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An Expansive Framing Intervention and its Influence on Nursing Students' Perceptions of Value for Mathematics

Kimberly Evagelatos Beck
Utah State University

AN EXPANSIVE FRAMING INTERVENTION AND ITS INFLUENCE ON NURSING STUDENTS' PERCEPTIONS OF VALUE FOR MATHEMATICS

by

Kimberly Evagelatos Beck

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Approved:

Jessica Shumway, Ph.D. Major Professor	Katherine Vela, Ph.D. Committee Member
Michelle Frierson, Ph.D. Committee Member	Jody Clarke-Midura, Ed.D. Committee Member
Brynja Kohler, Ph.D. Committee Member	D. Richard Cutler, Ph.D. Vice Provost of Graduate Studies

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ABSTRACT

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Kimberly Evagelatos Beck
Utah State University, 2024

Major Professor: Jessica Shumway, Ph.D.
Department: School of Teacher Education and Leadership

Nurses regularly use mathematics on the job, yet they often do not view their work as mathematical. This may indicate a lack of transfer from the nursing school mathematics context to nursing practice. Further, nursing students often perceive very little usefulness and relevance for learning mathematics beyond simple calculations. Expansive Framing (EF) is a theory and instructional technique that has been shown to foster transfer by establishing intercontextuality, or connections made between disparate contexts. This research explored whether creating intercontextuality created through broad framing also improved perceptions of mathematics value and transferability, and how intercontextuality functioned as the driver of changes in perceptions of mathematics value and transferability.

This embedded case study mixed-methods analysis investigated these constructs by collecting qualitative and quantitative data from undergraduate nursing students in a College Algebra course. Data were analyzed using descriptive statistics, a Wilcoxon

Signed Rank test, and reflexive thematic analysis. Results varied; while quantitative analyses showed slight declines in positive value perceptions and a slight increase in negative value perceptions, the results were not statistically significant. Mixed and qualitative-focused analyses showed that participants experienced improved perceptions due to expansively framed activities in the course. The form of EF varied; while webinars showed mixed effectiveness, other expansively framed activities were identified as highly valuable for both groups. Overall, intercontextuality was an apparent motivator of changes in value and transferability perceptions.

Based on this research, I recommend that instructors seek opportunities to create intercontextuality by framing broadly across context during instruction, but also by applying EF to classroom activities through curricular integration of content. Future research across multiple classrooms, age groups, and cultural settings, is warranted to investigate the extent to which intercontextuality is the motivator of perception changes versus other factors and to further disentangle the individual roles of connecting settings versus student authorship in effective EF.

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PUBLIC ABSTRACT

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We don't accomplish anything in this world alone…and whatever happens is the result of the whole tapestry of one's life and all the weavings of individual threads from one to another that creates something. – Sandra Day O'Connor

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I dedicate this dissertation to Dad, who is always there. At the beginning you were physically there. Now you're just a little farther away, but I know you're still always there. 🐰 🐰

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CHAPTER I

INTRODUCTION

Problem Statement

Nurses regularly use mathematics on the job, yet they often do not view their work as mathematical (Hoyles et al., 2001). This may indicate a lack of transfer from the nursing school mathematics classroom to nursing practice. *Transfer* refers to a person's ability to abstract content learned in one context and apply it to another. To further compound the issue, mathematics is typically presented to nursing students as an isolated discipline (Hutton, 1998) and nursing students often perceive very little relevance for mathematics content beyond simple calculations (Hoyles et al., 2001). When students cannot see value in what they are learning, they may lack motivation and interest (Priniski et al., 2018) and experience lower levels of confidence (Hulleman et al., 2017). Further, when nursing students do not perceive value in the mathematics they are learning during their academic preparation, they may view mathematics superficially and have difficulty transferring what they learn to the nursing profession. More research is needed to determine effective ways to support nursing students in learning mathematics. Thus, this dissertation study examined how the framing of mathematics during nursing students' academic preparation functions as a driver of students' perceptions of mathematics value and transferability.

Significance of the Problem

It is critical that nurses enter the workforce mathematically competent. Nurses make high-stakes calculations every day that can impact patient health. However, many nurses demonstrate insufficient numeracy skills (Dubovi et al., 2018) and often do not see the value of learning mathematics beyond simple arithmetic (Hoyles et al., 2001). Further, pass rates for College Algebra and other entry-level college mathematics courses are at alarmingly low levels nationwide (Kosovich et al., 2019). This high failure rate perpetuates College Algebra's reputation as a "gatekeeper" course and serves to keep many students from pursuing their educational and career goals (Nguyen, 2015). Accordingly, this study investigated ways to improve nursing students' perceptions of College Algebra's value and transferability.

In this study, a framing intervention was enacted to discover how nursing students perceive mathematics value and transferability. Since improved value beliefs have been shown to provide a myriad of benefits, including but not limited to increased pass rates (Kosovich et al., 2019), this intervention could be one way to help nursing students be successful in this "gatekeeper" College Algebra course. More importantly, it could lead to graduating nurses understanding mathematics more deeply and on a less procedural level, thus providing the workforce with more quantitatively capable nurses.

Background of the Problem

Transfer of learning has been studied for over a century (Barnett & Ceci, 2002) and has been referred to by some as the ultimate purpose of education (Mayer & Wittrock, 1996). However, there is considerable debate surrounding the way transfer functions, the mechanisms and drivers of transfer, and how to show evidence that transfer has occurred (Roberts et al., 2007; Nakakoji & Wilson, 2020). In response to this debate, Engle et al. (2006) proposed a new approach to study transfer through a lens of Situated Cognition (Greeno et al., 1993; Lave & Wenger, 1991). They developed the theory of Expansive Framing to help explain and facilitate mechanisms of transfer. Engle et al. posited that by framing content and context broadly, *intercontextuality* – connections between contexts – will be created, and students will be more likely to transfer their knowledge to other settings. Research on framing has shown that making broad connections across time, place, people, roles, and topics (Lam et al., 2014) fosters transfer (Engle et al., 2011). Expansive Framing and its connection to intercontextuality is the first construct of the present study.

Another construct that may play a role in transfer is value beliefs, which are how one views the worth of engaging in a task. Value beliefs can be broken into four dimensions: intrinsic value (personal enjoyment and interest), attainment value (the perceived importance of success), utility value (usefulness of the task), and cost value (what is necessary to give up to be successful; Eccles et al., 1983). Students' value beliefs for mathematics tend to decrease over time (Gaspard et al., 2021), which is particularly problematic for adult learners. However, research shows that interventions aimed at increasing value beliefs generally, and utility value and relevance specifically, are highly effective in improving value perceptions of mathematics (Gaspard et al., 2015). This is significant because increased value beliefs improve self-perceived competence and motivation (Durik & Harackiewicz, 2007; Shechter et al., 2011), course grades (Hulleman & Harackiewicz, 2009), pass rates (Kosovich et al., 2019), personal connections to course content (Rosenzweig et al, 2019), and confidence levels (Hulleman et al., 2017). Research has not yet been conducted to determine whether broad framing and intercontextuality also influence perceptions of mathematics value.

This study brings together transfer and value beliefs with a uniting thread of intercontextuality. Creating intercontextuality through Expansive Framing may transform how learners perceive the value and relevance of mathematics and its transfer to nursing. A natural extension of Expansive Framing and a way to facilitate the creation of intercontextuality is by integrating other disciplines within mathematics instruction. Integrated instruction has been shown to provide diverse benefits, including but not limited to, improved mathematics achievement (Bachman et al., 2016; Leandro et al., 2018), greater knowledge retention (Rosen-O'Leary & Thompson, 2019), higher levels of attention and interest (An et al., 2017; Dame et al., 2019), motivation (Brezovnik, 2015), confidence (Bachman et al., 2016; Dame et al., 2019), and reduced mathematics anxiety (St. Clair, 2018). In the present study, nursing content was partnered with mathematics through enhanced integration, a type of curricular integration in which mathematics is the main discipline, but with other content areas brought into instruction (Hurley, 2001). Integrated curricula have been shown to provide myriad benefits to participants, and Expansive Framing suggests that the reason these benefits can be realized is because broad framing in integrated curricula promotes intercontextuality.

Purpose and Research Questions

The purpose of this study was to explore how intercontextuality, created through an expansively framed intervention, shapes nursing students' perceptions of mathematics transferability and value. To accomplish this purpose, the study brings together two strands – Expansive Framing as a motivator of transfer and value beliefs – with a uniting thread of intercontextuality. An overarching goal was to explore how intercontextuality created through Expansive Framing functions as the driver of perceptions of mathematics value and transferability. Thus, the research questions for this study are as follows:

1. How does expansive versus bounded framing of mathematics affect nursing students' perceptions of mathematics value?
2. How does expansive versus bounded framing of mathematics influence how nursing students perceive mathematics value, and in particular, mathematics utility and relevance?
3. How does expansive versus bounded framing of mathematics influence how nursing students perceive transferability of mathematics?
4. In what ways is intercontextuality the driver of perceptions of value and transferability?

Summary of Research Study Design

This embedded case study mixed-methods design employed both qualitative and quantitative data sources to investigate intercontextuality and how it influenced student perceptions of mathematics value and transferability. In this design, quantitative data is embedded within a qualitative case study model (Creswell & Plano-Clark, 2017). Quantitative data was included to answer portions of research questions that could not be answered with qualitative data alone. Participants included undergraduate students from a nursing school's College Algebra course. Participants were assigned to one of two treatment groups: bounded and expansive. During the 3 weeks of the intervention, participants received mathematics instruction in either a bounded or expansive manner, depending on treatment group. Quantitative data was collected through a pre- and post-survey instrument designed to assess value beliefs. The survey also included three open-response qualitative prompts. Additional qualitative data was collected from semi-structured interviews with participants. Data strands were combined after all data collection and were interpreted together, with quantitative data intended to enhance and more deeply interpret qualitative results (Creswell & Plano-Clark, 2017). Quantitative data was analyzed using descriptive statistics and a Wilcoxon Signed Rank test (Marshall & Boggis, 2016) and qualitative data was analyzed using reflexive thematic analysis (Braun & Clarke, 2022).

Scope and Assumptions of the Study

This study focused on adult learners in a College Algebra course at a nursing college during a single semester. The course was fully online, and instruction took place through direct-instruction webinars. To avoid confounding variables the study was limited to recorded webinars only and excluded live attendees. Participation was voluntary, so the study was limited to willing participants and did not include all College Algebra students at the school. Students at this college were required to score at a certain level on the Accuplacer entrance placement exam to enter the College Algebra course, so it was assumed they had the prerequisite knowledge to be successful. It was also assumed that participants were receiving their instruction from their course instructor (myself) through webinars and not receiving significant supplemental instruction outside of class.

I also assumed that participants were truthful and accurate in their reporting. This was encouraged by eliminating as much perceived undue influence by me, their course instructor, as was possible. For example, my dissertation chair Dr. Jessica Shumway managed recruitment efforts, I did not offer course incentives such as extra credit in exchange for participation, and I employed a research assistant to conduct interviews with students. Finally, based on the existing literature on Expansive Framing (e.g., Engle et al., 2011, 2012), I assumed that broad framing made transfer more likely to occur. This study did not purport to measure transfer or show that it had occurred, but rather aimed to investigate (among other constructs) how students *perceive* transferability of content (RQ3).

Positionality

My undergraduate education is in the field of engineering, and I worked as an engineer for several years before leaving to pursue a career in education. This practical experience with using mathematics to create city roads, municipal water systems, and other infrastructure opened my eyes to the applicability of mathematical thinking in "real life." When I became an educator, I had a deep desire to find ways to show my students that mathematics is valuable to learn. I acknowledge that engineering is an inherently mathematical field, yet I believe that mathematics can be found everywhere, even in unexpected domains like art, literature, dance, and music. Helping my students make these connections has become one of my greatest sources of satisfaction as a teacher.

In my current role as a mathematics educator of nursing students at a nursing college, I have noticed that many of my students do not initially see the rationale for the requirement to learn algebra to prepare for a career as a nurse. More broadly, mathematics has a reputation for being not worth learning beyond the basics, perhaps more than any other subject. Social media memes such as "Another day has passed, and I still haven't used algebra once!" are shared broadly. In my opinion, this is likely due to the disconnected, calculation-focused way mathematics has often been presented to learners. Most people would likely agree mathematics is useful for tasks such as shopping or budgeting; however, many fail to recognize how often they use numeracy and algebraic reasoning skills in other areas of life, such as in their writing, traveling, moving, speaking, and creating. Expansive Framing has traditionally been applied to transfer, but I found myself wondering whether it could also hold potential for helping learners perceive value in mathematics and ultimately gain a broader understanding of the world's complexities and how mathematics fits within them.

Definition of Terms

Intercontextuality – the product of linking two or more learning contexts.

