefs about digital math games. For example, the model used in this study included learning modules as short learning experiences (Sardone & Devlin-Scherer, 2009, 2010) that provided specific interactions with design features and academic language features. These short learning modules provided definitions of each feature and allowed preservice teachers to use these features to evaluate a digital math game in a guided experience where each feature was discussed using the evaluation rubric. Then, preservice teachers used their increased awareness to re-evaluate three digital math games. These types of experiences can increase awareness of design features and academic language features because it encourages preservice teachers to consider what makes a digital math game effective (Sardone & Devlin-Scherer, 2009). Thus, preparation programs could use similar experiences to help preservice teachers increase their awareness of design features

and academic language features in digital math games.

Finally, this study provided rich data about preservice teachers' awareness and beliefs about design features and academic language features when choosing digital math games for ELLs. Future research could continue to examine preservice teachers' awareness of design features and academic language features and how this awareness may influence how preservice teachers choose and evaluate digital math games for ELLs, especially with a more representative population of elementary preservice teachers. Future research could also examine how preservice teachers evaluate design features and academic language features across digital math games with mathematics content other than fractions (e.g., addition, subtraction, multiplication, division, geometry) to better understand how preservice teachers choose and evaluate digital math games for ELLs in additional content areas of mathematics. To advance the field, researchers could examine preservice teachers choosing and evaluating digital math games for ELLs, then examine the preservice teachers' use of the games in a lesson they teach. This may provide better insights into how preservice teachers choose digital math games and integrate them to enhance instruction for ELLs. Future research could also revise the rubric to include five scoring categories for the academic language features that align with WIDA proficiency levels. This would allow preservice teachers to better identify how language features might indicate how a digital math game better supports ELL students at different English proficiency levels.

Limitations

The results of this study should be viewed through the lens of the limitations of this study. The small population size, the lack of diversity within the population, and the use of convenience sampling limited this study. First, there are limitations within the population due to the small number of participants recruited from one university and the lack of diversity within the convenience sampling of participants. Thus, generalizability across populations is limited because the sample does not represent all characteristics of every preservice teacher that completes the university requirements to become a practicing teacher (Terrell, 2015). Another limitation was the short time (i.e., 4 hours) that preservice teachers interacted with the modules in this study. Due to this short duration, preservice teachers could not learn how to determine the appropriateness of input for ELL students at different WIDA proficiency levels. Instead, preservice teachers focused on the appropriateness of input based on grade and mathematics content. Additionally, I was the only coder for the qualitative data analysis, creating the potential for bias of the researcher's influence on the qualitative coding process. Given these limitations, future research should use a larger and more representative population by sampling preservice teachers across diverse populations.

Conclusion

The results of this study indicated that preservice teachers' felt better prepared to integrate digital math games into mathematics instruction for ELLs after participating in the learning modules. There were significant changes in preservice teachers' beliefs about

their preparation for using digital math games to support mathematics learning for ELLs from pre- to post-survey. Preservice teachers also self-reported changes in their awareness of the design features and academic language features in the digital math games. This indicates that the learning modules, and the processes that the preservice teachers engaged in while evaluating the digital math games, supported positive changes in their beliefs, increased awareness of the features, and ability to choose and evaluate features of the digital math games for ELLs.

These findings advance the research literature about innovative experiences for preparing preservice teachers to choose and evaluate digital math games. These results can provide a model of how to help preservice teachers develop an awareness of design features and academic language features in digital math games, which can lead to preservice teachers effectively using digital math games to enhance mathematics instruction for ELLs.

REFERENCES

- Adams, T. L. (2003). Reading mathematics: More than words can say. *The Reading Teacher*, 56(8), 786-795. <http://www.jstor.org/stable/20205297>
- Aguirre, J. M., & Zavala, M. D. R. (2012). Making culturally responsive mathematics teaching explicit: A lesson analysis tool. *Pedagogies: An International Journal*, 8(2), 163-190. <https://doi.org/10.1080/1554480X.2013.768518>
- Andrews, S. (2001). The language awareness of the L2 teacher: Its impact upon pedagogical practice. *Language Awareness*, 10(2-3), 75-90. <https://doi.org/10.1080/09658410108667027>
- Andrews, S. (2007). *Teacher language awareness*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511497643>
- Avraamidou, A., Monaghan, J., & Walker, A. (2012). Abstraction through game play. *Technology, Knowledge and Learning*, 17, 1-21. <https://doi.org/10.1007/s10758-012-9189-2>
- Bedwell, W. L., Pavlas, D., Heyne, K., Lazzara, E. H., & Salas, E. (2012). Toward a taxonomy linking game attribute to learning: An empirical study. *Simulation & Gaming*, 43(6), 729-760. <https://doi.org/10.1177/1046878112439444>
- Belbase, S. (2015). A preservice mathematics teacher's beliefs about teaching mathematics in technology. *International Journal of Research in Education and Science*, 1(1), 31-44. <https://doi.org/10.21890/ijres.36926>
- Benton, L., Saunders, P., Kalas, I., Hoyles, C., & Noss, R. (2018). Designing for learning mathematics through programming: A case study of pupils engaging with place value. *International journal of child-computer interaction*, 16, 68-76. <https://doi.org/10.1016/J.IJCCI.2017.12.004>
- Boone, H. N., & Boone, D. A. (2012). Analyzing Likert data. *Journal of Extension*, 50(2), 1-5. <https://tigerprints.clemson.edu/joe/vol50/iss2/48>
- Boyer-Thurgood, J. M. (2017). *The anatomy of virtual manipulatives apps: Using grounded theory to conceptualize and evaluate educational mathematics apps* (Doctoral Dissertation). Utah State University. <https://doi.org/10.26076/9f1f-0a04>
- Callaghan, M. N., & Reich, S. M. (2018). Are educational preschool apps designed to teach? An analysis of the app market. *Learning, Media and Technology*, 43(3), 280-293. <https://doi.org/10.1080/17439884.2018.1498355>

- Capraro, M. M., Nite, S., Koplara, M., Capraro, R., Morgan, J., & Barrosa, L. (2015). Appropriate technology in STEM education: Using a rubric to assess iPad Apps. In *Proceedings of E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education* (pp. 1719-1725). Kona, HI: Association for the Advancement of Computing in Education (AACE). <https://www.learntechlib.org/primary/p/152219/>
- Castellar, E. N., All, A., Marez, L., D., & Looy, J. V. (2015). Cognitive abilities, digital games and arithmetic performance enhancement: A study comparing the effects of a math game and paper exercises. *Computers & Education*, 85, 123-133. <https://doi.org/10.1016/j.compedu.2013.12.021>
- Clariana, R. B., Wagner, D., & Murphey, L. C. R. (2000). Applying a connectionist description of feedback timing. *Educational Technology Research and Development*, 48(3), 5-21. <https://doi.org/10.1007/BF02319855>
- Clark, S. L., & Andreasen L. (2021). Exploring elementary teacher self-efficacy and teacher beliefs: Are we preparing teachers to teach culturally diverse students? *Asia-Pacific Journal of Teacher Education*, 49(1), 128-142, <https://doi.org/10.1080/1359866X.2020.1777528>
- Clason, D. L., & Dormody, T. J. (1994). Analyzing data measured by individual Likert-type items. *Journal of Agriculture Education*, 35(4), 31-35. <https://doi.org/10.5032/jae.1994.04031>
- Coady, M., Harper, C., & de Jong, E. (2011). From preservice to practice: Mainstream elementary teacher beliefs of preparation and efficacy with English language learners in the state of Florida. *Bilingual Research Journal*, 34(2), 223-239. <https://doi.org/10.1080.15235882.2011.597823>
- Common Core State Standards. (2010). Washington, DC: National Governors Association Center for Best Practices & Council of Chief State School Officers.
- Cooksey, R. W. (2020). *Illustrating statistical procedures: Finding meaning in quantitative data*. Springer Singapore. https://doi.org/10.1007/978-981-15-2537-7_5
- Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publication Inc.
- Creswell, J. W., & Poth, C. N. (2017). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE Publication Inc.
- De Bock, D., Neyens, D., & Van Dooren, W. (2017). Students' ability to connect function properties to different types of elementary functions: An empirical study on the role of external representations. *International Journal of Science and*

Mathematics Education, 15(5), 939–955. <https://doi.org/10.1007/s10763-016-9724-z>