Framing – "the metacommunicative act of characterizing what is happening in a given context and how different people are participating in it" (Engle et al., 2012, p. 217).

Transfer – as an individual's ability to abstract content learned in one context and generalize and extend it to different contexts.

Intrinsic value – a positive value facet; personal enjoyment and interest.

Attainment value – a positive value facet; perceived importance of success.

Cost value – a negative value facet; what is necessary to give up in order to be successful.

Utility value – a positive value facet; the usefulness of a topic in achieving ones' short- or long-term goals.

Relevance – "the presence of a relationship between one topic of idea and another topic or idea, which could include a goal but also includes a broader set of relationships" (Hulleman et al., 2017, p. 388).

CHAPTER II

LITERATURE REVIEW

Transfer has been studied extensively for over a century and is arguably the paramount goal of education. However, history has shown that studying transfer is fraught with difficulty (National Research Council, 2000), with "little agreement in the scholarly community about the nature of transfer, the extent to which it occurs, and the nature of its underlying mechanisms" (Barnett & Ceci, 2002, p. 612). The purpose of this study was to explore how intercontextuality created through expansively framed instruction shaped nursing students' perceptions of mathematics transferability and value. Expansive Framing is a theory and an instructional technique that concedes the debate surrounding transfer, but reconceptualizes the notion through a situative lens, positing that content knowledge and context of use are linked (Engle et al., 2012). The terminology *intercontextuality* refers to connections made between contexts that can be facilitated by Expansive Framing (Engle, 2006). This literature review will focus on the primary construct of intercontextuality which originates from broad framing and its connections to integrated curricula and value beliefs.

To examine these phenomena, this literature review will provide more context within the field by delving into existing research on transfer and Expansive Framing as a theory and as an instructional technique, investigating how it informs research on intercontextuality that is created through expansively framed curricula. The second goal of the review is to explore how intercontextuality aids learner perceptions of mathematics value. To meet these two goals, first, I will discuss the research behind transfer, its history, and its controversies. Second, I will discuss scholarship on Expansive Framing and explain the basic tenets of this learning theory/instructional technique. Third, I will present the conceptual framework for this dissertation study and discuss the relationships between intercontextuality, value, and transfer. Next, I will discuss the research on contextual and content-based framing through integrated curricula. Finally, I will explore the literature on value perception.

Transfer

At its core, Expansive Framing is a theory that helps to explain and facilitate transfer, so a comprehensive investigation into the theory necessarily begins with an examination of transfer. The phenomenon of transfer has been well-documented for over a century (Barnett & Ceci, 2002), yet it remains an elusive educational construct, notoriously difficult to define and measure (Nakakoji & Wilson, 2020; Roberts et al., 2007). In general, transfer can be described as an individual's ability to abstract content learned in one context and generalize and extend it to different contexts. For example, a person may transfer (or fail to transfer) their trigonometry or geometry skills learned in a mathematics classroom context to the design of an article of clothing or a painting of a landscape. The importance of the transfer of school-based learning to non-school-based contexts is paramount, with some calling it the ultimate purpose of education (Mayer & Wittrock, 1996). This section of the literature review will examine how the concept of transfer has evolved over the past century and new avenues modern researchers are exploring based on specific elements of learning to foster transfer.

Evolution of Research on Transfer

Research on transfer dates as far back as the early 1900s, when Charles Judd reported evidence of transfer in an experiment in which boys who had received instruction on refraction (the way light passes through water) were more successful in throwing darts at underwater targets than boys who had not (Judd, 1908). However, other scholars – most notably Edward Thorndike – opposed Judd's views and performed experiments that appeared to show that transfer was not occurring across contexts (as cited in Roberts et al., 2007). Nearly 80 years later, Gick and Holyoak (1980) claimed evidence of transfer in an experiment in which participants were asked to devise a treatment for a stomach tumor that delivered maximum radiation while damaging as little of the surrounding tissue as possible. A portion of the students were also presented with an analogous problem in which a military general attempted to infiltrate a fortress. All roads leading to the fortress were impassable, rendering a direct attack impossible, so the general chose to split his forces into smaller groups and convergently attack the fortress from multiple sides. This divide-and-conquer approach also happened to be the best solution to the tumor radiation problem. Those who were given the military strategy problem first were better able to solve the radiation problem than those who were not (Gick & Holyoak, 1980). This indicated that transfer due to analogous similarities between contexts had occurred, which spurred additional research on links between content and context.

While Gick and Holyoak's (1980) findings suggested that transfer can occur when content and context are disparate, some scholars' work indicated that content and context are tightly embedded. Carraher et al. (1985) discovered a lack of transfer among children working as street vendors in Recife, Brazil. These children were able to competently perform complex calculations while selling food on the street but were unable to replicate the same mathematics on a paper-and-pencil test in a school setting. The authors concluded the problem-solving strategies the children used while working on the street were not activated in a context-free environment, thus indicating a lack of transfer between contexts. Expanding on this work, Catambrone and Holyoak (1989) and Mayer and Wittrock (1996) showed transfer most effectively occurred when content was presented in the same context. To examine this relationship between an individual's ability to transfer skills within varying or similar contexts, these scholars used comparison questions to activate participants' prior knowledge. Findings suggested that learning of content was embedded within the context in which it was learned. Despite some successful empirical research, there remains debate surrounding the various types of transfer, and how to show evidence of transfer.

Reconceptualizing Studies on Transfer

In response to the lack of industry-standard definitions of transfer and variability in study findings, Barnett and Ceci (2002) proposed a taxonomy to better operationalize transfer. This taxonomy classified the various types of transfer (i.e., near transfer, far transfer, content-based transfer, contextual transfer), establishing a more comprehensive definition for transfer. They defined *near transfer* as the conveyance of learning between similar contexts (for example, mathematics and engineering), and *far transfer* as the transmission of content between very different systems (such as mathematics and art).

Their taxonomy further differentiated between *content* (what is transferred) and *context* (when and where content is transferred from and to), which provided a way to standardize and structure future transfer research. Engle et al. (2011, 2012) expanded upon Barnett and Ceci's notion of *contextual transfer* and applied it to framing, which they defined as, "the metacommunicative act of characterizing what is happening in a given context and how different people are participating in it" (Engle et al., 2012, p. 217). They posited that transfer is facilitated by framing content and context widely across time, place, roles, topics, and groups of people. Expansive Framing offers a new way to continue studying transfer through a situative lens, meaning that transfer is investigated in terms of the social context in which learning occurs and where it is applied, not simply the content or skills that are transferred.

Theoretical Framework: Expansive Framing

Expansive framing is a theory that helps explain and facilitate mechanisms of transfer and an instructional technique to frame content and context broadly. Engle (2006) took a situative approach to transfer and developed expansive framing based on theories of situated cognition (Greeno et al., 1993; Lave & Wenger, 1991). Situated cognition claims learning is highly contextual and inseparable from the social environment in which it occurs, which results in a stronger emphasis on contextual factors of learning. Expansive framing is built on the foundation of situated cognition and aligns with the theory's emphasis on learning as highly contextual but diverges in that expansive framing places a greater emphasis on how content and context are *framed*.

Framing of Content and Context

Framing refers to the way subjects and learning contexts are characterized and presented to learners. Bernstein (1996) described framing as the classification of knowledge. Whereas classification is the boundary between knowledge, framing is the way that boundary is communicated. “Framing is…about the selection of knowledge, its sequencing, its pacing, the criteria of selection, and the social/educational interactions that communicate that knowledge” (Au, 2012, p. 43). Bernstein (1996) described the power of framing and classification as, “silence which carries the message of power. It is the full stop between one category of discourse and another. It is the dislocation in the potential flow of discourse which is crucial to the specialization of any category” (p. 20). In this conception, framing of knowledge can either communicate distinct isolation between ideas or alternately, portray knowledge domains as highly interconnected.

Frames can also communicate the meaning of content. For example, Hand et al. (2012) described an experiment in which participants were asked whether they would choose a treatment for a deadly flu that would save 200 (out of 600) people, or a treatment in which two-thirds of the 600 people would die. The authors concluded that the positive framing of the first option (“save 200 people”) versus the negative framing of the second option (“two-thirds of the 600 people would die”) led the majority (72%) of participants to choose the first option, even though both options resulted in the exact same number of deaths. In this research, framing was shown to be a powerful way to affect content interpretation, which may have implications in school settings as well.

In schools, content and context can be framed in ways that are tightly bounded, where subjects are isolated from one another in individual classroom spaces and meaningful connections to other contexts outside of each classroom are rare. In contrast, Engle et al. (2011) introduced the theory of Expansive Framing to explore the idea that broad framing may serve to encourage transfer. The authors asserted that Expansive Framing softens boundaries and promotes application to a learner's own experiences, rather than being compelled to view new knowledge through another person's frame.

Creating Intercontextuality

When learning experiences are framed in a bounded manner, there are no connections made outside of that experience. In contrast, Expansive Framing is a theory that posits transfer between systems is more likely to occur when topics are framed widely: across time, place, people, roles, and topics (Lam et al., 2014). Engle et al. (2012) found that teachers more effectively facilitated transfer by framing a lesson as the start of an ongoing discussion about a topic students will continue to use beyond a single setting. The practice of framing content and context expansively creates *intercontextuality* between frames. "Intercontextuality occurs when two or more contexts become linked with one another. When this occurs between learning and transfer contexts, the content established during learning is considered relevant to the transfer context" (Engle, 2006, p. 456). Learners are then able to use this intercontextuality to create connections and gain a larger perspective.

Engle et al. (2011) graphically represented the difference between Expansive Framing and Bounded Framing as shown in Figure 1.

Figure 1

Expansive versus Bounded Framing

Note. Expansive and Bounded Framing. Adapted from "The influence of framing on transfer: Initial evidence from a tutoring experiment," by R. A. Engle, P. D. Nguyen, & A. Mendelson, 2011, *Instructional Science, 39*(5), 603-628. Copyright 2010 by the authors.

Instead of conceptualizing school subjects (mathematics, science, art, literature, etc.) and contexts (classroom spaces, groups of people, segments of time, etc.) as distinct silos of information (as depicted on the right side of Figure 1), Expansive Framing asserts it is more accurate to view content areas as a series of interrelated, overlapping ideas with no clear beginning, middle, or end (as depicted on the left side of Figure 1).

Empirical research on using Expansive Framing practices is minimal, but the research that does exist supports the theory. For example, in a one-on-one tutoring experiment, students who received expansively framed instruction in biology topics were better able to transfer facts, concepts, and strategies from tutoring sessions to a written assessment (Engle et al., 2011). Further, when students aligned with the values of Expansive Framing (in other words, they recognized that content they learned was connected to other times, places, participants, topics, and roles), it resulted in higher levels of transfer and greater perceived relevance across settings and content areas (Lam et al., 2014). Expansive Framing teaching practices also helped students in an urban classroom position themselves as agents of change in an experiment on environmental science (Tierney et al., 2020). Results suggested at the end of the course, participants saw themselves as responsible environmental citizens and were able to reframe their initial powerless, pessimistic view of environmental change, thus transforming their previously held perceptions of helplessness into positions of power. In another study, Chapman (2022) found foregrounding conversations on framing helped students to identify school mathematics in a community of practice focused on learning to knit. Learners successfully transferred the mathematics learned in school into a new context (knitting summer camp), which served to blur the boundary between school mathematics and mathematics in other areas.

While Expansive Framing is a theory used primarily in the Learning Sciences field, its application to mathematics education may provide opportunities to promote meaningful learning of mathematics in multiple contexts and through varied content areas. Mathematics is often taught in a vacuum, completely isolated from other subjects and applications, when mathematics can be found everywhere and in everyday situations. While traditionally compartmentalized framing may lead learners to have a very limited view of the true depth and utility of mathematics beyond the classroom context, scholars and educators have an opportunity to enhance opportunities for learning using Expansive Framing to facilitate deeper mathematical connections through the creation of intercontextuality.

Intercontextuality Facilitated by Expansive Framing of Context

Engle (2006) argued transfer occurs more readily when framing promotes intercontextuality, which is when multiple contextual frameworks become interlinked. Engle et al. (2011) said, “The creation of intercontextuality is thought to give learners the message that they are allowed, encouraged, and even responsible for transferring what they know from one context to all others linked with it” (p. 605). Bloome et al. (2009) described intercontextuality through a sociocultural lens, asserting that social relationships and contextual cues are what drive connectivity. They proposed that for intercontextuality to occur in a social setting, there must be:

- a proposal for connecting a specific set of events;
- acknowledgment of the proposal by others who must;
- recognize the set of events proposed for juxtaposition; and
- the realization of a social consequence(s), value, or meaning of the juxtaposition. (Bloome et al., 2009, p. 319)

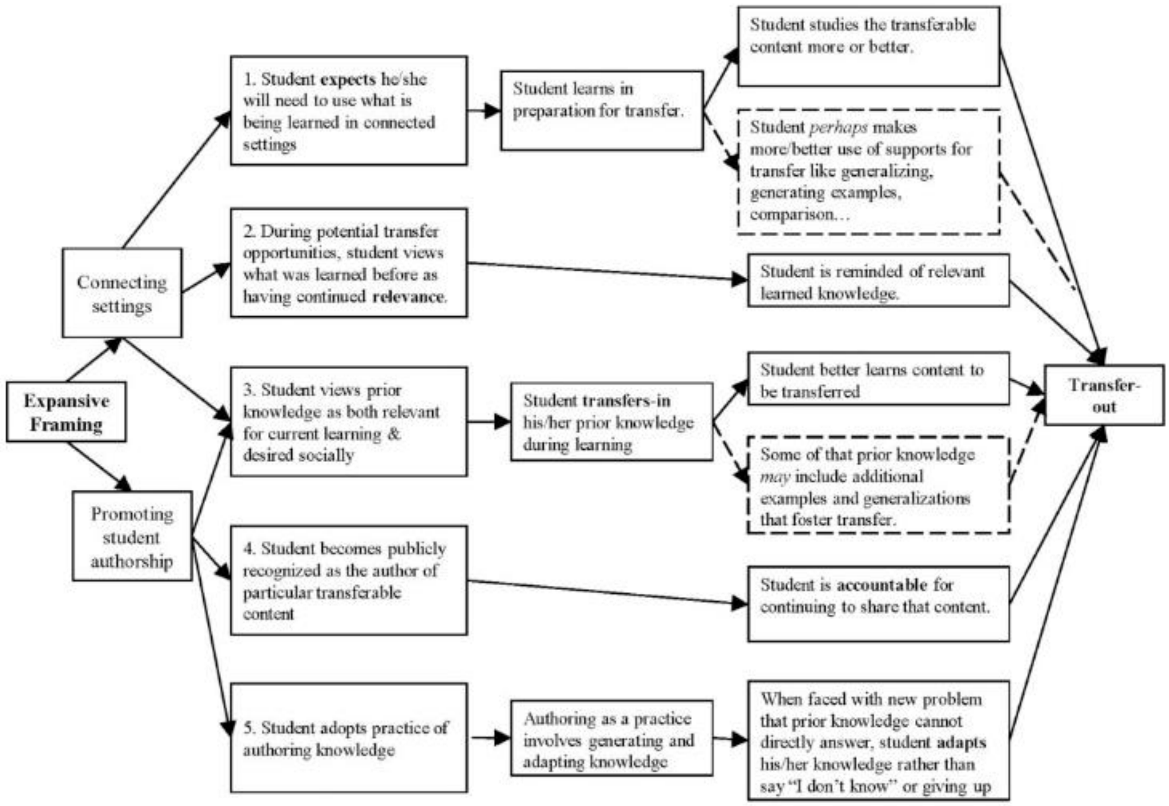
In other words, socially constructed intercontextuality follows a prescribed process which leads to recall of knowledge (transfer) across settings. In this view, creating intercontextuality is both a procedure that occurs through framing as well as an interpretive process whereby the learner assigns socially-based meaning to new knowledge.

Mechanisms Driving Contextual Transfer

The specific mechanisms driving transfer via intercontextuality require further research. Engle et al. (2012) proposed five possibilities to explain how intercontextuality via Expansive Framing may facilitate transfer. Two explanations begin by connecting settings; one explanation begins by both connecting settings and promoting student authorship; the final two explanations begin by promoting student authorship (Figure 2).

Figure 2

Five Explanations for How Expansive Framing May Foster Transfer



Author Note. Dashed arrows and boxes indicate processes that may or may not occur depending on what content-based supports for transfer are available.

Note. Five Potential Explanations for How Expansive Framing May Foster Transfer. Reprinted from "How does expansive framing promote transfer? Several proposed explanations and a research agenda for investigating them," by R. A. Engle, D. P. Lam, X. S. Meyer, & S. E. Nix, 2012, *Educational Psychologist, 47*(3), 215-231. Copyright 2012, American Psychological Association.

First, Engle et al. (2012) proposed that connecting learning environments promotes transfer both during learning by creating the expectation that knowledge will be used later (explanation #1) and during subsequent contexts where students perceive their prior knowledge as having continued relevance (explanation #2). These explanations are depicted in the top two branches of Figure 2. Further, the authors theorized that by expansively framing a learning context across time (in other words, connecting current settings to past learning) as well as positioning learners as creators of their own knowledge, they will more effectively transfer-in prior knowledge (explanation #3), which yields deeper initial learning, priming the learner for transfer to new contexts (Engle et al., 2012). This explanation is depicted in the middle branch of Figure 2.

The final two explanations rely solely on promoting student authorship. Students who are identified by their peers as experts of their own created knowledge may feel accountable to that content (explanation #4). These learners see themselves as responsible for speaking intelligently on the topic, making transfer across contexts more likely. Framing students as authors of their own knowledge may also nurture adaptation as a common practice, thus promoting the adjustment of existing knowledge in a new problem context more readily (explanation #5). These two explanations are shown in the bottom two branches of Figure 2.

The present study focused on the explanations related to connecting settings (#1, 2, and 3) and deemphasized explanations related to promoting student authorship (#4 and 5). This is due to the study context in which participants attended webinars online in a primarily solo setting, without an opportunity to socially construct meaning or participate in meaningful discourse with peers. This approach was intended to help disentangle the explanations of connecting settings versus promoting student authorship.

Contextual Characteristics of Learning Contexts

Regarding contextual framing, Lam et al. (2014) noted that empirical research showed five distinct characteristics of learning contexts that can be framed expansively to create intercontextuality: people, places, time, roles, and topics. They furthered the work of Engle et al. (2012) by proposing the intercontextual links that occur when each of these five characteristics are framed widely across contexts (Table 1).

Table 1

Intercontextualities Created by Expansive Framing and Mechanisms for How Each May Lead to Transfer

Contextual aspect	Proposed intercontextuality	Transfer mechanism
Time: When is the lesson happening?	The lesson is part of an ongoing activity that started in the past and will continue into the future.	Students draw on prior knowledge during the lesson. They learn content expecting to be able to use it in the future.
Place: Where is it happening?	The lesson is relevant outside the classroom (e.g., to rest of school, homes, local community, places around the world, other institutions, etc.).	Students draw on experiences from other places during the lesson. They learn current content expecting it to be applicable in other places.
Participants: Who is participating?	The lesson is relevant to a broad community that extends throughout and beyond the classroom.	Students consider the relevance of interactions with others during the lesson. They learn current content expecting it to be of interest to others.
Topics: What is the topical scope of the lesson?	The lesson is part of larger and interrelated units, topics, and subject areas.	Students see connections between the lesson and other topics they have studied and will study.
Roles: How are learners positioned intellectually?	Learners are authors who are responsible for developing, sharing, and defending their own ideas.	Students feel accountable for using and sharing the ideas they author. They may also adopt the practice of generating and adapting ideas to attempt to solve novel problems.

Note. Reprinted from *"Learner alignment with expansive framing as a driver of transfer"* [Paper presentation] by D. P. Lam, A. Mendelson, X. S. Meyer, & L. Goldwasser, 2014, International Conference of the Learning Sciences.

Engle et al. (2011) tested these intercontextual aspects in their experiment that investigated whether re-framing social contexts in a one-on-one tutoring session affected transfer. Biology students met with tutors who were trained to frame content either boundedly or expansively across settings (time, place, and participants), topics, and roles (instructed or positioned). For example, tutors expansively framed temporal contexts by referring to other times in the past or future, both within and without the experiment. In contrast, tutors boundedly framed temporal contexts by using statements such as “you’re done learning about that now” and deliberately avoiding reference to any future or past contexts. Researchers found the tutor’s bounded versus expansive framing of content and context had a significant impact on transfer of biology facts, conceptual principles, and learning strategies across systems (Engle et al., 2012). The authors concluded this was due to the intercontextuality that the expansive condition created for students. While this demonstrates Expansive Framing’s power in affecting transfer due to contextual framing, Expansive Framing principles can also be applied to content.

Intercontextuality via Expansive Framing of Content in Integrated Curricula

Interdisciplinary curricula are a way to expansively frame across content areas (topics) and break through rigid classifications. Integrated curricula are not novel; educators and instructional designers have long sought ways to show students how the mathematics they learn in school connects to other areas. Some research shows curricula that integrates mathematics with other disciplines can be powerful in improving student outcomes across many diverse variables. The other content areas included in these studies are varied: dance (Bachman et al., 2016; Leandro et al., 2018), art (Brezovnik, 2015; Rosen-O’Leary & Thompson, 2019; Schoevers et al., 2020; St. Clair, 2018), language arts (Cunnington et al., 2014), science (Dame et al., 2019), computer science (Shumway et al., 2021), history (Kapofu & Kapofu, 2020), and cultural studies (Ogunkunle & George, 2015). However, no matter which content area was paired with mathematics, researchers found improvements in areas of student achievement, retention of knowledge, affective components of learning, and cultural re-framing.

Integrated Curricula and Student Achievement

Integrated mathematics curricula have been shown to improve mathematics achievement (defined as test scores and/or grades). In a study by Bachman et al. (2016), the authors investigated mathematics test scores of a group that participated in an integrated math-dance university course. They reported that the treatment group scored 26 points higher on the post-test than the control group, and 83% of the treatment group improved from pre- to post-test compared to only 71% of the control group. Leandro et al. (2018) also found benefits to their math-dance integrated course with 7- and 8-year-old children, citing significant learning gains as compared to the control group. Brezovnik (2015) and Cunnington et al. (2014) conducted math-visual arts integrated studies in elementary schools and both related higher statistically significant achievement gains in the interdisciplinary students' performance. Echoing these findings, Schoevers et al. (2020) found that students in an integrated program improved their test scores in geometry when they perceived geometry as related to visual art. However, Schoevers et al. also noted there were no differences found between the groups in the areas of geometrical creative thinking. While not directly based on test score gains, Shumway et al. (2021) found that using computer programming toys elicited kindergarten students' more effective use of mathematics principles. These relatively consistent findings across all studies indicate integrated curricula's potential to narrow achievement gaps in students' mathematics learning.

Integrated Curricula and Knowledge Retention

While several studies have shown mathematics test scores improved with an interdisciplinary approach, most of those studies did not track long-term retention of those gains. With a viewpoint of enduring learning in mind, some researchers focused on the study variables of retention and consolidation. Students in two separate studies showed a higher retention rate one month after an interdisciplinary intervention than students in a traditional classroom (Leandro et al., 2018; Rosen-O'Leary & Thompson, 2019). Further, children who consolidated their new mathematics knowledge via creative dance instead of a text-based worksheet demonstrated deeper conceptual knowledge and long-term retention (Leandro et al., 2018). Overall, this indicates that integrated curricula also can provide durable knowledge retention in addition to short-term gains.

Longitudinal studies also indicated positive effects of interdisciplinarity over relatively longer periods of time. Cunnington et al. (2014) created a standards-based integrated curriculum that was implemented in six high-poverty New York City public elementary schools over the course of three years. Student participants were tracked longitudinally, and researchers concluded that after three years students in the interdisciplinary program showed higher levels of long-term cognitive skill development in the areas of literacy and mathematics than their counterparts who did not participate in the program. Overall, this indicates an interdisciplinary approach may have the potential to not only improve student test scores, but to make those gains permanent. It should be noted that all these studies focused primarily on integrating content rather than the framing of context. Contextual framing represents a gap in the research which the present study aims to address.

Integrated Curricula and Affective Components of Learning

Affective components of learning, such as attitude, interest, motivation, and confidence, are variables in mathematics learning that have been shown to be affected by interdisciplinary learning. Bachman et al. (2016) found students in an integrated math-dance college course improved their overall attitude score by 6.33 points (out of a maximum of 35) while the control group improved by only 1.82 points, with both measures reported as statistically significant. Students who engaged in lessons where mathematics was integrated with another topic (i.e., dance, music) also reported higher levels of attention and interest (An et al., 2017; Dame et al., 2019), motivation (Brezovnik, 2015), and confidence (Bachman et al., 2016; Dame et al., 2019). Further, St. Clair (2018) reported the integration of cartooning into a finite mathematics college course reduced levels of mathematics anxiety when students created cartoons to visually represent mathematics concepts in the real world. The deeper levels of interest generated by interdisciplinary mathematics instruction also fostered more meaningful mathematical thinking. Gadanidis et al. (2011) found gifted learners felt discouraged to express new mathematical ideas in their traditional lessons and as such had a relatively superficial understanding of the content. However, in their integrated lessons, which combined elements of mathematics, poetry, and drama, the same learners discovered deep mathematical thoughts. Kapofu and Kapofu (2020) reported similar results in their study of learner perception of the Pythagorean Theorem from a combined math-history context. Students recounted a desire to know more about the mathematics. These studies confirm that interdisciplinary learning provides significant and diverse affective benefits to students.