- Denham, A. R. (2015). Supporting conceptual understanding of the associative and distributive properties through digital gameplay. *Journal of Computer Assisted Learning*, 31(6), 706-721. <https://doi.org/10.1111/jcal.12113>
- Durgunoglu, A. Y., & Hughes, T. (2010). How prepared are the U.S. preservice teachers to teach English language learners? *International Journal of Teaching and Learning in Higher Education*, 22(1), 32-41.
- Echevarria, J., Short, D. J., & Vogt, M. E. (1999). *Making content comprehensible for English language learners: The SIOP Model*. Prentice-Hall.
- Echevarria, J., Vogt, M. E., & Short, D. J. (2010). *The SIOP model for teaching mathematics to English learners*. Pearson.
- Echevarria, J., Vogt, M. E., & Short, D. J. (2017). *Making content comprehensible for English learners: The SIOP model*. Pearson.
- Ellis, R. (2015). *Understanding second language acquisition*. Oxford University Press.
- Falloon, G. (2013). Young students using iPads: App design and content influences on their learning pathways. *Computers & Education*, 68, 505-521. <https://doi.org/10.1016/j.compedu.2013.06.006>
- Falloon, G. (2014). What's going on behind the screens? *Journal of Computer Assisted Learning*, 30(4), 318-336. <https://doi.org/10.1111/jcal.12044>
- Franklin, T. (2011). Special issue: Digital games and simulations in teacher preparation. *Journal of Technology and Teacher Education*, 19(2), 239-242. <https://www.learntechlib.org/primary/p/38515/>
- Gándara, P., Maxwell-Jolly, J., & Driscoll, A. (2005). *Listening to teachers of English language learners: A survey of California teachers' challenges, experiences, and professional development needs*. University of California Linguistic Minority Research Institute. <https://escholarship.org/uc/item/6430628z>
- Ganesh, T. G., & Middleton, J. A. (2006). Challenges in linguistically and culturally diverse elementary settings with math instruction using learning technologies. *Urban Review*, 2, 101-143. <https://doi.org/10.1007/s11256-006-0025-7>
- Gass, S. M., Plonsky, L., & Behney, J. (2013). *Second language acquisition: An introductory course* (4th ed.). Routledge. <https://doi.org/10.4324/9780203137093>

- Gavriushenko, M., Karilainen, L., & Kankaanranta, M. (2015, October 21-24). Adaptive systems as enablers of feedback in English language learning game-based environments. *2015 IEEE Frontiers in Education Conference (FIE)*, El Paso, TX. <https://doi.org/10.1109/fie.2015.7344107>
- Gee, J. P. (2007). *What video games have to teach us about learning and literacy*. St. Martin's Griffin.
- Gibson, S. (2002). Incorporating computer-based learning into preservice education courses. *Contemporary Issues in Technology and Teacher Education*, 2(1), 97-118. <https://www.learntechlib.org/primary/p/14518/>
- Goldin, G. A. (2003). Representation in school mathematics: A unifying research perspective. In J. Kilpatrick, W. G. Martin, & D. Schifter (Eds.), *A research companion to principles and standards for school mathematics* (pp. 275-285). National Council of Teachers of Mathematics.
- Grandgenett, N. F. (2008). Perhaps a matter of imagination: TPCK in mathematics education. In *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* (pp. 145-166). AACTE Committee on Innovation and Technology.
- Gresalfi, M. S., Rittle-Johnson, B., Loehr, A., & Nichols, I. (2018). Design matters: Exploration of content and design in fraction games. *Educational Technology Research Development*, 66, 579-596. <https://doi.org/10.1007/s11423-017-9557-7>
- Gutiérrez-Fallas, L. F., & Henriques, A. (2021). Design principles of a TPACK-based experience in mathematics pre-service teacher education. *Zetetike*, 29, 1-20. <https://doi.org/10.20396/zet.v29i00.8661780>
- Halliday, M. A. K. (1978). Sociolinguistics aspects of mathematical education. In M. Halliday (Ed.), *The social interpretation of language and meaning* (pp. 194-204). University Park.
- Handal, B., Campbell, C., Cavanagh, M., & Petocs, P. (2016). Characterizing the perceived value of mathematics educational apps in preservice teachers. *Mathematics Education Research Journal*, 28, 199-221. <https://doi.org/10.1007/s13394-015-0160-0>
- Hansen-Thomas, H., Langman, J., & Sokoloski, T. F. (2018). The role of language objectives: Strengthening math and science teachers' language awareness with emergent bilinguals in secondary classrooms. *LACLIL*, 11(2), 193-214. <https://doi.org/10.5294/laclil.2018.11.2.2>
- Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, 11(1), 81-112. <https://doi.org/10.3102/003465430298487>

- Hsu, C-Y., Liang, J-C., Chai, C. S., & Tsai, C-C. (2013). Exploring preschool teachers' technological pedagogical content knowledge of educational games. *Journal of Educational Computing Research*, 49(4), 461-479. <https://doi.org/10.2190/EC.49.4.c>
- Hsu, C-Y., Liang, J-C., Chuang, T-Y., Chai, C. S., & Tsai, C-C. (2020). Probing in-service elementary school teachers' perception of TPACK for games, attitudes towards games, and actual teaching usage: A study of their structural models and teaching experiences. *Educational Studies*. <https://doi.org/10.1080/03055698.2020.1729099>
- Hsu, C-Y., Tsai, M-J., Chang, Y-H., & Liang, J-C. (2017). Surveying in-service teachers' beliefs about game-based learning and perceptions of technological pedagogical content knowledge of games. *Educational and Society*, 20(1), 134-143. <https://www.jstor.org/stable/jeductechsoci.20.1.134>
- Huerta, M., Garza, T., Murukutla, M., & Zhang, X. (2022). Pre-and in-service teacher attitude related to English learner instruction in content-areas: A mixed-method study. *Teaching and Teacher Education*, 119, 103867. <https://doi.org/10.1016/j.tate.2022.103867>
- Hummel, K. M. (2014). *Introducing second language acquisition: Perspectives and practices*. Wiley-Blackwell.
- Ke, F. (2013). Computer-game-based tutoring of mathematics. *Computers & Education*, 60, 448-457. <https://doi.org/10.1016/j.compedu.2012.08.012>
- Ke, F., & Abras, T. (2013). Games for engaged learning of middle school children with special learning needs. *British Journal of Educational Technology*, 44(2), 225-242. <https://doi.org/10.1111/j.1467-8535.2012.01326.x>
- Krashen, S. D. (1982). *Principles and practice in second language acquisition*. Pergamon Press Inc.
- Kruz, T. L., Gomez, C., & Jimenez-Silva, M. (2017). Guiding preservice teachers to adapt mathematics word problems through interactions with ELLs. *Journal of Urban Mathematics Education*, 10(1), 32-51. <https://doi.org/10.21423/jume-v10i1a291>
- Lachner, A., Fabian, A., Franke, U., Preiß, J., Jacob, L., Führer, C., Küchler, U., Paravicini, W., Randler, C., & Thomas, P. (2021). Fostering pre-service teachers' technological pedagogical content knowledge (TPACK): A quasi-experimental field study. *Computers & Education*, 174, 104304. <https://doi.org/10.1016/j.compedu.2021.104304>

- Li, Q. (2013). Digital games and learning: A study of preservice teachers' perception. *International Journal of Play*, 2(2), 101-116. <https://doi.org/10.1080/21594932.2013.817105>
- Lichtman, K., & VanPatten, B. (2021). Was Krashen right? Forty years later. *Foreign Language Annals*, 54(2), 283–305. <https://doi.org/10.1111/flan.12552>
- Lindahl, K. (2013). *Exploring an invisible medium: Teacher language awareness among preservice k12 educators of English language learners*. (Doctoral Dissertation). University of Utah.
- Lindahl, K. (2019). Teacher language awareness development and its implication for new educators. *The New Educator*, 15(2), 85-100. <https://doi.org/10.1080/154788X.2018.1526356>
- Lindahl, K., & Watkins, N. M. (2014). What's on the "LO" menu? Supporting academic language development. *The Clearing House*, 87, 197-203. <https://doi.org/10.1080/00098655.2014.918531>
- Long, M. (1983). Native speaker/non-native speaker conversation in the second language classroom. In M. Long & C. Richards (Eds.), *Methodology in TESOL: A book of readings* (pp. 339-354). Newbury House.
- López, O. S. (2010). The digital learning classroom: Improving English language learners' academic success in mathematics and reading using interactive whiteboard technology. *Computers & Education*, 54(4), 901-915. <https://doi.org/10.1016/j.compedu.2009.09.019>
- Lucas, T., Strom, K., Bratkovich, M., & Wnuk, J. (2018). Inservice preparation for mainstream teachers of English language learners: A review of the empirical literature. *The Educational Forum*, 82(2), 156-173. <https://doi.org/10.1080/00131725.2018.1420852>
- Lucas, T., & Villegas, A. M. (2010). The missing piece in teacher education: The preparation of linguistically responsive teachers. *National Society for the Study of Education*, 109(2), 297-318. <https://doi.org/10.1177/016146811011201402>
- Lucas, T., & Villegas, A. M. (2013). Preparing linguistically responsive teachers: Laying the foundation in preservice education. *Theory Into Practice*, 52(2), 98-109. <https://doi.org/10.1080/00405841.2013.770327>
- Lucas, T., Villegas, A. M., & Freedson-Gonzalez, M. (2008). Linguistically responsive teacher education preparing classroom teachers to teach English language learners. *Journal of Teacher Education*, 59(4), 361-373. <https://doi.org/10.1177/0022487108322110>

- Lux, N. J., Bangert, A. W., & Whittier, D. B. (2011). The development of an instrument to assess preservice teacher's technological pedagogical content knowledge. *Journal of Educational Computing Research*, 45(4), 415-431. <https://doi.org/10.2190/EC.45.4.c>
- Marton, F., & Booth, S. (1997). *Learning and awareness*. Routledge.
- McFarland, J., Hussar, B., Zhang, J., Wang, X., Wang, K., Hein, S., Diliberti, M., Forrest Cataldi, E., Bullock Mann, F., & Barmer, A. (2019). *The condition of education 2019* (NCES 2019-144). U.S. Department of Education. National Center for Education Statistics. <https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2019144>
- McGinnis, J. R., Kramer, S., Shama, G., Graeber, A. O., Parker, C. A., & Watanabe, T. (2002). Undergraduates' attitudes and beliefs about subject matter and pedagogy measured periodically in a reform-based mathematics and science teacher preparation program. *Journal of Research in Science Teaching*, 39(8), 713–737. <https://doi.org/10.1002/tea.10042>
- McLeman, L., & Fernandes, A. (2012). Unpacking preservice teachers' beliefs: A look at language and culture in the context of the mathematics education English learners. *Journal of Mathematics Education*, 5(1), 121-135. <https://doi.org/10.5951/matheaceduc.1.1.0010>
- Meletioui-Mavrotheris, M., & Prodromou, T. (2016). Pre-service teacher training on game-enhanced mathematics teaching and learning. *Technology, Knowledge and Learning*, 21, 379-399. <https://doi.org/10.1007/s10758-016-9275-y>
- Metz, M. (2018). Pedagogical content knowledge for teaching critical language awareness: The importance of valuing student knowledge. *Urban Education*, 1-29. <https://doi.org/10.1177/0042085918756714>
- Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017-1054. <https://doi.org.10.1111/j.1467-9620.2006.00684x>
- Moschkovich, J. (2013). Principles and guidelines for equitable mathematics teaching practices and materials for English language learners. *Journal of Urban Mathematics Education*, 6(1), 45-57.
- Moyer-Packenham, P. S., Ashby, M. J., Litster, K., Roxburgh, A. L., & Kozlowski, J. S. (2020). Examining how design features promote children's awareness of affordances in digital math games. *Journal of Computers in Mathematics and Science Teaching*, 39(2), 169-180. <https://www.learntechlib.org/primar/p/210963/>

- Moyer-Packenham, P. S., & Bolyard, J. J. (2016). Revisiting the definition of a virtual manipulative. In P. S. Moyer-Packenham (Ed.), *International perspectives on teaching and learning mathematics with virtual manipulatives* (pp. 3–23). Springer. https://doi.org/10.1007/978-3-319-32718-1_1
- Moyer-Packenham, P. S., Litster, K., Roxburgh, A. L., Kozlowski, J. S., & Ashby, M. J. (2019). Relationships between mathematical language, representation connections, and learning outcomes in digital games. In D. C. Gibson & M. N. Ochoa (Eds.), *Research highlights in technology and teacher education 2019* (pp. 55-64). Association for the Advancement of Computing in Education (AACE).
- Moyer-Packenham, P., Lommatsch, C. W., Litster, K., Ashby, M. J., Bullock, E. K., Roxburgh, A., Shumway, J., Speed, E., Covington, B., Hartmann, C. Clarke-Midura, J., Skaria, J., Westenshow, A., MacDonald, B., Symanzik, J., & Jordan, K. (2019). How design features in digital math games support learning and mathematics connections. *Computers in Human Behavior, 91*, 316-332. <https://doi.org/10.1016/j.chb.2018.09.036>
- Namukasa, I. K., Gadanidis, G., Sarina, V., Scucuglia, S., & Aryee, K. (2016). Selection of Apps for teaching difficult mathematics topics: An instrument to evaluate touch-screen tablet and smartphone mathematics apps. In P. Moyer-Packenham (Ed.), *International perspectives on teaching and learning mathematics with virtual manipulatives mathematics education in the digital era* (pp. 275-300). Springer. http://doi.org/10.1007/978-3-319-32718-1_12
- National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston.
- National Education Association. (2011). *Professional development for general education teachers of English language learners*. http://www.nea.org/assets/docs/PB32_ELL11.pdf
- Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technological pedagogical content knowledge. *Teaching and Teacher Education, 21*, 509-523. <https://doi.org/10.1016/j.tate.2005.03.006>
- O'Rourke, J., Main, S., & Hill, S. M. (2017). Commercially available digital game technology in the classroom: Improving automaticity in mental-maths in primary-aged students. *Australian Journal of Teacher Education, 42*(10). <http://dx.doi.org/10.14221/ajte.2017v42n10.4>
- Petri, G., & Gresse von Wangenheim, D. C. (2016). How to evaluate educational games: A systematic literature review. *Journal of Universal Computer Science, 22*(7), 992-1021.

- Richards, J. C. (1998). *Beyond training: Perspective on language teacher education*. Cambridge University Press. <https://doi.org/10.1590/S1984-63982001000100010>
- Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.). *Handbook of research on teacher education* (2nd ed., pp. 102-119). Macmillan. <https://doi.org/10.4324/9780203938690>
- Reeves, J. R. (2006). Secondary teacher attitudes towards including English-language learners in mainstream classrooms. *The Journal of Educational Research*, 99(3), 131-142. <https://doi.org/10.3200/JOER.99.3.131-143>
- Robbins, N. B., & Heiberger, R. M. (2011). Plotting Likert and other rating scales. In *Proceedings of JSM* (pp. 1058-1066). Alexandria, VA, United States: American Statistical Association.
- Rüth, M., Birke, A., & Kaspar, K. (2022). Teaching with digital games: How intentions to adopt digital game-based learning are related to personal characteristics of pre-service teachers. *British Journal of Educational Technology*, 53(5), 1412–1429. <https://doi.org/10.1111/bjet.13201>
- Saldaña, J. (2016). *The coding manual for qualitative researchers*. SAGE Publication Inc.
- Sardone, N., & Devlin-Scherer, R. (2009). Teacher candidates' views of digital games as learning devices. *Issues in Teacher Education*, 18(2), 47-67.
- Sardone, N., & Devlin-Scherer, R. (2010). Teacher candidate responses to digital games. *Journal of Research on Technology in Education*, 42(4), 409-425. <https://doi.org/10.1080/15391523.2010.10782558>
- Schleppegrell, M. S. (2004). *The language of schooling: A functional linguistic perspective*. Lawrence Erlbaum.
- Schleppegrell, M. S. (2007). The linguistic challenges of mathematics teaching and learning: A research review. *Reading & Writing Quarterly*, 23, 139-159. <https://doi.org/10.1080/1057356060118461>
- Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK). *Journal of Research on Technology in Education*, 42(2), 123-149. <https://doi.org/10.1080/15391523.2009.10782544>
- Sedig, K. (2008). From play to thoughtful learning: A design strategy to engage children with mathematical representations. *Journal of Computers in Mathematics and Science Teaching*, 27(1), 65–101. <https://www.learntechlib.org/primary/p/23627/>

- Sedig, K., & Liang H. (2006). Interactivity of visual mathematical representations: Factors affecting learning and cognitive processes. *Journal of Interactive Learning Research*, 17(2), 179-212. <https://www.learntechlib.org/primary/p/6138/>
- Shah, M., & Foster A. (2015). Developing and assessing teachers' knowledge of game-based learning. *Journal of Technology and Teacher Education*, 23(2), 241-267. <https://www.learntechlib.org/primary/p/147391/>
- Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, 78(1), 153-189. <https://doi.org/10.3102/0034654307313795>
- Siew, P. H. (2018). Pedagogical change in mathematics learning: Harnessing the power of digital game-based learning. *Educational Technology & Society*, 21(4), 259–276. <http://www.jstor.org/stable/26511553>
- South, L., Saffo, D., Vitek, O., Dunne, C., & Borkin, M. (2022). Effective use of Likert scales in visualization evaluations: A systematic review. *Computer Graphics Forum*, 41(3), 43-55. <https://doi.org/10.31219/osf.io/6f3zs>
- Squire, K. (2006). From content to context: Videogames as designed experience. *Educational Researcher*, 35(8), 19-29. <https://doi.org/10.3102/00131189X035008019>
- Swain, M. (1985). Communicative competence: Some roles of comprehensible input and comprehensible output in its development. In S. Gass, & C. Madden (Eds.), *Input in second language acquisition* (pp. 235-253). Newbury House.
- Takeuchi, L. M., & Vaala, S. (2014). *Level up learning: A national survey on teaching with digital games*. The Joan Ganz Cooney Center at Sesame Workshop. <https://files.eric.ed.gov/fulltext/ED555585.pdf>
- Tashakkori, A., & Teddlie, C. (2010). *Handbook of mixed methods in social and behavioral sciences* (2nd ed.). SAGE Publications. <https://doi.org/10.4135/9781506335193>
- Terrell, S. R. (2015). *Writing a proposal for your dissertation: Guidelines and examples*. Guilford Press.
- Thornbury, S. (2017). *About language* (2nd ed.). Cambridge University Press.
- Turken, S., & Jong, E., J., D. (2018). An exploration of preservice teachers' reasoning about teaching mathematics to English language learners. *Teacher Education Quarterly*, 45(2), 37-59. <https://doi.org/10.2307/90020314>