Integrated Curricula and Culture

Reframing content through integrated curricula may also improve educational equity. Mathematics is often seen as an entirely neutral subject, yet it is primarily based on a Euro-centric model of content and algorithmic skill. Ogunkunle and George (2015) wrote, “the implication [of this Euro-centric model] was that western education as introduced in the colonized countries did not reflect the cultures, worldviews, and environment of the people. This led to the erroneous impression that mathematics was not indigenous to non-western cultures” (p. 387). Ethnomathematics is an interdisciplinary approach that offers a way to study the intersection of mathematics and culture, and students who have been instructed with an ethnomathematics approach show stronger learning gains and a re-framing of their personal views of mathematics (Chapman, 2022; Ogunkunle & George, 2015). Additionally, Cunnington et al. (2014) reported an interdisciplinary math-art curriculum narrowed the achievement gap for students growing up in poverty, effectively increasing both mathematics and art learning. These cross-curricular modes of teaching and learning not only narrowed achievement gaps for marginalized groups but also helped revise cultural frames and expand views on what counts as knowledge.

Mathematics and Nursing Curricula

While nurses regularly use numeracy skills on the job, Hoyles et al. (2001) asserted nurses often do not see their work as mathematical, and that their characterizations of on-the-job mathematical thinking are often reduced to that of simple calculations. Further, mathematics is typically presented to nursing students as an isolated discipline (Hutton, 1998), and very little research currently exists on enhanced integration of nursing education in a mathematics classroom. This is an area that merits further research.

Additionally, some nursing students perceive very little relevance for mathematics beyond basic arithmetic (Hoyles et al., 2001). Creating intercontextuality through enhanced integration of nursing concepts in a mathematics classroom (e.g., framing broadly across topics) may serve to link content areas for nursing students and promote how they perceive the value and relevance of mathematics. According to Engle (2006), "When [intercontextuality] occurs between learning and transfer contexts, the content established during learning is considered *relevant* [emphasis added] to the transfer context" (p. 456). In other words, intercontextuality frames knowledge from one setting as relevant to another setting – a central component of intercontextuality – which ultimately facilitates transfer (Engle et al., 2012). Not only does intercontextuality set the expectation for transfer of knowledge, but it also fosters perceptions of relevance and value. These study results are important to consider for the present study. Integrated curricula have been shown to provide diverse benefits to participants. Expansive Framing suggests the reason these benefits can be realized is because of the intercontextuality that broad framing achieves.

Perception of Mathematics Relevance and Value

Over 100 years ago, John Dewey first proposed that helping students recognize ways content is personally relevant and valuable may serve to stimulate their interests. He wrote, “things indifferent or even repulsive in themselves often become of interest because of assuming relationships and connections of which we were previously unaware” (Dewey, 1913, p.22). Increasing the perceived personal relevance and value of content helps students identify themselves in what they are learning, ultimately leading to greater interest and motivation (Priniski et al., 2018). Thus, educators are continually seeking ways to improve how their students perceive value in mathematics content, and Expansive Framing may provide a new direction.

While Expansive Framing of content and context has been shown to improve propensity to transfer facts, principles, and strategies (Engle et al., 2011), it may also improve how learners perceive relevance and value (Engle et al., 2012). Knowledge from one setting being used in another setting signals to learners that content is relevant outside of the space where it is initially learned (Wagh & Gouvea, 2018). Further, if students can see their knowledge maintains relevance over time, they are more likely to transfer that knowledge to other contexts (Engle et al., 2012; Lam et al, 2014). More research is needed to determine the link, if any, that exists between Expansive Framing and value beliefs.

The Four Value Facets

Eccles et al. (1983) proposed that achievement and behavior are affected by the value a person places on a certain task. They conceptualized value with four dimensions: intrinsic value (personal enjoyment and interest), attainment value (the perceived importance of success), utility value (usefulness of the task), and cost value (what is necessary to give up being successful). The first three value facets (intrinsic, attainment, and utility value) are considered positive value facets, while cost is considered a negative value facet because it refers to the detrimental effects of engaging in a task.

Gaspard et al. (2015) expanded upon this work by breaking down these four value facets into 11 subfacets. Utility value is subdivided into utility for school, utility for daily life, social utility, utility for job, and general utility for future life. Attainment value is subdivided into importance of achievement and personal importance. Cost value is subdivided into effort required, emotional cost, and opportunity cost. These value facets are represented conceptually in Figure 3.

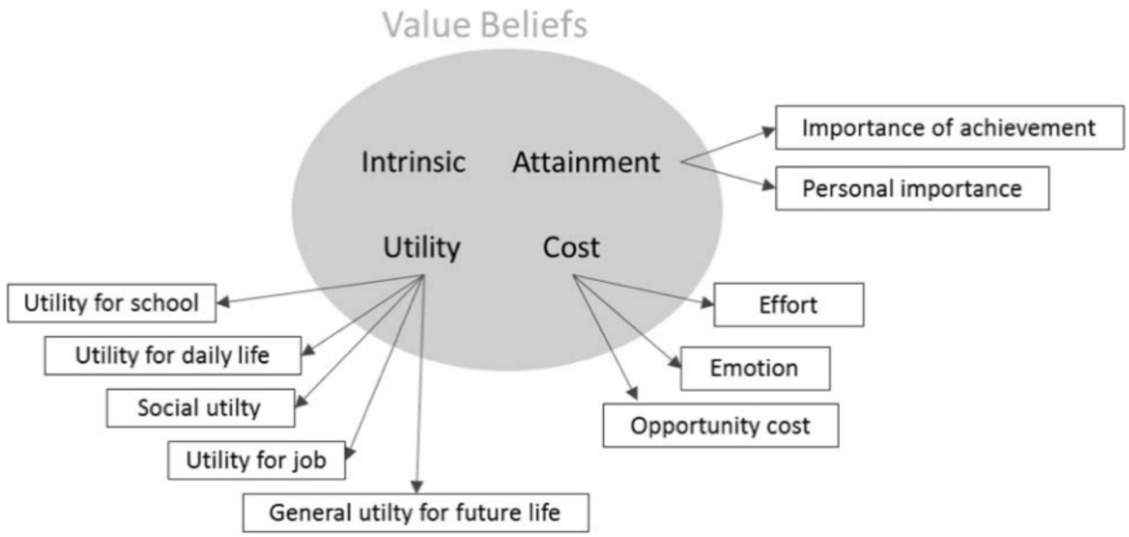
In this study, all four value facets were measured; however, there was an emphasis on utility value because of its close relationship with relevance. Relevance and utility value are quite similar, and the two terms are often used interchangeably in the literature, yet there are some important differences. Hulleman et al. (2017) explain,

> Whereas utility value refers to usefulness to a proximal or distal goal, relevance simply refers to the presence of a relationship between one topic or idea and another topic or idea, which could include a goal but also includes a broader set of relationships. (p. 388)

In other words, utility value signifies how useful a topic is in achieving one’s short- or long-term goals, while relevance denotes how useful a topic is in a much broader sense.

Figure 3

Conceptual Representation of Value Facets



Note. Conceptual Representation of Value Facets Assessed in Our Study. Reprinted from "More value through greater differentiation: Gender differences in value beliefs about math," by H. Gaspard, A.-L. Dicke, B. Flunger, B. Schreier, I. Häfner, U. Traitwein, and B. Nagengast, 2015, *Journal of Educational Psychology, 107*(3), 663-677. Copyright 2015 by the authors.

Because of the close relationship between relevance and utility value, and the fact the two terms are often used interchangeably in the literature, I have included empirical research on both constructs in the same section in this literature review.

Empirical Research on Relevance and Utility Value

Students' value beliefs tend to decrease over time and as grade level increases (Gaspard et al., 2021). This is particularly problematic for mathematics as a subject, but especially for female students in mathematics (Watt, 2004). Several researchers have focused on relevance and/or utility value interventions to improve value beliefs in mathematics. Gaspard et al. (2021) identified two types of intervention approaches that have been studied: first, explicit instruction in which utility information is clearly communicated to learners. This approach showed improvements in measured competence, self-perceived competence, and motivation (Durik & Harackiewicz, 2007; Shechter et al., 2011), yet Bernacki and Walkington (2018) reported mixed results with this intervention technique. The second intervention style is to aid students in generating connections to utility value themselves. This technique yielded improvements in course grades, particularly in students with low expectancies (Hulleman & Harackiewicz, 2009). Overall, research shows that both types of utility value interventions show promise for improving how participants perceive utility value.

Relevance and utility value are closely related, and research has indicated relevance interventions can also increase utility value (Gaspard et al., 2021). Further, an improved utility value resulted in higher pass rates in an algebra class (Kosovich et al., 2019), promoted personal connections to course material in an online mathematics course (Rosenzweig et al, 2019), and increased confidence levels (Hulleman et al., 2017). Relevance and utility value interventions have also been shown to reduce achievement gaps for marginalized groups. For example, Harackiewicz et al. (2016) found an intervention in which participants journaled about utility value was effective in reducing the achievement gap for minorities, particularly first-generation minority college students. Hulleman et al. noted their utility value intervention was most effective for the lowest-performing students. Dobie (2019) studied the relationship between Latinx students' perception of the usefulness of mathematics and their personal values and beliefs. They found a strong relationship between personal values and mathematics utility value, and students were able to identify practical ways mathematics could be used to help others in their community. However, some research is mixed. Kosovich et al. (2019) noted their utility value intervention in an algebra class was primarily successful in improving passing rates for men, and less successful in improving passing rates for women and low-achieving students in general. Further research is necessary to determine the most effective relevance and utility value interventions specifically for marginalized groups.

Rosenzweig et al. (2019) conducted a case study to investigate how utility value interventions in mathematics are affected by different educational contexts, which speaks to Expansive Framing's emphasis on situated learning and framing across contexts. They noted that while utility value interventions may focus on the same psychological developments across contexts, the effectiveness of the intervention may be altered by novel contexts. When testing utility value interventions in a new context, they found mixed results; some interventions resulted in higher utility value while others did not. Situative and contextual aspects of learning experiences are essential to study further to better understand how one's environment influences learning (Dobie, 2019). The results of these studies are important to consider in the proposed study, which aims to provide further exploration into the extent to which expansively framed instruction across educational contexts affects the way students perceive relevance, utility value, and value of mathematics content more broadly.

Future Research

The research that does exist on Expansive Framing is promising, but very little empirical work currently exists. Most of the research that has been conducted focused on disciplines other than mathematics. Further, very little research on enhanced integrated curricula linking nursing concepts in a mathematics classroom currently exists. Thus, the field is rife with opportunity for more investigation into how framing may affect mathematics value beliefs, and how these constructs work to aid in transfer, especially for nursing students.

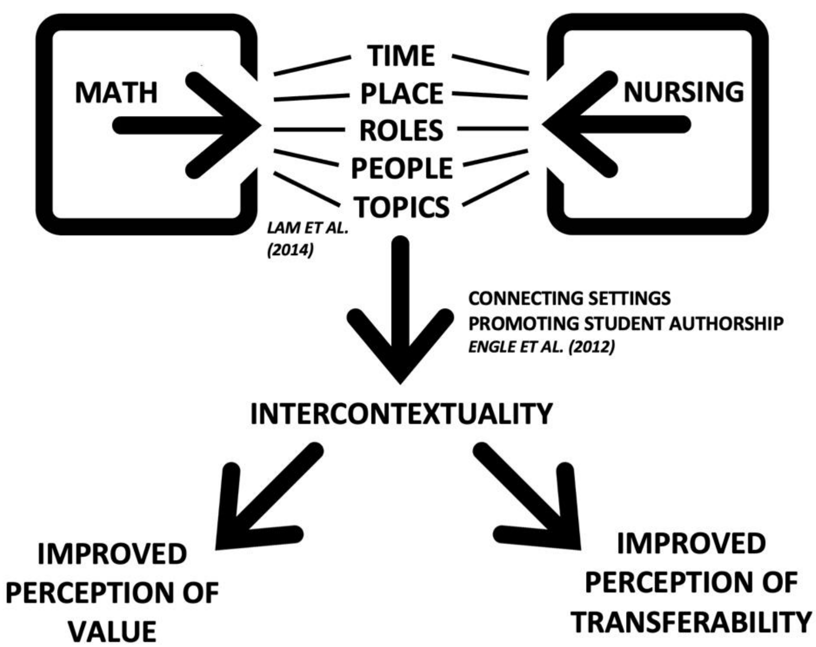
Engle et al. (2012) proposed a research agenda for future experiments, broken into three categories: first, disentangling experiments, which are intended to extricate aspects of framing that have the great impact on learning. Second, the authors suggested comparative classroom studies. These may include both within and between classroom research, and could focus on how framing affects student transfer, or even how students notice and adapt to expansive framing. Third, Engle et al. suggested embedding microgenetic investigations such as intensive videotaping and interviewing to help explain and document thinking processes and provide evidence for transfer. In addition to these research recommendations, I submit there is space to investigate value perceptions through a lens of intercontextuality. Though there is extensive research on relevance and utility value in mathematics education, there is, yet, very little that links value beliefs to intercontextuality via Expansive Framing of context and content.