- Von Esch, K. S., & Kavanagh, S. S. (2018). Preparing mainstream classroom teachers of English learner students: Grounding practice-based designs for teacher learning in theories of adaptive expertise development. *Journal of Teacher Education*, 69(3), 239-251. <https://doi.org/10.1177/0022487117717467>
- Watts, C. C., Moyer-Packenham, P. P., Tucker, S. S., Bullock, E. E., Shumway, J. J., Westenskow, A. A., Boyer-Thurgood, J., Anderson-Pence, K., Mahamane, S., & Jordan, K. K. (2016). An examination of children's learning progression shifts while using touch screen virtual manipulative mathematics apps. *Computers In Human Behavior*, 64, 814-828. <https://doi.org/10.1016/j.chb.2016.07.029>
- White, L. (1987). Against comprehensible input: The Input Hypothesis and the development of second-language competence. *Applied Linguistics*, 8(2), 95–110. <https://doi.org/10.1093/applin/8.2.95>
- White, T., & Pea, R. (2011). Distributed by design: On promises and pitfalls of collaborative learning with multiple representations. *Journal of the Learning sciences*, 20(3), 489-547. <https://doi.org/10.1080/10508406.2010.542700>
- WIDA. (2012). *Amplification of the English language development standards kindergarten-grade 12*. <https://wida.wisc.edu/sites/default/files/resource/2012-ELD-Standards.pdf>

APPENDICES

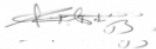

Appendix A

Institutional Review Board (IRB) Approval



Institutional Review Board

Expedite #7
Letter of Approval

From: Melanie Domenech Rodriguez, IRB Chair 
Nicole Vouvalis, IRB Director 

To: **Patricia Moyer-Packenham**

Date: **April 7, 2021**

Protocol #: **11852**

Title: **How Preservice Teachers' Awareness of Design Features and Academic Language Features Relates to Choosing and Evaluating Digital Math Games for English Language Learners**

Your proposal has been reviewed by the Institutional Review Board and is approved under expedite procedure #7 (based on the Department of Health and Human Services (DHHS) regulations for the protection of human research subjects, 45 CFR Part 46, as amended to include provisions of the Federal Policy for the Protection of Human Subjects, January 21, 2019):

Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

This study is subject to ongoing COVID-19 related restrictions. As of March 15, 2020, the IRB has temporarily paused all in person research activities, including but not limited to recruitment, informed consent, data collection and data analysis that involves personal interaction (such as member checking and meaning-making). If research cannot be paused, please file an amendment to your protocol modifying procedures that are conducted in person. The IRB will notify you when in person research activities are once again permitted.

This approval applies only to the proposal currently on file for the period of approval specified in the protocol. You will be asked to submit an annual check in around the anniversary of the date of original approval. As part of the IRB's quality assurance procedures, this research may also be randomly selected for audit. If so, you will receive a request for completion of an Audit Report form during the month of the anniversary date of original approval. If the proposal will be active for more than five years, it will undergo a full continuation review every fifth year.

Any change affecting human subjects, including extension of the expiration date, must be approved by the IRB **prior** to implementation by submitting an Amendment request. Injuries or any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Institutional Review Board. If Non-USU Personnel will complete work on this project, they may not begin until an External Researcher Agreement or Reliance Agreement has been fully executed by USU and the appropriate Non-USU entity, regardless of the protocol approval status here at USU.

Prior to involving human subjects, properly executed informed consent must be obtained from each subject or from an authorized representative, and documentation of informed consent must be kept on file for at least three years after the project ends. Each subject must be furnished with a copy of the informed consent document for their personal records.

Upon receipt of this memo, you may begin your research. If you have questions, please call the IRB office at (435) 797-1821 or email to irb@usu.edu.

The IRB wishes you success with your research.

435.797.1821 | 1450 Old Main Hill | Logan, UT 84322 | MAIN 155 | irb@usu.edu | FWA#00003308

Appendix B

Preservice Teachers' Beliefs about Preparation with Digital Math
Games for ELLs Survey

Preservice Teachers' Beliefs about Preparation with Digital Math Games for ELLs Survey

Part 1: Likert Scale Ratings

Item		Strongly Disagree					Strongly Agree
1	I feel confident in choosing linguistically appropriate learning experiences for English language learners in mathematics.	1	2	3	4	5	6
2	I feel prepared to choose learning experiences that meet the needs of English language learners in mathematics.	1	2	3	4	5	6
3	I have adequate training to work with English language learners.	1	2	3	4	5	6
4	I have adequate training to integrate digital math games into mathematics instruction.	1	2	3	4	5	6
5	Using digital math games in mathematics lessons can improve students' understanding of mathematics.	1	2	3	4	5	6
6	I can identify the knowledge related to the mathematics in digital math games.	1	2	3	4	5	6
7	I can tell when the digital math games represent the targeted mathematics knowledge.	1	2	3	4	5	6
8	I can identify whether the targeted mathematics concepts are displayed in digital math games.	1	2	3	4	5	6
9	Game features in digital math games can help students learn mathematics content.	1	2	3	4	5	6
10	I can identify design features in digital math games that can support learning.	1	2	3	4	5	6
11	I understand the language demands in mathematics that may impact learning for English language learners.	1	2	3	4	5	6
12	I can identify language demands in digital math games that may impact learning for English language learners.	1	2	3	4	5	6

Part 2: Open-Ended Responses

	Item	Response
1	What are some of the things teachers need to know in order to integrate digital math games in mathematics instruction for English language learners?	
2	What are three gaming features most important to you? <ul style="list-style-type: none"> • Accuracy Feedback • Multiple Attempts • Hints/Tutorials • Focused Constraint • Progressive Levels • Game Efficiency • Linked Representation • Linked Physical Action Explain why each one is important.	
3	What academic language features in digital math games are important to learning mathematics? <ul style="list-style-type: none"> • Appropriate level for age-group/content • Amount of speech • Symbols • Visual support • Speech density • Multiple meaning of words and phrases • Simple sentences • Use of first language Explain why each one is important.	

Note. Items were adapted from the research literature on digital math games and teacher beliefs about ELLs

Demographics

Name								
Gender								
Age								
How would you best describe yourself?	Native American, American Indian, or Alaska Native	Asian	Black/African American	Native Hawaiian or Other Pacific Islander	Hispanic/LatinX/Spanish origin	White	Other	Prefer not to say
Do you speak a second language?	Yes. Please specify which language(s).				No, I only speak English			
Grade Prefer to Teach	Early Elementary (K-2)				Upper Elementary (3-5)			
Have you taken 4061?	Yes, during _____ (Please indicate which semester. For example, Spring 2021)				No.			
Have you taken 4062?	Yes, during _____ (Please indicate which semester. For example, Spring 2021)				No.			

Appendix C

Digital Math Game Evaluation Rubric

Digital Math Game Evaluation Rubric

Game Title:

Part 1: Game Overview

1. What is the objective(s) of the game?
2. What academic content and skills can be learned from this game?
3. What is your overall impression of the game?
4. How does the digital math game use language to support academic language development for English language learners?

Part 2: Evaluating Design Features

Design Feature	1	2	3
Accuracy Feedback	Accuracy feedback is given by showing the correct answer without explaining why the answer was incorrect.	Accuracy feedback is minimally provided with explanations as to why the answer is correct or incorrect.	Accuracy feedback is provided with explicit explanation as to why the answer was correct or incorrect.
Multiple Attempts	One attempt is provided for students to experiment with mathematical concepts.	Limited attempts are provided for students to experiment with mathematical concepts.	Multiple or unlimited attempts are provided for students to experiment with mathematical concepts.
Hints/ Tutorials	No hints or tutorials are provided to explain the game or what to do next.	Limited hints or tutorials are provided to explain the game or what to do next.	Appropriate amount of hints or tutorials are provided to explain the game or what to do next.
Focused Constraint	Game does not break down content into smaller parts to support learning.	Some of the content components are broken into smaller parts to support learning.	Game appropriately breaks up content components into smaller parts to support learning.
Progressive Levels	Only one level of difficulty that limits students' experiences.	At least three levels of difficulty (e.g., easy, medium, high).	Multiple levels of difficulty that provides personalized learning experiences.
Game Efficiency	There are no features that promoted students to be more efficient.	Limited features were used to help students be more efficient.	Multiple features were used to help students be more efficient.
Mathematics learning	The game focuses on low-level mathematics learning and only uses drill-and-practice.	The game provides limited problem-solving experiences where students use some skills, but still contains drill-and-practice.	The game provides a challenging problem-solving experience where students use higher-order skills to learn content.
Linked Representations	No representations were linked in the game.	Limited representations were linked in the game.	Multiple representations were linked in the game.
Linked Physical Action	There were no links between physical actions of the game and the mathematics.	Some links were made between physical actions in the game and the mathematics.	Multiple links were made between physical actions and mathematics in the game.

Note. Design features are based on design feature literature (Avraamidou et al., 2012; Benton et al., 2018; Boyer-Thurgood, 2017; Castellar et al., 2015; De Bock et al., 2017; Denham, 2015; Falloon, 2013, 2014; Gee, 2007; Hattie & Timperley, 2007; Ke & Abras 2013; Moyer-Packenham, Lommatsch, et al., 2019; Sedig, 2008; Siew, 2018; White & Pea, 2011).

Part 3: Evaluating Academic Language Features

Language Feature	1	2	3
Appropriate level of language for age-group/content	The language is too advanced or too simplistic.	Language is appropriate for targeted age-group/content.	Language is sensitive to cultural and language diversity.
Amount of speech	The game uses a large amount of language (written or auditory) that students have to process in order to participate in the game.	The game uses a moderate amount of language (written or auditory) that students have to process in order to participate in the game.	The game uses a low amount of language (written or auditory) that students have to process in order to participate in the game.
Symbols	Symbols are used implicitly with unclear association with concepts.	Symbols are implicitly used, but promote associations with the concepts if the game is played multiple times.	Symbols are explicitly explained and help students associate the symbols with the math concepts.
Visual Support	Minimal use of visuals are provided for students to connect with language to build an understanding.	Some visuals are provided for students to connect with language to build an understanding.	Many visuals are provided for students to connect with language to build an understanding.
References require sentences to be translated into symbolic representation	Translation of sentences into symbolic representation was used with no support for students.	Translation of sentences into symbolic representation was used with little support for students.	Translation of sentences into symbolic representation was used with considerable support for students.
Speech density of formal/informal language use	Only formal mathematics language is used.	Formal mathematics language is used with limited informal language helping students build an understanding.	Formal mathematics language is used in connection with informal language to help students build an understanding.
Multiple meaning words and phrases	Words/phrases used are unclear. Students have to infer what the game is asking them to do to a great extent.	Words/phrases used are somewhat clear and explicit. Students sometimes have to infer what the game is asking them to do.	Words/phrases used are clear and explicit. Students do not have to infer what the game is asking them to do.
Simple sentences	Complex sentences were used throughout the entire game.	Some complex sentences were used, but mostly simple sentences were used throughout the game.	Simple sentences were used throughout the entire game.
Use of first language	Only uses English.	Uses mix of some L1, but mostly English.	Allows students to choose their first language to interact with the game.

Note. Academic language features are based on academic language feature literature (Adams, 2003; Ke, 2013; Lucas et al., 2008, 2018; Lucas & Villegas, 2010, 2013; Moschkovich, 2013; Moyer-Packenham, Litster et al., 2019; Schleppegrell, 2007; WIDA, 2012).

Appendix D

Module Reflections: Design Features and Academic Language Features

Module 2 Reflection: Design Features

1. Did you watch the video?
2. How would you define design features?
3. How do you think design features helped promote mathematics learning in the digital math game shown in the video?
4. What was your impression of the design features in the digital math game shown in the video?
5. What role do you think design features play in helping ELLs learn mathematics in digital math games?

Module 3 Reflection: Academic Language Features

1. Did you watch the video?
2. How would you define design features?
3. How do you think academic language features helped promote mathematics learning in the digital math game shown in the video?
4. What was your impression of the academic language features in the digital math game shown in the video?
5. What role do you think academic language features play in helping ELLs learn mathematics in digital math games?

Note. Reflection questions are based on literature about educational digital games and teacher beliefs about ELLs (Aguirre & Zavala, 2012; Sardone & Devlin-Scherer, 2009).

Appendix E

Interview Protocol: Preservice Teachers, Digital Math Games, and ELLs

Interview Protocol: Preservice Teachers, Digital Math Games, and ELLs

1. Do you feel that your teaching preparation courses have prepared you to integrate digital math games into mathematics instruction for English language learners? If so, how? If not, why? (Probe: Tell me more).
2. How did your prior experiences and impressions about using digital math games influence how you chose and evaluated games for English language learners? Did these impressions change after learning about design features and academic language features? (Probe: How so? Tell me more).
3. Do you remember the three design features most important to you at the beginning of this study? What were they? Did these design features stay the same or change when you reevaluated the digital math games? (Probe: How so? Tell me more).
4. Did the three academic language features most important to you stay the same or change when you reevaluated the digital math games? (Probe: How so? Tell me more).
5. Have your views about the role of *academic language features* in digital math games changed since you initially chose and evaluated the digital math games? If so, how?
6. Have your views about the role of *design features* in digital math games changed since you initially chose and evaluated the digital math games? If so, how?
7. Do you think your attitude has changed towards using digital math games in mathematics instruction for English language learners since choosing and evaluating the digital math games? How so? Why do you think it changed? Or why not?

Note. Questions were adapted from the research literature on digital math games and teacher beliefs about ELLs (Aguirre & Zavala, 2012; Bedwell et al., 2012; Gibson, 2002; Franklin, 2007; Shah & Foster, 2015).

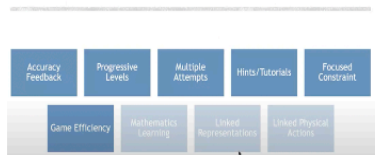
Appendix F

Learning Modules Screenshots

Module 2: Design Features

Definition of Design Features

Nine Design Features



Game attributes that can determine learning potential in digital games (Bedwell et al., 2012); elements (e.g., feedback, hints, linked representations) that are programmed to determine how a game functions (Boyer-Thurgood, 2017).

Example of Design Features

Accuracy Feedback & Progressive Levels

Accuracy Feedback

- Feedback on accuracy
 - Visual
 - Auditory
 - Numerical

Progressive Levels

- Difficulty in the game moves from easy to difficult
- Conceptual difficulty

Mathematics Learning, Linked Representations, & Linked Physical Actions

Mathematics Learning

- Level of mathematics learning
 - Low level
 - Orbit and Practice
 - Higher-order thinking
 - Problem solving
 - Connections among mathematical ideas

Linked Representations

- Game connects multiple representations
 - Shape
 - Language
 - Graphics
 - Words

Linked Physical Actions

- Game connects physical action to the mathematics
 - Threading a shape
 - Physical action refers to size

Evaluated Design Features Using Game Evaluation Rubric

Evaluating Design Features in A Digital Math Game

Evaluate the digital math game based on the 8 academic language features below on a scale of 1 to 5, where 1 is a low rating for the design feature and 5 is a high rating.

Accuracy Feedback

- 1. Feedback provided: High accuracy feedback (visual, auditory, numerical) is provided.
- 2. Feedback provided: High accuracy feedback (visual, auditory, numerical) is provided.
- 3. Feedback provided: High accuracy feedback (visual, auditory, numerical) is provided.

Multiple Attempts

- 1. Multiple attempts are provided for each question.
- 2. Multiple attempts are provided for each question.
- 3. Multiple attempts are provided for each question.

Evaluating Design Features in A Digital Math Game

Evaluate the digital math game based on the 8 academic language features below on a scale of 1 to 5, where 1 is a low rating for the design feature and 5 is a high rating.

Progressive Levels

- 1. Difficulty increases as the player progresses through the game.
- 2. Difficulty increases as the player progresses through the game.
- 3. Difficulty increases as the player progresses through the game.

Linked Representations

- 1. Game connects multiple representations (shape, language, graphics, words).
- 2. Game connects multiple representations (shape, language, graphics, words).
- 3. Game connects multiple representations (shape, language, graphics, words).

Linked Physical Actions

- 1. Game connects physical action to the mathematics (threading a shape, physical action refers to size).
- 2. Game connects physical action to the mathematics (threading a shape, physical action refers to size).
- 3. Game connects physical action to the mathematics (threading a shape, physical action refers to size).

Module 3: Academic Language Features

Definition of Academic Language Features

Nine Academic Language Features



Oral and written language that includes the language dimensions of linguistic complexities, language forms and conventions, and vocabulary usage (WIDA, 2012).