Conceptual Framework

Expansive Framing can occur across both context and content. Mathematics can be expansively framed by integrating it with other content areas and creating connections to other contexts, thus creating intercontextuality. This intercontextuality is theorized to foster transfer outside of the learning context and prompts learners to perceive more value of mathematics. The conceptual framework in Figure 4 represents the foundational constructs of this dissertation study which focused on examining the effects and influences that expansively framed mathematics webinars had on nursing students' perceptions of value and transferability via intercontextuality.

Figure 4

Conceptual Framework



The boxed content areas – mathematics on the left and nursing on the right – indicate the traditionally siloed nature of individual subject areas. The arrows breaking through each box suggest that broad contextual framing across time, place, roles, people, and topics can link and de-silo content areas (Lam et al., 2014). Engle et al. (2012)

indicated this type of framing serves to connect settings and promote student authorship, and ultimately leads to the formation of intercontextuality. This intercontextuality results in two hypothesized outcomes: improved perceptions of mathematics value and improved perceptions of transferability. The relationships among these constructs are described in the paragraphs that follow.

Relationships Among Framing, Context, Content, and Intercontextuality

Softening boundaries between learning contexts by framing expansively casts knowledge as "wide-ranging and permeable, increasing the number of contexts that can become inter-contextually linked with them" (Engle et al., 2011, p. 605). Lam et al. (2014) noted five different aspects of learning contexts can be framed expansively: time, place, participants, topics, and roles, as indicated by Figure 4. Content can also be framed expansively, and pairing mathematics with other content areas in integrated curricula is a way to accomplish this. In the present study, mathematics content was integrated with nursing content through enhanced integration, a type of curricular integration in which mathematics is the main discipline, and other content areas are brought into instruction (Hurley, 2001). Following the theory of Expansive Framing then means that framing broadly across contexts and content areas by integrating nursing into mathematics leads to intercontextuality.

Relationships Among Intercontextuality, Value, and Transferability

Figure 4 shows how Expansive Framing of content and context works to create intercontextuality, which in turn affects how students transfer what they learn (Engle et al., 2011). Thus, transfer is an expected outcome of intercontextuality. Further, Expansive Framing may serve to promote how learners perceive the value of content. Helping students create intercontextuality between mathematics and other content areas promotes the perception that both disciplines are valuable, relevant, and useful outside of their individual spheres. It suggests to students the content is worthwhile to learn because it will be used in other school subjects and contexts as well as one's career and life.

Conclusion and Research Questions

The intent of this study was to determine how a framing intervention influences these interrelationships between framing, intercontexuality, and perceptions of value and transferability. Thus, the research questions this study sought to answer are as follows:

1. How does expansive versus bounded framing of mathematics affect nursing students' perceptions of mathematics value?
2. How does expansive versus bounded framing of mathematics influence how nursing students perceive mathematics value, and in particular, mathematics utility and relevance?
3. How does expansive versus bounded framing of mathematics influence how nursing students perceive transferability of mathematics?
4. In what ways is intercontextuality the driver of perceptions of value and transferability?

School mathematics has too long been perceived as an isolated discipline, despite its connections to nearly every other learning domain. For nursing students, quantitative literacy is of extreme importance. By applying Expansive Framing to mathematics education and curriculum design in the nursing field, we can reopen the discussion on transfer, portray content as interconnected and overlapping, and foster broad connection-making, which will help our learners to view the world in a whole new way. Expansive Framing provides a lens through which we can better understand how interconnected the world really is.

CHAPTER III

METHODS

Through this research I aimed to investigate Expansive Framing as a theory and an instructional technique in a College Algebra course. The intent of this study was to determine how a framing intervention influenced nursing students' perceptions of mathematics value and transferability. An overarching goal was to explore the ways intercontextuality created through Expansive Framing functioned as the driver of perceptions of mathematics value and transferability. In this chapter I describe the methods for the study. First, I introduce the purpose and research questions. Next, I describe the mixed-methods research design, then the setting and participants of the study. This is followed by a section outlining the data sources and instruments that will be used. Next, I outline the procedures for data collection and data analysis. Finally, I discuss limitations to the proposed study.

Purpose and Research Questions

The purpose of this study was to determine how a framing intervention influenced nursing students' perceptions of mathematics value and transferability. An overarching goal was to explore the ways intercontextuality created through Expansive Framing functioned as the driver of perceptions of mathematics value and transferability. Thus, the research questions are as follows.

1. How does expansive versus bounded framing of mathematics affect nursing students' perceptions of mathematics value?

2. How does expansive versus bounded framing of mathematics influence how nursing students perceive mathematics value, and in particular, mathematics utility and relevance?

3. How does expansive versus bounded framing of mathematics influence how nursing students perceive transferability of mathematics?

4. In what ways is intercontextuality the driver of perceptions of value and transferability?

Research Design

This research study employed both qualitative and quantitative methods to investigate intercontextuality and student perceptions of mathematics value and transferability, using an embedded case study mixed-methods design (Creswell & Plano-Clark, 2017). Researchers using this type of design gather qualitative data and quantitative data, embedded within the qualitative case study model. The quantitative data serves to guide portions of research questions that cannot be answered with qualitative data alone. Quantitative data is intended to enhance qualitative analysis and help researchers interpret qualitative results (Simon, 2019; Terrell, 2016). The boundaries of the case in this study are the students in the researcher’s sections of the College Algebra course over a single semester. To gather the data, I recruited a convenience sample of volunteer participants from students within the case boundaries. This group provided both quantitative data in the form of survey responses (n = 11) and qualitative data in the form of open-response survey questions (n = 11) and interview transcripts (n = 10). Both data types were mixed and interpreted together.

Setting and Participants

The participants in this project were nursing students enrolled in the Fall 2023 College Algebra course at a nursing college located in the western U.S. The students enrolled in this school are typically nontraditional learners (83% age 25 or older), who are primarily female (87% of the student population) (College Navigator, 2023). The school's racial and ethnic makeup is approximately 37% White, 21% Latinx, 17% Black, 16% Asian, with the remainder identifying as another race or ethnicity (College Navigator, 2023). While the school is in the western United States, the students are very geographically diverse since students complete their coursework online prior to a supervised clinical practice in their home state. The school has a student population of approximately 3,000 learners located throughout the United States (College Navigator, 2023).

The school's students must take College Algebra to meet their general education requirements for all nursing degrees. College Algebra is an online, primarily asynchronous course, with a webinar component. Students are required to participate in a weekly one-hour video conference webinar via Microsoft Teams, during which their instructor teaches a broad overview of the weekly course material. Learners are encouraged to participate in a live session, but webinars are recorded and posted online for later viewing if live attendance is not possible. To ensure privacy, live attendees must consent to being recorded. Because of this format's constraints, direct instruction via lecture is the primary method of instruction with some student interaction occurring primarily using the chat feature in Microsoft Teams. Attendance is recorded, and students are given points toward their grade for completing each webinar. After attending live or watching the recording of the weekly webinar, students work independently on their homework assignments using the Knewton adaptive learning program. Instructors check in with their students regularly and meet one-on-one or in small groups as needed throughout the week.

Participants were assigned to one of two treatment groups: a bounded framing group or an expansive framing group. The bounded framing group participated in webinars taught using bounded framing, while the expansive framing group participated in webinars taught using expansive framing. These groups are explained in more detail in the procedures section. To eliminate potential variations between participants who attend live versus those who watch the recorded webinar, the study focused only on asynchronous recorded webinars. In other words, during treatment weeks, participants in both the bounded and expansive framing groups did not have the option to attend a live session but instead were provided with a recorded video lecture.

I recruited students to participate in the study group by offering incentives such as financial compensation for their time. Recruitment was conducted by my dissertation chair Dr. Jessica Shumway and the nursing school's Communications Director through Canvas announcements and emails. Initially, 15 students agreed to participate in the study, but four were lost due to attrition and other factors. Of these, 10 students (6 from the bounded group and 4 from the expansive group) participated in a semi-structured interview. These 10 interviews produced approximately 200 minutes of audio. The intent of these in-depth interviews was to gain deeper insight into how nursing students perceive mathematics' transferability to and usefulness in their profession. In addition to these students, I also recruited a small sample of anonymous participants who completed a post-survey. These anonymous participants did not complete pre-tests and pre-surveys, nor did they participate in interviews.

Description of Treatment Types: Expansively and Boundedly Framed Webinars

I designed two webinars for each of the study's three weeks: one that employed only bounded framing and one that employed only expansive framing. Each recorded webinar lasted approximately 60 minutes. I chose to include content from the College Algebra course's Weeks 6, 9, and 10. Weekly content is summarized in Table 2. I identified these weeks for the study due to the strong inherent connections between the mathematics presented during these webinar sessions and the medical field.

Table 2

Summary of Content by Study Week

Week number	Mathematics content	Nursing applications
Week 6	Rational expressions and proportions.	Proportional reasoning for dosage calculations.
Week 9	Quadratic equations and introduction to functions.	Functions as relationships between two variables, such as the relationship between respiratory rate and heart rate; speaking the language of mathematics to understand medical literature.
Week 10	Graphs of functions.	Understanding graphs of patient vitals and medical research.

Weeks 7 and 8 represented a gap between treatment weeks and were considered non-treatment weeks excluded from the research. During this gap, participants received business-as-usual instruction, meaning they had the option to attend a standard live or recorded webinar to meet course requirements and these class sessions were not part of the study. Further, during these non-treatment weeks, my webinar instruction remained as neutral as possible, with no particular lean toward bounded or expansive framing. For each treatment week of the study (Weeks 6, 9, and 10), I provided the bounded group with a link to the recorded webinar taught using bounded framing, and I provided the expansive group with a link to the recorded webinar taught using expansive framing. Participants only had access to their assigned webinar recording. I used Engle et al.'s (2011) tutoring experiment as a guide to create my webinar lesson plans. In this investigation, Engle et al. detailed their methods of framing content as either bounded or expansive in tutoring sessions for biology students. Table 3 provides an overview of how each learning context may be framed expansively or boundedly during the webinar.

In the present study, the framing of roles was deemphasized due to the focus on connecting contexts instead of promoting student authorship (see Figure 2). Example lesson plans can be found in Appendix B.

Unplanned Expansive Framing Activities

While the focus of this study was on contextual and content-based framing during webinars, other classroom activities also emerged as unanticipated sources of EF for both groups. While these activities were not planned as EF experiences for students, they ended up playing an important role in students' survey and interview responses and as such will be described in this section. These activities included weekly "Why Should I Care?" announcements and contextual nursing-based extra credit assignments. Both are

Table 3

How Framing May Be Controlled as Expansive or Bounded

Learning context	Example of expansive framing	Example of bounded framing
People	Connect content to groups of people outside of class (e.g., other college professors, future employers).	Treat webinar as a private event between instructor and student only.
Places	Refer to other locations where they will use what they are learning both outside of class and outside of the college.	Frame location as "this class" or "the college" only.
Time	Set the expectation that content learned will continue to be relevant in the course and beyond (e.g., "We will return to this idea later on").	Frame learning as a one-time occurrence with no other application outside of the course (e.g., "We're done learning about proportions now").
Topics	Connect mathematics to nursing concepts through enhanced integration (e.g., a graph showing concentration of medication in bloodstream to explore functions).	Isolate mathematics content and present it devoid of application.
Roles	Students framed as creators of their own knowledge.	Instructor framed as expert.

normal classroom activities and thus were included in both the bounded and expansive group's course content.

The weekly "Why Should I Care?" announcements consisted of examples of how that week's content relates to the medical field. For example, during Week 10, when students learned about graph features (minimum, maximum, intervals of increase or decrease, etc.) the announcement displayed a heart rate graph and read:

> This week we're continuing to learn about functions and how to identify attributes, such as local maxima and minima and intervals of increase/decrease. The graph below depicts a person's heart rate (beats per minutes, or BPM) over time. Notice the function notation at the top of the graph? Can you see the local maxima and minima? What do they represent? Can you identify where the function is increasing and/or decreasing? What might that tell you about this

patient?

Another example is from Week 6, when students learned about rational expressions. This announcement displayed a medication label and the text read:

> This week we're learning about rational expressions and functions. The foundation of rational expressions and functions is in its name: *ratio*. A ratio is two quantities compared to each other. A fraction is one way to write a ratio. Check out the medication label below. Do you see any ratios on this label? (Hint: Look at the red box.) What quantities are being compared here? Why do you think a nurse would need to understand ratios/fractions/rational expressions?