Example of Academic Language Features

Appropriate Level & Amount of Speech

Appropriate level of language for age-group/content

- The language used in the game should be appropriate for the audience
- Too simpler/difficult

Amount of Speech

- Amount of speech that needs to be processed in order to understand the game
- Too much

Multiple Meaning Words and Phrases, Simple Sentences, & Use of First Language

Multiple Meaning words and Phrases

- Clarity of words/phrases in the game
- Not clear, right/wrong, better
- Not clear, better/worse
- Range: the difference between two numbers used for cooking

Simple Sentences

- Consistency of sentences (written or auditory) used in the game
- Use of conjunctions in mathematics (and, if, when, because)

Use of First Language

- The language options are available in the game
- It only in English

Evaluated Academic Language Features Using Game Evaluation Rubric

Evaluating Academic Language Features in A Digital Math Game

Evaluate the digital math game based on the 9 academic language features below on a scale of 1 to 3, where 1 is a low rating for the academic language feature and 3 is a high rating.

Appropriate level of language for age-group/content

1 The language is too simple for the audience
2 The language is appropriate for the audience
3 The language is too difficult for the audience

Amount of speech

1 The game has a large amount of text that is not necessary for understanding the game
2 The game has a moderate amount of text that is necessary for understanding the game
3 The game has a small amount of text that is necessary for understanding the game

Evaluating Design Features in A Digital Math Game

Evaluate the digital math game based on the 8 academic language features below on a scale of 1 to 3, where 1 is a low rating for the design feature and 3 is a high rating.

Multiple Meaning Words and Phrases

1 The language is not clear
2 The language is clear
3 The language is very clear

Simple Sentences

1 The sentences are not consistent
2 The sentences are consistent
3 The sentences are very consistent

Use of First Language

1 The language options are not available
2 The language options are available
3 The language options are very available

CURRICULUM VITAE**ALLISON L. ROXBURGH**

801-608-1844

alroxburgh@gmail.com

EDUCATION

- Ph.D. Expected December 2022
Education, Utah State University
Specialization: Curriculum and Instruction
Concentration: Mathematics Education and Leadership
Dissertation: *How Preservice Teachers Develop Awareness and Beliefs about Design Features and Academic Language Features When Choosing and Evaluating Digital Math Games for English Language Learners.*
(Chair: Patricia S. Moyer-Packenham)
- M.Ed. Expected December 2022
Masters of Education, Utah State University
Concentration: Instructional Technology
- M.Ed. December 2016
Masters of Education, Utah State University
Mathematics Endorsement
- B.S. December 2012
Elementary Education, Utah State University
Level 2 Elementary Teaching Certificate (1-8), Utah

EMPLOYMENT HISTORY**University Of Northern Colorado**

Adjunct Professor & Teacher Candidate Supervisor (Fall 2022)
University of Northern Colorado, College of Education and Behavioral Sciences,
School of Teacher Education, Greeley, Colorado
Responsibilities include teaching a face-to-face elementary introduction course and mentoring three elementary pre-service teachers in practicum settings.

Utah State University

Adjunct Professor (Fall 2022)

Graduate Research & Teaching Assistant (2017-2022)

Presidential Doctoral Research Fellow (2018-2022)

Utah State University, College of Education & Human Services, School of Teacher Education and Leadership, Logan, Utah

Research responsibilities included collaborating with professors on various research projects in mathematics education on coding data, writing literature reviews, conducting research interviews, conducting data analyses, writing, and presenting at professional conferences. Teaching assistant responsibilities included teaching face-to-face Mathematics Methods for Elementary Teachers, mentoring pre-service teachers in practicum settings, and teaching online Masters-level Elementary Math Endorsement courses for in-service teachers.

PUBLIC SCHOOL TEACHING EXPERIENCE

Elementary School Teacher, Grade 3, all subjects (2014-2017)

Wilson Elementary, Logan, Utah

Responsibilities included planning, designing and teaching curricula in all content areas from the Utah Core Standards for third grade. Classes ranged from 19-24 ethnically diverse students, including students with resource services in math and reading, students with speech difficulties, and students with ESL services. Worked with a Professional Learning Community (PLC) to design data driven instructional assessments and interventions in a Response to Intervention (RtI) model to meet the needs of all learners.

Elementary School Teacher, Grade 4, all subjects (2013-2014)

Stansbury Park Elementary, Stansbury, Utah

Responsibilities included planning, designing and teaching curricula in all content areas from the Utah Core Standards for fourth grade. Instructed thirty ethnically diverse students, including students with resource services in math and reading, students with speech difficulties, and students with behavioral issues. Worked with a Professional Learning Community (PLC) to design data driven instructional assessments and interventions in a Response to Intervention (RtI) model to meet the needs of all learners.

AWARDS & PROFESSIONAL RECOGNITION

Presidential Doctoral Research Fellowship (\$20,000 annually). Graduate Research and Teaching Assistantship, Utah State University, Logan, UT (2018-2022).

Teacher of the Year Graduate Student Award (2021). Teacher Education and Leadership, Utah State University, Logan, UT.

Outstanding Paper Award (2018). Society for Information Technology and Teacher Education (SITE). Paper: Moyer-Packenham, P. S., Lommatsch, C., Litster, K., Ashby, M. J., & **Roxburgh, A.** (2018). The role of design features in the affordances of digital math games. In E. Langran & J. Borup (Eds.), *Proceedings of the Society for Information Technology and Teacher Education (SITE) International Conference* (pp. 465-473), Waynesville, NC: Association for the Advancement of Computing in Education (AACE).

School of Teacher Education and Leadership (TEAL) Scholarship (\$17,000). Graduate Research and Teaching Assistantship, Utah State University, Logan, UT (2017-2018).

RESEARCH

Research Interests:

- Socio-cultural and linguistic issues related to how students learn mathematics.
- How technology mediates mathematics learning.
- Elementary mathematics teacher education.

Research Projects:

Affordances of Virtual Manipulatives Grades 3-6 (2017 - 2022). Utah State University (with PI Dr. Patricia Moyer-Packenham and the Virtual Manipulatives Research Group). My role: analyze and code data (qualitatively code videos of interviews with interaction of mathematics iPad apps); develop and lead collaborative presentations and publications.

Fractions Group for Undergraduate Pre-Service Teachers (2019). Utah State University (With PI Dr. Diana Moss, Dr. Beth MacDonald, Dr. Claudia M. Bertolone-Smith, and Dr. Steven Boyce). My role: analyze and code data (qualitatively code videos of student explanations during a fraction lesson).

Early Count Grade 1 (2018-2019). Utah State University (with PI Dr. Beth MacDonald). My role: Witness early count activities with first grade students, help determine activities for students, analyze and code video data; collaborative presentations and publications.

PUBLICATIONS

Journal Articles (Refereed)

Moyer-Packenham, P.S., **Roxburgh, A.L.**, Litster, K., & Kozlowski, J.S. (2021). Relationships between semiotic representational transformations and performance outcomes in digital math games. *Technology, Knowledge, and Learning*.
<https://doi.org/10.1007/s10758-021-09506-5>

- Bullock, E.P., **Roxburgh, A.**, Moyer-Packenham, P.S., & Bektas, E. (2021). Connecting the dots: Understanding the interrelated impact of type, quality and children's awareness of design features and mathematics content learning goals in digital math games and related learning outcomes. *Journal of Computer Assisted Learning*, 37(2), 557-586. <https://doi.org/10.1111/jcal.12508>
- Moyer-Packenham, P. S., Ashby, M. J., Litster, K., **Roxburgh, A. L.**, & Kozlowski, J. S. (2020). Examining how design features promote children's awareness of affordances in digital math games. *Journal of Computers in Mathematics and Science Teaching*, 39(2), 169-180.
- MacDonald, B., Hunt, J., Litster, K., **Roxburgh, A.**, & Leitch, M. (2020). Diego's number understanding development through subitizing and counting. *Investigations in Mathematics Learning*, 12(4), 275-288. <https://doi.org/10.1080/19477503.2020.1824287>
- Litster, K., Lommatsch, C. W., Novak, J. R., Moyer-Packenham, P. S., Harmon, M. J., **Roxburgh, A. L.**, & Bullock, E.P. (2020). The role of gender on the associations among children's attitudes, mathematics knowledge, digital game use, perceptions of affordances, and achievement. *International Journal of Science and Mathematics Education*. <https://doi.org/10.1007/s10763-020-10111-8>
- Moyer-Packenham, P., Lommatsch, C. W., Litster, K., Ashby, M. J., **Roxburgh, A.**, Shumway, J., Speed, E., Covington, B., Hartmann, C. Clarke-Midura, J., Skaria, J., Westenshow, A., MacDonald, B., Symanzik, J., & Jordan, K. (2019) How design features in digital math games support learning and mathematics connections. *Computers in Human Behavior*, 91, 316-332. <https://doi.org/10.1016/j.chb.2018.09.036>

Book Chapter

- Moyer-Packenham, P. S., Litster, K., **Roxburgh, A. L.**, Kozlowski, J. S., & Ashby, M. J. (2019). Relationships between mathematical language, representation connections, and learning outcomes in digital games. In D. C. Gibson & M. N. Ochoa (Eds.), *Research highlights in technology and teacher education 2019* (pp. 55-64). Association for the Advancement of Computing in Education (AACE).

CONFERENCE PROCEEDINGS

- Roxburgh, A.** & Moyer-Packenham, P.S. (2022). Preservice teachers' beliefs and awareness about design features and academic language features when choosing and evaluating digital math games for English language learners. In E. Langran

(Ed.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 1549-1558). San Diego, Ca, United States: Association for the Advancement of Computing in Education (AACE).

Roxburgh, A., Moyer-Packenham, P.S., & Bullock, E. P. (2022). Relationships between students' use of gestures and learning outcomes in digital math games. In E. Langran (Ed.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 528-532). San Diego, Ca, United States: Association for the Advancement of Computing in Education (AACE).

Roxburgh, A. L., Moyer-Packenham, P., & Bullock, E. (2021). Children's use of systemic functional linguistic metafunctions during digital math gameplay. In E. Langran & L. Archambault (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 1164-1170). Online, United States: Association for the Advancement of Computing in Education (AACE).

Litster, K., Moyer-Packenham, P., Ashby, J., **Roxburgh, A.** & Kozlowski, J. (2019). Digital math games: Importance of strategy and perseverance on elementary children's learning opportunities. In K. Graziano (Ed.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 2157-2162). Las Vegas, NV, United States: Association for the Advancement of Computing in Education (AACE).

Moyer-Packenham, P., Ashby, M.J., Litster, K., **Roxburgh, A.** & Kozlowski, J.S. (2019). How design features promote children's awareness of affordances in digital math games. In K. Graziano (Ed.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 2192-2200). Las Vegas, NV, United States: Association for the Advancement of Computing in Education (AACE).

Moyer-Packenham, P. S., Lommatsch, C., Litster, K., Ashby, M. J., & **Roxburgh, A.** (2018, March). The role of design features in the affordances of digital math games. In E. Langran & J. Borup (Eds.), *Proceedings of the Society for Information Technology and Teacher Education (SITE) International Conference* (pp. 465-473), Waynesville, NC: Association for the Advancement of Computing in Education (AACE). **OUTSTANDING PAPER AWARD**

Moyer-Packenham, P. S., Litster, K., Lommatsch, C., Ashby, M. J., & **Roxburgh, A.** (2018, March). Mediators of learning in game-based mathematics apps. In E. Langran & J. Borup (Eds.), *Proceedings of the Society for Information Technology and Teacher Education (SITE) International Conference* (pp. 454-464), Waynesville, NC: Association for the Advancement of Computing in Education (AACE).

MANUSCRIPTS IN PREPARATION

Roxburgh, A. *Students' use of counting routines and number lines to build number sense.*

Roxburgh, A. *Linguistic diversity in digital math games: Critical review of the literature.*

UNIVERSITY TEACHING

Utah State University, Logan, Utah (2017-2022)
College of Education and Human Services

TEAL 6521/5521- Mathematics for Teaching K-8: Numbers and Operations (*Spring 2018, Spring 2020, Fall 2021, Fall 2022*)

Graduate course. This course, for K-8 teachers, will cover the content of Number and Operations to develop comprehensive understanding of our number system and relate its structure to computation, arithmetic, algebra, and problem solving. Online Course.

TEAL 6522/5522-Mathematics for Teaching K-8: Rational Numbers and Proportional Reasoning (*Spring 2018, Spring 2020, Fall 2021, Fall 2022*)

Graduate course. To provide practicing teachers a deeper understanding of rational numbers, operations with rational numbers, and proportionality, and instructional strategies to facilitate the instruction of this content for elementary students. Online course.

TEAL 6523/5523 - Mathematics for Teaching K-8: Algebraic Reasoning (*Spring 2018, Spring 2020, Fall 2021, Fall 2022*)

Graduate course. To provide practicing teachers a deeper understanding of algebraic expressions, equations, functions, real numbers, and instructional strategies to facilitate the instruction of this content for elementary students. Online Course.

TEAL 6524/5524 – Mathematics for Teaching K-8: Geometry and Measurement (*Spring 2018, Spring 2020, Fall 2021, Fall 2022*)

Graduate course. To provide practicing teachers a deeper understanding of the geometry and measurement context that exists in the state core and instructional strategies to facilitate the instruction of this content. Online Course.

TEAL 6525/5525- Mathematics for Teaching K-8: Data Analysis and Problem Solving (*Spring 2020, Fall 2021, Fall 2022*)

Graduate course. To provide practicing teachers a deeper understanding of probability and data representation and analysis. Online course.

TEAL 6551/5551 - Mathematics for Teaching K-8: Assessment and Intervention (*Spring 2018, Spring 2020, Fall 2021, Fall 2022*)

Graduate course. To provide practicing teachers a deeper understanding of the various types of assessment and their appropriate use for guiding instruction, intervention and evaluation of student learning. Online Course.

TEAL 6552- Mathematics Education Leadership Knowledge and Skills (*Spring 2020, Fall 2021, Fall 2022*)

Graduate course. To develop the following mathematics education leadership knowledge and skills: policy and curriculum issues; research informing instructional practice; implementation and evaluation of professional development; evaluation of educational structures that affect equity; and responsibilities of math coaches and mentors. Online course.

TEAL 6300/5560 - Special Topics: Elementary Mathematics Teaching Academy (*Spring 2018, Spring 2020, Fall 2021, Fall 2022*)

Graduate course. Field-based program focusing upon characteristics of effective teaching methodologies, teaching performance, curriculum decision making, value guidelines, and the characteristics of the learner. Online course.

EDUC 4061 – Teaching Elementary School Mathematics I: Rational Numbers, Operations, and Proportional Reasoning (*Fall 2019, Fall 2020, Spring 2021, Spring 2022, Fall 2022*)

Undergraduate Course. Develop pedagogical content knowledge in rational number, operations, and proportional reasoning for teaching grades preschool to grade 6. Understanding characteristics of instruction, assessments, and intervention are considered critically. Online Course.

EDUC 4062 - Teaching Elementary School Mathematics II: Number, Operations, and Algebraic Reasoning (*Fall 2017, Fall 2018, Spring 2019, Spring 2022*)

Undergraduate Course. Development of pedagogical content knowledge in number, operations, and algebraic reasoning for teaching grades preschool to grade 6. Methods for designing and implementing mathematics instruction, assessment, remediation, and intervention will be applied in a field-based placement. Face-to-Face Course combined with Practicum Supervision.

ITLS 5500- Integration and Innovation of Technology in Education (*Fall 2018*)

Undergraduate course. Research and practice means to creatively and effectively integrate technology into teaching and learning, based on local and national standards. Develop methods and resources to implement standards using technologies pertinent to student's field of study. Produce a portfolio of artifacts. Online Course.

University of Northern Colorado, Greeley, Colorado (2022)
College of Education and Behavioral Sciences

EDEL 101- Elementary Teaching as a Profession (Fall 2022)

Undergraduate course. Introduces the Interdisciplinary Studies Elementary Teaching major (ISET) and the Elementary Professional Teacher Education Program (PTEP). Examines professional expectations of today's elementary teachers and how UNC coursework prepares candidates for teaching. Face-to-Face Course.

CURRICULUM DEVELOPMENT

Utah State University, Logan, Utah (Summer 2019)
College of Education and Human Services

TEAL 6551/TEPD 5551: Mathematics for Teaching K-8: Assessment and Intervention. Graduate course. To provide practicing teachers a deeper understanding of the various types of assessment and their appropriate use for guiding instruction, intervention and evaluation of student learning. Materials developed included readings, video lectures, application assignments, and assessments for online course delivery. Developed nine modules as equivalent to a 15-week 3-credit course.

GRANTS FUNDED

Travel Grant, Research and Graduate Studies, School of Teacher Education and Leadership (TEAL). (\$600). Presentation at the Society for Information Technology and Teacher Education (SITE). (2022) San Diego, California.

Travel Grant, Research and Graduate Studies. (\$500). Presentation at the National Council of Teachers of Mathematics (NCTM). (2019) San Diego, California.

Travel Grant, Research and Graduate Studies, School of Teacher Education and Leadership (TEAL). (\$600). Presentation at Society For Information Technology and Teacher Education (SITE). (2018) Washington, D.C.

Battle of the Books (\$400). Logan City School District. The purpose of this grant was to buy books for third grade students to participate in a district book battle during the 2016-2017 school year. This was intended to motivate students to read and help build comprehension skills.