In each instance, students were expected to reply to the announcement with thoughts on the prompts and discuss potential applications with other students.

The extra credit assignments consisted of four optional tasks that learners were given to earn extra points at various times throughout the semester. Each task included a contextual nursing-based calculation to complete. For example, one extra credit involved calculating the amount of fluid a burn patient should receive during the first 24 hours of care using a formula. A second asked students to complete unit conversions to calculate appropriate medication dosages, and a third required body surface area (BSA) calculations based on a formula that involves a square root. The fourth and final extra credit used three different ratios to calculate pediatric doses, and students must choose the correct formula based on information given and calculate the appropriate dose.

Research Instruments

Two instruments were used for this research. First, to assess value perceptions (RQ1 and RQ2), I administered a slightly modified version of Gaspard et al.'s (2015) Value Beliefs instrument. Changes included minor wording changes (such as changing the word “math” to “algebra”) and adding an open-response component. Second, I used a researcher-developed interview protocol to evaluate how framing influenced mathematics utility and relevance (RQ2) and perceptions of transferability (RQ3) and to address the overarching research question of how intercontextuality drives perceptions of value and transferability (RQ4). A content-based pre-test (see Appendix C) was not considered a data source and was used solely to stratify groups by achievement score (i.e., low, mid, high).

Value Beliefs Instrument

The purpose of the Value Beliefs Instrument (Gaspard et al., 2015) was to quantitatively assess value perceptions (RQ1 and RQ2). The instrument is a survey that assesses perceptions of value and includes 37 four-point Likert-scale items that measure the dimensions of value beliefs described below. Items on the Likert-scale range from a choice of 1 for completely disagree, 2 for somewhat disagree, 3 for somewhat agree, and 4 for completely agree. In addition to the quantitative survey items, I provided a qualitative component to the survey in the form of three open-response questions from the interview protocol. The data collected from these questions provided more qualitative data from the entire population, on top of interview data from a subset of the population.

The Value Beliefs Instrument is based on Expectancy Value Theory (Eccles et al., 1983) which posits that achievement and behavior are affected by task value, or in other words, the amount of value a person believes to be inherent in doing a certain task drives their willingness to engage in that task. Eccles et al. originally conceptualized value with four dimensions: intrinsic value (personal enjoyment and interest), attainment value (the perceived importance of success), utility value (usefulness of the task), and cost value (what is necessary to give up to be successful). Gaspard et al. (2015) expanded upon this work by subdividing the four dimensions into 11 subconstructs. Utility value is subdivided into utility for school, utility for daily life, social utility, utility for job, and general utility for future life. Attainment value is subdivided into importance of achievement and personal importance. Cost value is subdivided into effort required, emotional cost, and opportunity cost. The Value Beliefs instrument measures the four original value constructs as well as the 11 subconstructs. The survey instrument can be found in Appendix D.

The Value Beliefs Instrument was validated using Confirmatory Factor Analysis (Gaspard et al., 2017). Gaspard et al. computed Raykov's ρ, which is a measure of reliability that ranges between 0 and 1, with higher numbers indicating higher reliability (Raykov, 2009). Gaspard et al. found $\rho > 0.7$ on all mathematics values except for personal importance ($\rho = 0.65$) and utility for school ($\rho = 0.65$). In this same study, the authors employed the Value Beliefs tool to determine how value beliefs changed over time in five subjects: German, English, mathematics, biology, and physics. They found that in general, value beliefs declined as student grade level increased, though there was some variability based on value facet and subject (Gaspard et al., 2017). The Value Beliefs instrument was used in the present study to assess how nursing students perceive the value of learning College Algebra.

Interview Protocol

The primary purpose of the researcher-developed interview protocol was to evaluate how framing influences perceptions of transferability (RQ3) and to address the overarching research question of how intercontextuality drives perceptions of value and transferability (RQ4). Additionally, qualitative and quantitative data converged in RQ2 to explain perceptions of value, and in particular, mathematics utility and relevance. In this embedded case study mixed-methods design, the qualitative data was forefront, with embedded quantitative data gathered to support explanations and inferences (Creswell & Plano-Clark, 2017).

The semi-structured interview protocol contains questions that ask participants to describe the value of learning mathematics in context of their life and career. A graduate research assistant in mathematics education was trained to use the interview protocol as a guide but to ask additional probing questions as needed. An example of an interview question is, “What connections do you see between College Algebra and the nursing profession?” The entire interview protocol can be found in Appendix E. On average, each interview lasted between 20-30 minutes.

Procedures for Data Collection

The procedures for the present study included five major stages: (1) Recruitment, informed consent, and content-based pre-test, (2) Value Beliefs pre-survey, (3) Expansive/bounded framed webinars, 4) Value Beliefs post-survey, and 5) Semi-structured interviews. Table 4 provides an overview of the procedures and data collection according to the weeks in the students’ fall semester schedule.

Table 4

Schedule of Procedures According to Week in the Students' Semester

Week	Activity
1 – 3	Participant recruitment, informed consent, content-based pre-test, and creation of stratified groups
4 – 5	Pre-intervention Value Beliefs survey
6	Webinar (rational expressions and proportions)
7 – 8	Gap between treatment weeks
9	Webinar (quadratic equations and introduction to functions)
10	Webinar (graphs of functions)
11	Post-intervention Value Beliefs survey
12	Interviews

Weeks 1 through 5: Informed Consent, Pre-Survey, and Pretest

The study occurred during the Fall 2023 semester of the College Algebra course. I recruited participants during the first three weeks of the semester. To avoid students perceiving undue influence by me, their course instructor, my dissertation chair, Dr. Jessica Shumway, and the nursing school's Communications Director managed all recruitment efforts. Participants were provided with recruitment materials through Canvas Inbox and course announcements.

After completing informed consent using Qualtrics, participants were asked to take the content-based pre-test (see Appendix C). This test included content from the three mathematics topics of each of the 3 weeks of the study. Questions for the pretest were pulled from a pool of quiz prompts in the Knewton adaptive learning software. This software contains College Algebra-based content questions aligned with the content of Week 6 (rational expressions and proportions), Week 9 (quadratic equations and introduction to functions), and Week 10 (graphs of functions). Participants completed the test on Qualtrics by choosing the appropriate multiple-choice answer. The test took students approximately 30 minutes to complete. Based on test performance, participants were stratified into three groups: low, mid, and high. Each stratum was split into two treatment groups: bounded and expansive. Students were assigned to a treatment group based on which course section they were enrolled in, and I attempted to split the sections as evenly as possible considering stratified groups. The content-based pre-test was only used to stratify and group the sample, and results were not applied to any data analysis. During Weeks 4 and 5, participants completed the Value Beliefs survey to establish a pre-intervention baseline (see Appendix D). The survey took students approximately 20 minutes to complete.

Weeks 6 through 12: Webinars, Post-Survey, and Interviews

During Weeks 6, 9, and 10, I provided each group with a link to a recorded webinar taught using bounded or expansive framing (see Appendix B). Participants only had access to their assigned video webinar recording and did not have the option to attend a live webinar that week. Weeks 7 and 8 were considered a gap between study weeks. During this gap, participants received business-as-usual instruction, meaning that they were permitted to choose whether to attend a live session or watch a recorded video webinar to meet course requirements.

During Week 11, I administered the post-intervention Value Beliefs survey (see Appendix D) via Qualtrics to all study participants. I also obtained a small sample of post-intervention Value Beliefs surveys from anonymous students, which is the only study activity these anonymous participants completed. During Week 12, ten participants (six from the bounded group, and four from the expansive group) participated in an interview (see Appendix E). Interviews were conducted by a research assistant via Zoom and were audio recorded. Each interview lasted between 20-30 minutes. The data collection concluded at the end of Week 12.

Data Analysis

During the data analysis phase, I analyzed quantitative and qualitative data to investigate student perceptions of mathematics value and transferability and how intercontextuality functions as a driver of these perceptions. The embedded case study mixed-methods design calls for quantitative and qualitative strands to be combined and interpreted together, with quantitative data being embedded within the qualitative data (Creswell & Plano-Clark, 2017). Table 5 shows each research question paired with its corresponding data source and data analysis procedure.

Quantitative Data Analysis

The Value Beliefs survey provided the quantitative data for the study and RQ1 in particular (How does expansive versus bounded framing of mathematics affect nursing students' perceptions of mathematics value?). The quantitative data analysis was a multi-step process conducted using SPSS statistical analysis and Microsoft Excel software programs. First, I screened the data for missing data and outliers. I eliminated one participant based on straight-line survey responses, which is discussed further in the

Table 5

Summary of Research Questions, Data Sources, and Data Analysis

Research question	Data source	Data analysis
1. How does expansive versus bounded framing of mathematics affect nursing students' perceptions of mathematics value?	Value Beliefs instrument (Gaspard et al., 2015): Pre and Post survey for all participants	QUANT: Descriptive statistics, Wilcoxon Signed Rank test
2. How does expansive versus bounded framing of mathematics influence how nursing students perceive mathematics value, and in particular, mathematics utility and relevance?	Value Beliefs instrument (Gaspard et al., 2015): Pre and Post survey for all participants Open-response survey items and transcripts from student interviews	Convergence of qualitative and quantitative data QUANT: Descriptive statistics, Wilcoxon Signed Rank test QUAL: Reflexive thematic analysis
3. How does expansive versus bounded framing of mathematics influence how nursing students perceive transferability of mathematics?	Open-response survey items and transcripts from student interviews	QUAL: Reflexive thematic analysis
4. In what ways is intercontextuality the driver of perceptions of value and transferability?	Open-response survey items and transcripts from student interviews	QUAL: Reflexive thematic analysis

Results section. I then conducted descriptive statistics such as measures of central tendency and boxplots on each of the four value facets and 11 subfacets.

While a one-way repeated-measures ANOVA test would be an appropriate choice to make pairwise comparisons between the composite means of each value facet of the two groups (bounded and expansive) by comparing the ratio of between-group variance to the within group variance, this study did not produce the number of participants required for statistical power with ANOVA, so I resorted to a paired samples *t* test. This test allowed me to compare the composite means of each value facet from the pre- and post-intervention survey responses for each group (bounded and expansive) separately. While there is debate over whether Likert scale data can be treated as continuous and analyzed using a *t*-test, research supports using a paired *t*-test for pre-post study design with a categorical independent variable (bounded and expansive condition; Robitzsch, 2020).

I first checked for normality using the Shapiro-Wilk Test for normality. Because the *p*-value of the Shapiro-Wilk test was less than .05 for multiple value facets, the results indicated that the data was not normally distributed. Thus, I conducted a Wilcoxon Signed Rank test, which is the nonparametric equivalent of the paired *t* test (Marshall & Boggis, 2016). The Wilcoxon Signed Rank test compares medians of each value facet and assigns a ranking to examine whether the ranks differ from pre- to post-survey.

Based on the results of the Wilcoxon Signed Rank test, I identified three value facets (intrinsic, attainment, and utility) and one sub-facet (personal importance) that yielded more overall positive ranks than negative ranks across one or both groups. I then created line graphs for each of the 11 participants to visualize how their individual perceptions changed across each facet from pre- to post-intervention.

Convergence of Quantitative and Qualitative Data

To answer RQ2 (How does expansive versus bounded framing of mathematics influence how nursing students perceive mathematics value, and in particular, mathematics utility and relevance?) I used both quantitative and qualitative data, which includes Value Beliefs survey responses and student interview transcripts. I isolated quantitative data for the students who participated in interviews ($N = 10$) and used descriptive statistics and visual data representations such as line graphs to analyze changes over time. I also analyzed interview transcripts and open-response survey written answers qualitatively using a reflexive thematic analysis process (Braun & Clarke, 2022) with the goal of developing explanatory themes (Simon, 2019). Initial codes that eventually helped to answer RQ2 included phrases such as *meaningful*, *relevant*, *useful,* or conversely, *waste of time, not important,* or *pointless.*

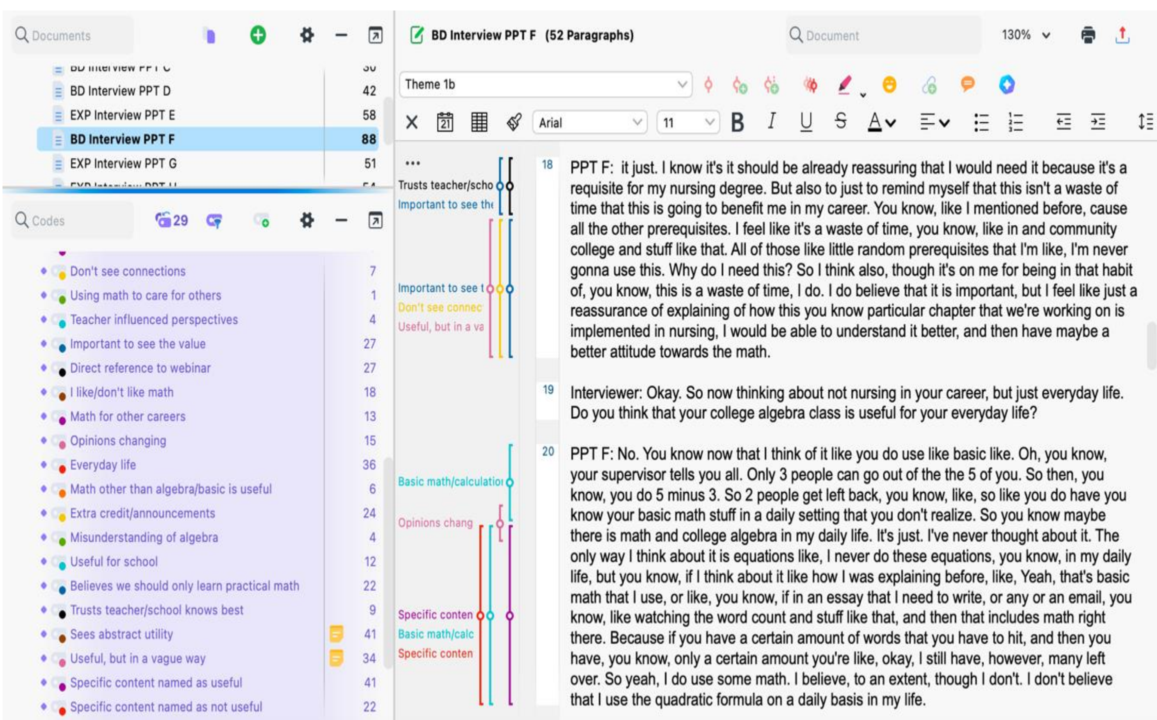
Qualitative Data Analysis

Student responses to the three open-response items on the Value Beliefs Survey and transcripts from participant interviews provided the qualitative data for the study. I used the data to answer RQ3 (How does expansive versus bounded framing of mathematics influence how nursing students perceive transferability of mathematics?) and RQ4 (In what ways is intercontextuality the driver of perceptions of value and transferability?) by following a reflexive thematic analysis process (Braun & Clarke, 2022) and developed explanatory themes (Simon, 2019). It is important to detail exactly how qualitative data will be interpreted to avoid as much researcher bias as possible (de Freitas et al., 2017), so I will describe the process in the paragraphs that follow. However, Braun and Clarke (2022) acknowledge that the concept of researcher bias is contrary to reflexive thematic analysis and that themes should be considered *constructed* by the researcher (and thus inherently subjective) rather than *discovered*.

To conduct the reflexive thematic analysis (Braun & Clarke, 2022), I first cleaned written responses from open-response survey items and transcripts from interview audio recordings. The process of cleaning helped to acquaint myself with the data. I ended this phase by writing familiarization notes for the dataset. Next, I entered these files into MAXQDA software and conducting an initial line-by-line analysis using initial (open) coding (Saldaña, 2021). During this phase I remained flexible and open to any potential outcomes and created codes as the data dictated. For example, initial codes included phrases like *meaningful*, *relevant*, or *useful* (RQ2), *apply*, *transfer*, *use*, *outside of school*, *on the job*, or *everyday life* (RQ3), and *do/don't see connections*, *relationships*, or references to moments in the webinar that helped students make those mental connections (RQ4). A screenshot of a portion of the coding that occurred on MAXQDA is shown in Figure 5. Initial codes are shown in the lower left corner and a snippet of a participant's interview transcript is shown on the right with codes applied.

Figure 5

Screenshot of First Round of Qualitative Coding in MAXQDA



I then conducted a second pass through the data on MAXQDA and continued to refine the code book. The results of this iteration were exported into an Excel spreadsheet, and I used color coding to group codes into similar themes (Figure 6). This process took multiple passes through the data as I attempted to inferentially draw themes and patterns from the analysis (Simon, 2019). I generated a set of initial themes by collapsing codes and analyzing the relationships between them. The themes were continually refined through multiple iterations of comparison between codes and themes. I also used my conceptual framework (Figure 4) to focus my analysis on how intercontextuality functions as a driver of value perceptions and perceptions of transferability.

Figure 6

Screenshot of Thematic Grouping in Excel

Code System	Memo	Frequency
Code System		622
Sees abstract utility	PPT thinks math/algebra will be useful for things like critical thinking, problem solving, precision	41
Useful, but cannot articulate how	PPT thinks math/algebra will be useful but cannot articulate specifically where or why	34
Specific content named as useful		41
Specific content named as not useful		22
Algebra is "overkill"	Some is useful, but most is not Too much homework that's not relevant	39
Med math	Conversions, metric/imperial, measurements, dosages	89
Basic math/calculations only		49
In-practice experience		25

Summary

This study aimed to investigate Expansive Framing as a theory and an instructional technique through a framing intervention in a College Algebra course for nursing students. I employed an embedded case study mixed-methods design (Creswell & Plano-Clark, 2017) and assigned participants to either a bounded or expansive framing group. Each group participated in three webinars that were taught using either bounded or expansive framing techniques. They completed a Value Beliefs survey (Gaspard et al., 2015) both before and after the intervention and the results constituted all the quantitative and some of the qualitative data for analysis. Also, participants in both groups were interviewed after the intervention and the interview transcripts made up the rest of the qualitative data. Quantitative data were analyzed using descriptive statistics, boxplots, line graphs, and a Wilcoxon Signed Rank test. Qualitative data were analyzed using reflexive thematic analysis (Braun & Clarke, 2022). Quantitative analysis supported the qualitative analysis as it was embedded in the case study. The results of this analysis will be discussed in the next section.

CHAPTER IV

RESULTS

The purpose of this study was to explore nursing students' perceptions of mathematics transferability and value, and how intercontextuality influenced those perceptions after participating or not participating in an expansively framed intervention. Thus, the research questions this study analyzed were as follows.

1. How does expansive versus bounded framing of mathematics affect nursing students' perceptions of mathematics value?
2. How does expansive versus bounded framing of mathematics influence how nursing students perceive mathematics value, and in particular, mathematics utility and relevance?
3. How does expansive versus bounded framing of mathematics influence how nursing students perceive transferability of mathematics?
4. In what ways is intercontextuality the driver of perceptions of value and transferability?

I used qualitative and quantitative data to answer the research questions. This chapter presents the results of the mixed methods analysis, organized by research question. The first section shows quantitative results that answer research question #1, the second section shows the results of the convergence of qualitative and quantitative data to answer research question #2, and the third section shows the qualitative results that answer research questions #3 and #4. In this chapter, participants have been given a pseudonym with a notation indicating which group they were in (bd for bounded or exp for expansive). For example, participant Anna who was in the bounded group would be denoted Anna (bd). Anonymous participants who only completed the post-survey were given a pseudonym based on number and group. For example, anonymous participant #1 in the expansive group would be denoted Anon1 (exp).

Research Question #1: Survey Results for Perceptions of Mathematics Value

The first research question used quantitative data to answer how expansive versus bounded framing affected perceptions of mathematics value. The results in this section show the quantitative analysis for participants who completed both a pre- and post-intervention survey (N = 11). While 15 participants completed the content-based pre-test and the pre-survey, three dropped the course prior to taking the post-survey (all from the expansive group) and one (also from the expansive group) was eliminated due to straightline survey responses (i.e., entering the same answer to every survey question). These four participants were not included in the analysis nor in the results that follow.

I carefully considered the implications of dropping data from the study. Reuning and Plutzer (2020) emphasized that straightlining in and of itself is not a reason to eliminate data; rather, researchers should identify whether the respondent engaged in valid (thoughtful, truthful responses) or invalid (utilizing minimal thought and effort) straightlining. I determined that one participant, Julian (exp), engaged in invalid straightlining. This participant answered, “completely disagree” to every question, including reverse-coded questions such as “algebra is not important to me” and “algebra is very important to me.” Julian also spent less time completing the survey than most participants (8 minutes compared to an average of 15 minutes) and spent most of those 8 minutes providing in-depth responses to the open-response questions, consisting of about three paragraphs. The reverse-coded questions and short response time provided enough evidence to justify eliminating this participant's survey responses (Curran, 2016).

Table 6 shows the breakdown of participants in each stratum based on the results of their content-based pre-test. It should be noted that this information is presented here for context only, as scores from the content-based pretest were only used to stratify the groups and were not used for any data analysis.

Table 6

Breakdown of Participants by Stratum Based on Content Pretest Score

Group	Low	Mid	High
Bounded	3	3	1
Expansive	2	0	2

Descriptive Statistics

Table 7 presents the mean, median, and range of pre-survey and post-survey scores for all participants, bounded group only, and expansive group only, broken down by value facet. The table shows that median scores in the bounded framing group increased slightly from pre- to post-survey for positive value facets intrinsic (+0.2) and utility (+0.3) while mean scores declined some for intrinsic (-0.2) and utility (-0.2) value. Median scores in the bounded group also increased slightly for the negative value facet, cost (+0.4). In comparison, median scores in the expansive framing group marginally declined for positive value facets intrinsic (-0.5) and utility (-0.1), while median scores for attainment value increased slightly (+0.2). Cost value scores in the expansive framing group also increased slightly (+0.6), revealing that the perception of how much they would have to give up to be successful marginally increased over time. The lowest median ratings in the bounded group occurred for the utility facet (pre) and the attainment facet (post), while the lowest median ratings in the expansive group occurred for the intrinsic facet. The widest ranges occurred for the intrinsic and cost facets. The key takeaway from Table 7 is that there were minimal changes in self-reported perceptions of value beliefs. The slight changes that did occur showed that positive value beliefs generally declined slightly (with a few exceptions such as the attainment median in the expansive group), while negative value beliefs increased slightly.

Table 7

Descriptive Statistics for Pre- and Post-Survey by Value Facet

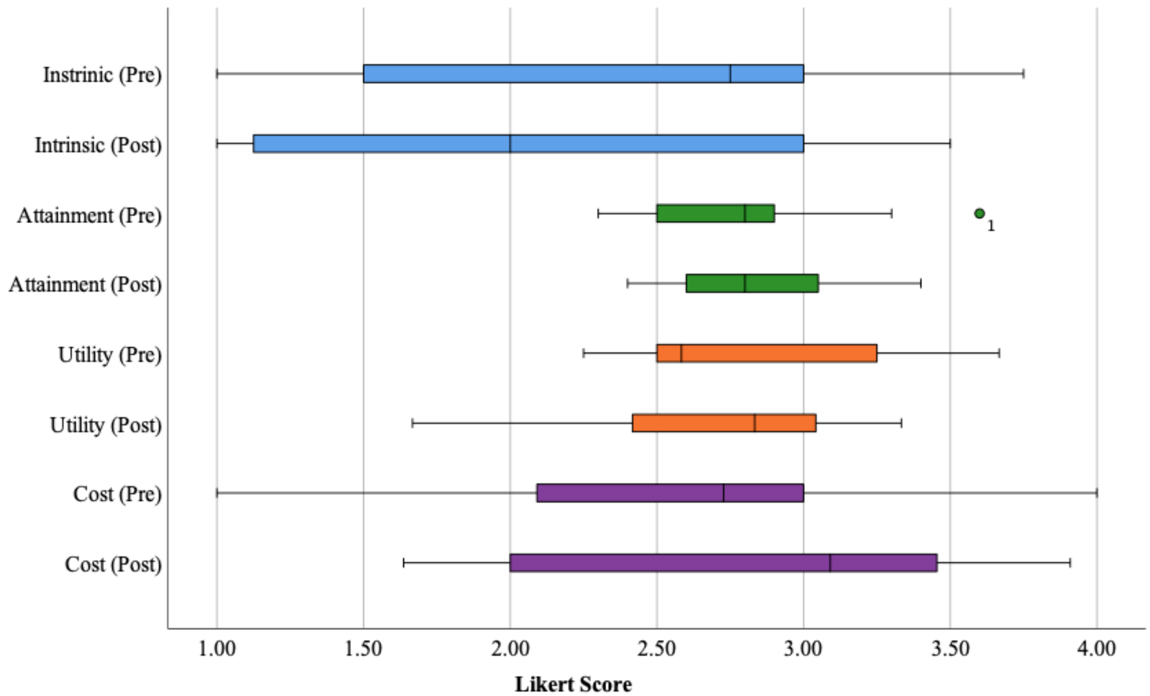
	All (*N* = 11)			Bounded (*n* = 7)			Expansive (*n* = 4)		
Value facet	*M*	*Mdn*	Range	*M*	*Mdn*	Range	*M*	*Mdn*	Range
Pre-Survey									
Intrinsic	2.4	2.8	2.8	2.5	2.8	2.8	2.3	2.1	2.5
Attainment	2.8	2.8	1.3	2.8	2.8	1.1	2.8	2.7	1.0
Utility	2.8	2.6	1.4	2.9	2.6	1.4	2.8	2.7	1.0
Cost	2.6	2.7	3.0	2.6	2.7	2.2	2.5	2.8	2.5
Post-Survey									
Intrinsic	2.2	2.0	2.5	2.3	3.0	2.0	1.9	1.6	2.5
Attainment	2.8	2.8	1.0	2.9	2.8	1.0	2.8	2.9	0.6
Utility	2.7	2.8	1.7	2.7	2.9	1.7	2.7	2.6	0.8
Cost	2.8	3.1	2.3	2.7	3.1	2.3	3.0	3.4	2.1

Note. Scores represent responses on Likert scale from 1 (completely disagree) to 4 (completely agree).