PRESENTATIONS

International and National Presentations

- Roxburgh, A.** & Moyer-Packenham, P.S. (2022, April). *Preservice Teachers' Beliefs and Awareness about Design Features and Academic Language Features when Choosing and Evaluating Digital Math Games for English Language Learners*. 33rd annual conference of the Society for Information Technology and Teacher Education (SITE), San Diego, CA.
- Roxburgh, A.,** Moyer-Packenham, P.S., & Bullock, E. P. (2022, April). *Relationships Between Students' Use of Gestures and Learning Outcomes in Digital Math Games*. 33rd annual conference of the Society for Information Technology and Teacher Education (SITE), San Diego, CA.
- Roxburgh, A.,** Moyer-Packenham, P. & Bullock, E. (2021, April). *Children's use of systemic functional linguistic metafunctions during digital math gameplay*. Virtual Research Paper Presentation, 31st Society for Information Technology & Teacher Education International Conference.
- Moyer-Packenham, P., S., **Roxburgh, A.,** Litster, K., & Kozloweski, J. S. (2020, April). *Students Connections Among Semiotic Representation in Digital Games and Their Influence on Mathematics Learning*. Research Paper Presentation, American Educational Research Association (AERA) Annual Meeting, San Francisco, CA. [Conference Cancelled].
- Bullock, E. K., **Roxburgh A.,** Moyer-Packenham, P. S. (2020, April). *The Importance of Quality of Design Features in Digital Math Games*. Research Paper Presentation , American Educational Research Association (AERA) Annual Meeting, San Francisco, CA. [Conference Cancelled].
- Moyer-Packenham, P. S., **Roxburgh, A. L.,** & Kozlowski, J. S. (2019, November). *Students' Uses of Mathematical Representations and Their Learning Outcomes in Digital Games*. Research Paper Presentation , School Science and Mathematics Association (SSMA) Convention, Salt Lake City, UT.
- Bullock, E.P., **Roxburgh, A.,** Moyer-Packenham, P.S., & Bektas, E. (2019, November). *The Impact of High-Quality Features in Digital Math Games on Children's Learning*. School Paper Presentation, Science and Mathematics Association (SSMA) Convention, Salt Lake City, UT.
- Kozlowski, J. S., Shumway, J., **Roxburgh, A. L.** (2019, October). *Adapting Textbook Lessons to Help Students Construct Mathematics and to Access Diverse Mathematical Knowledge*. Presentation, National Council of Teachers of

Mathematics Research Conference (NCTM) Regional Conference and Exposition, Salt Lake City, UT.

MacDonald, B. L., Litster, K., & **Roxburgh, A.** (2019, October). *Students' Actions with Early Number to Guide Educators' Instruction*. Presentation, National Council of Teachers of Mathematics (NCTM) Regional Conference and Exposition, Salt Lake City, UT.

MacDonald, B. L., Urbanek-Carney, S., & **Roxburgh, A.** (2019, October). *Supporting Students with Severe Special Education Needs in Early Number Development*. Presentation, National Council of Teachers of Mathematics (NCTM) Regional Conference and Exposition, Salt Lake City, UT.

MacDonald, B. L., **Roxburgh, A.**, & Jenson, A. (2019, October). *Tasks Which Leverage Conceptual Number Understanding for Students Identified as Low-Achieving*. Presentation, National Council of Teachers of Mathematics (NCTM) Regional Conference and Exposition, Salt Lake City, UT.

Roxburgh, A. L., & Kozlowski, J. S. (2019, October). *Fostering Mathematical Discourse Through Inquiry-Based Tasks*. Presentation, National Council of Teachers of Mathematics Research Conference (NCTM) Regional Conference and Exposition, Salt Lake City, UT.

MacDonald, B. L., Urbanek-Carney, S., & **Roxburgh, A.** (2019, April). *Supporting Students with Severe Special Education Needs in Early Number Development*. Presentation, National Council of Teachers of Mathematics (NCTM) Annual Conference and Exposition, San Diego, CA.

Hackenberg, A. J., Jones, R., Hunt, J. H., Silva, J., MacDonald, B. L., & **Roxburgh, A.** (2019, April). *Differentiating Instruction in Mathematics Education*. Research Symposium at the Presentation, Annual National Council of Teachers of Mathematics Research Conference (NCTM-R), San Diego, CA.

Moyer-Packenham, P. S., Litster, K., Ashby, M. J., **Roxburgh, A. L.**, & Bullock, E. P. (2019, April). *Design Features of Digital Math Games through the Lens of ACAT*. Research Paper Presentation, National Council of Teachers of Mathematics Research Conference (NCTM-R), San Diego, CA.

Litster, K., Moyer-Packenham, P. S., Ashby, M. J., **Roxburgh, A. L.**, & Kozlowski, J. S. (2019, March). *Digital Math Games: Importance of Strategy and Perseverance on Elementary Children's Learning Opportunities*. Research Paper Presentation, Society for Information Technology and Teacher Education (SITE), Las Vegas, NV.

Moyer-Packenham, P. S., Ashby, M. J., Litster, K., **Roxburgh, A. L.**, & Kozlowski, J. S. (2019, March). *How Design Features Promote Children's Awareness of Affordances in Digital Math Games*. Research Paper Presentation, Society for Information Technology and Teacher Education (SITE), Las Vegas, NV.

Moyer-Packenham, P. S., Litster, K., **Roxburgh, A. L.**, Kozlowski, J. S., & Ashby, M. J. (2019, March). *Relationships between Mathematical Language, Representation Connections, and Learning Outcomes in Digital Math Games*. Research Paper Presentation, Society for Information Technology and Teacher Education (SITE), Las Vegas, NV.

Moyer-Packenham, P. S., Litster, K., Lommatsch, C., Ashby, M. J., & **Roxburgh, A.** (2018, March). *Mediators of Learning in Game-Based Mathematics Apps*. Research Paper Presentation, 29th annual conference of the Society for Information Technology and Teacher Education (SITE), Washington D.C.

Moyer-Packenham, P. S., Lommatsch, C., Litster, K., Ashby, M. J., & **Roxburgh, A.** (2018, March). *The Role of Design Features in the Affordances of Digital Math Games*. Research Paper Presentation, 29th annual conference of the Society for Information Technology and Teacher Education (SITE), Washington D.C.

State Presentations

Roxburgh, A. & Jensen, A. (2018, October). *Affordances in Early Conceptual Understanding Number Tasks in Grade 1 for Low-Achieving Students*. Presentation, Annual Utah Council of Teachers of Mathematics (UCTM) Conference, Draper, UT.

Local Presentations

Roxburgh, A. (2021, April). *How Preservice Teachers' Awareness of Design Features and Academic Language Features Relates to Choosing and Evaluating Digital Math Games for English Language Learners*. Virtual Research Presentation, SRS Student Research Symposium, Utah State University, Logan, UT.

Roxburgh, A. (2020, April). *A Systemic Functional Linguistic Approach to Examining Children's Language use in Digital Math Games*. Virtual presentation. SRS Student Research Symposium, Utah State University, Logan, UT.

Roxburgh, A. (2019, April). *Preliminary Findings on the Role of Feedback Design Features on Grade 4 Student Learning Outcomes and Student Awareness of Feedback Features*. Poster Presentation, SRS Student Research Symposium, Utah

State University, Logan, UT.

Roxburgh, A. (2018, April). *Preliminary Findings on the Role of App Design on Grade 4 Student Success and Learning*. Poster Presentation, SRS Student Research Symposium, Utah State University, Logan, UT.

Litster, K., MacDonald, B. L., & **Roxburgh, A.** (2018, August). *Virtual Cookies: Online Digital Resources and Strategies to Enhance In-Class and Distance Learning Experiences and Promote an Active Learning Environment*. Presentation, Together We Teach Conference, Utah State University, Logan, UT.

CONSULTING

Utah State Board of Education (USBE)

Facilitator, Mathematics Summer Professional Learning- What the Tech (2019, May, June)

Responsibilities include presenting material for technology incorporation in mathematics classrooms for secondary and elementary school practicing teachers, supply teachers with physical and online resources, and teach them the Triple E Framework.

SERVICE

Institutional Leadership & Service, Utah State University

Application Reviewer, Undergraduate Research Fellow (April 2021)

Responsibilities included scoring applications for the Undergraduate Research Fellow award.

Peer Reviewer, COMD 2600 (December 2019)

Responsibilities include using a rubric to score an online course by reviewing content in each module and providing feedback on ways to improve the course.

Judge, Fall Undergraduate Student Research Symposium (November 2018)

Responsibilities include scoring poster presentations of five undergraduate students, scoring one oral presentation, and providing feedback on presentation delivery.

Reviewer, Undergraduate Research and Creative Opportunities (URCO) Grant (November 2018)

Responsibilities include scoring grant proposals and providing feedback to undergraduate students.

STATE SERVICES**Granite School District, Utah. Application Reviewer, Utah PTA/PTSA Student Scholarship Cyprus High School (May 2021; May 2022)**

Responsibilities included reviewing high school student essays for the PTA/PTSA student scholarship.

CONTINUOUS LEARNING & SELF-DEVELOPMENT**Professional Affiliations**

American Educational Research Association (Since 2018)

National Council of Teachers of Mathematics (Since 2018)

School Science and Mathematics Association (Since 2019)

Society for Information Technology and Teacher Education (Since 2019)

Continuing Education Units

Reading Endorsement, Northern Utah Curriculum Consortium (Spring, 2017).

Intro R for Social Researchers (Fall, 2018)

Intermediate R (Fall, 2018)