Figure 7 displays boxplots that compare pre- to post-survey scores for all participants (*N* = 11), broken down by value facet. This figure provides a graphical representation of the descriptive statistics and shows the spread of responses. The boxplots confirm that perceptions remained relatively steady from pre- to post-survey with slight median declines for the intrinsic value facet and slight median increases for utility and cost. The range of intrinsic and cost value perceptions decreased slightly from pre- to post-survey.

Figure 7

Boxplots Comparing Pre- to Post-Survey Scores by Value Facet for All Participants



Boxplots in Figure 8 graphically presents data from Table 7, comparing pre- to post-survey scores for participants in the bounded group only ($n = 7$). The boxplots show that perceptions of those in the bounded group remained relatively steady from pre- to post-survey across most value facets, with slight median increases for intrinsic, utility, and cost value. Median attainment value perceptions held steady. The range of attainment value increased from pre- to post-survey, while the range of intrinsic value decreased slightly.

Figure 8

Boxplots Comparing Pre -to Post-Survey Scores by Value Facet for the Bounded Group

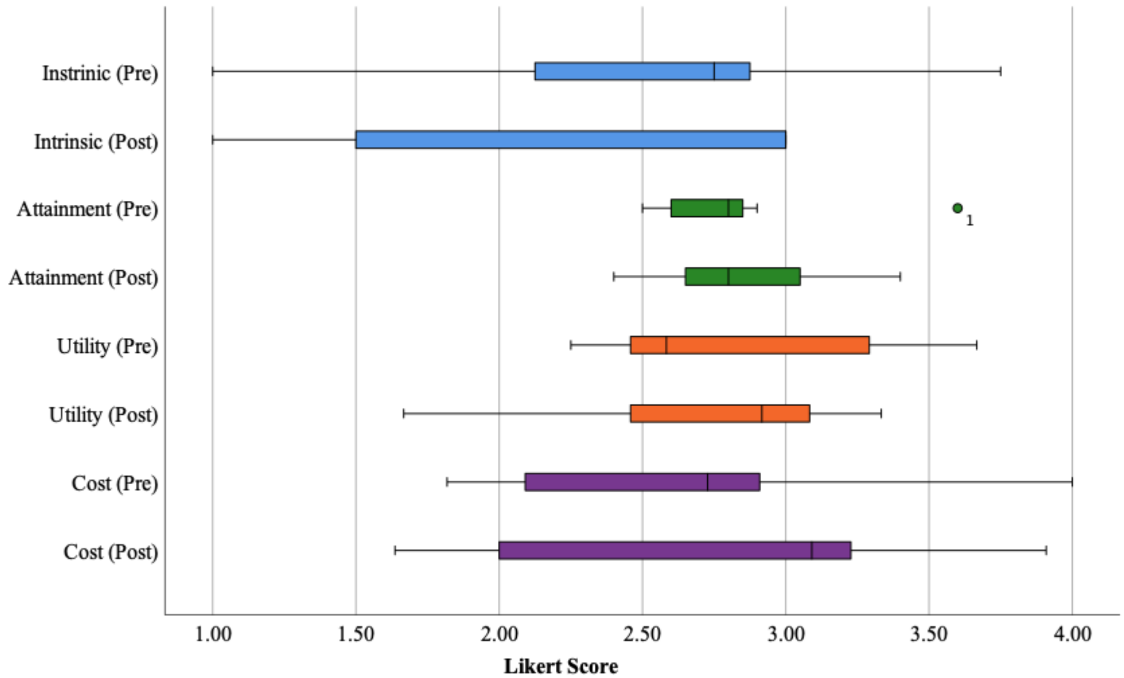


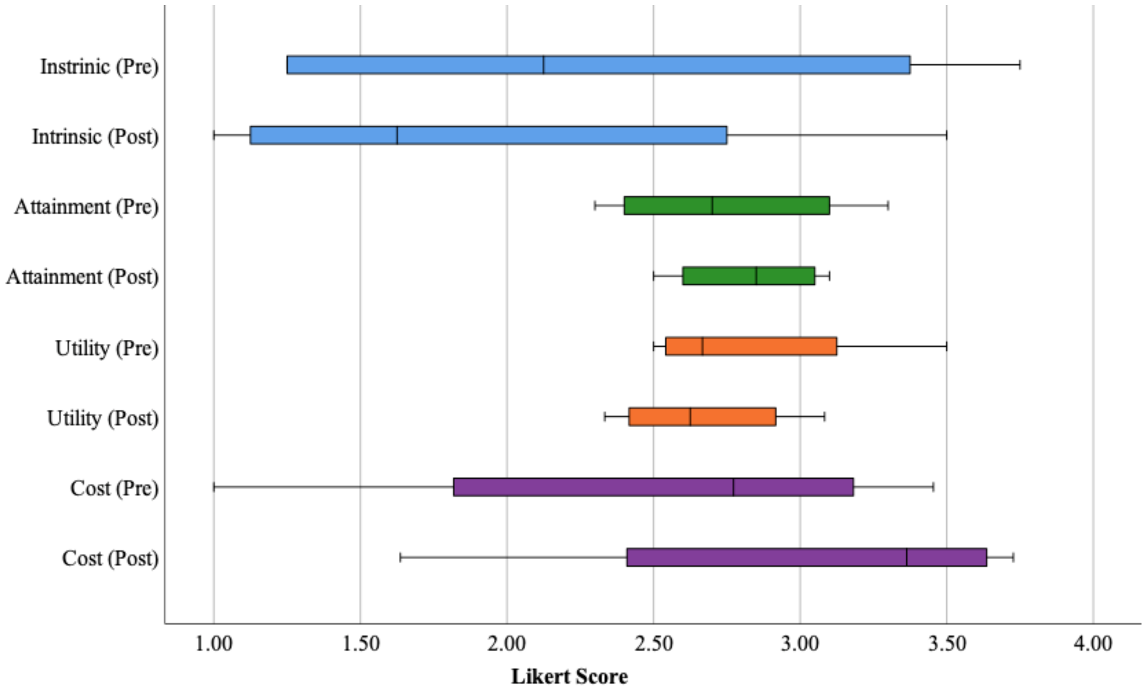
Figure 9 shows boxplots of data from Table 7, comparing pre- to post-survey scores for participants in the expansive group only (n = 4). Perceptions of those in the expansive group remained relatively steady from pre- to post-survey across most value facets, with slight median increases for attainment and cost value and slight median decreases for intrinsic and utility value. The range of data remained relatively unchanged, with only negligeable differences in all value facets from pre- to post-survey.

Wilcoxon Signed Rank Test

Because of the small sample size, I opted to check the data for normality using the Shapiro-Wilk test (Marshall & Boggis, 2016). The results of the Shapiro-Wilk test

Figure 9

Boxplots Comparing Pre- to Post-Survey Scores by Value Facet for the Expansive Group



indicated that the data was normally distributed across most of the value facets ($p > .05$), but two value facets did not have normally distributed data: utility (pre), $p = .49$; intrinsic (post), $p = .035$. Accordingly, I elected to conduct a Wilcoxon Signed Rank test, the non-parametric equivalent of the paired *t* test (Marshall & Boggis, 2016). By calculating a Wilcoxon Signed Rank test, I was able to examine whether any median changes in value perceptions from pre- to post-intervention were statistically significant within each group. Table 8 shows the results of the Wilcoxon Signed Rank test, broken down by value facet and group. The rankings were calculated by taking post-survey scores and subtracting pre-survey scores. Thus, negative rankings indicate that perceptions of a value facet declined from pre- to post-survey, and positive rankings reveal that perceptions of a value facet improved from pre- to post-survey. Ties show that there was no change in perceptions.

Table 8

Wilcoxon Signed Rank Test Results by Value Facet and Group

Value facet	Group	Neg/pos/ties	*N*	Mean rank	Sum of ranks	*z*	*p*
Intrinsic	Bounded	Negative	3	4.00	12.00	-1.225	.221
		Positive	2	1.50	3.00		
		Ties	2				
	Expansive	Negative	3	2.00	6.00	-1.633	.102
		Positive	0	0.00	0.00		
		Ties	1				
Attainment	Bounded	Negative	2	2.50	5.00	0.000	1.000
		Positive	2	2.50	5.00		
		Ties	3				
	Expansive	Negative	1	3.00	3.00	-0.756	.450
		Positive	3	2.33	7.00		
		Ties	0				
Utility	Bounded	Negative	4	4.50	18.00	-0.679	.497
		Positive	3	3.33	10.00		
		Ties	0				
	Expansive	Negative	3	2.00	6.00	-1.604	.109
		Positive	0	0.00	0.00		
		Ties	1				
Cost	Bounded	Negative	3	2.00	6.00	-0.406	.684
		Positive	2	4.50	9.00		
		Ties	2				
	Expansive	Negative	0	0.00	0.00	-1.826	.068
		Positive	4	2.50	10.00		
		Ties	0				

Note. Rankings are POST – PRE. Negative rankings indicate scores declined from pre to post; positive rankings indicate scores improved from pre to post.

Table 8 shows that median post-survey ranks were not statistically significantly different than the median pre-survey ranks in the bounded group for value facets intrinsic (z = -1.225, p = .221), attainment (z = 0.000, p = 1.000), utility (z = -0.679, p = .497), and cost (z = -0.406, p = .684). In the expansive group, median post-survey ranks were again not statistically significantly different than median pre-survey ranks for value facets intrinsic (z = -1.633, p = .102), attainment (z = -0.756, p = .450), utility (-1.604, p = .109), and cost (z = -1.826, p = .068).

The quantitative data analyzed in this study were used to answer the research question, “How does expansive versus bounded framing of mathematics affect nursing students’ perceptions of mathematics value?” Descriptive statistics and boxplots showed that there were minimal changes in self-reported perceptions of value beliefs. Positive value beliefs generally declined slightly (with a few minor exceptions), while negative value beliefs increased slightly across both treatment groups. However, the Wilcoxon Signed Rank test showed that these results were not statistically significant. Thus, based on available quantitative data, the answer to research question #1 is inconclusive. For that reason, I used individual students’ pre- to post-survey responses (line graphs) to further explore their self-reported perceptions along with the qualitative open-response and interview data. I will report this in the subsequent section.

Research Question #2: Both Groups Perceived Value

The qualitative analysis for research question #2 focused on perceptions of value, with a particular emphasis on utility value and relevance. I conducted a reflexive thematic analysis (Braun & Clarke, 2022) of interview transcripts (n = 10) and open response survey prompts (n = 11) following the process detailed in the Methods section. Phrases that included terms like *meaningful, relevant, useful,* or conversely, *waste of time, not* *important*, or *pointless* were coded to help answer this research question. Overall, the reflexive thematic analysis showed that Expansive Framing positively influenced the way nursing students perceived mathematics utility and relevance.

Once the qualitative analysis was completed, I extended the quantitative analysis by creating line graphs for each of the 11 participants who completed both surveys. The line graphs showed how value perceptions changed from pre- to post-survey across each of the four value facets. Figure 10 shows the line graphs of bounded participants' pre- and post-survey mean scores by value facet, and Figure 11 shows the line graphs of expansive participants' pre- and post-survey means cores by value facet.

Some participants (n = 3 from bounded group and n = 3 from expansive group) showed a decline in perceptions of positive value facets and an increase in perceptions of negative value facets (e.g., Betty (bd) in Figure 10). This pattern is consistent with the overall quantitative results across the whole group (presented in previous section). However, some individuals (n = 4 from bounded group and n = 1 from expansive group) showed improvements in perceptions of certain positive value facets and/or a decline in perceptions of cost value, a negative value facet (e.g., Ivan (bd) in Figure 10).

I then examined each participant's qualitative responses in more detail to ascertain which factors led to any changes shown on the line graphs. Some participants in the bounded group showed increased positive perceptions of utility value on the survey despite being in the bounded group. Their interviews revealed that this seemed to occur due to finding relevance to nursing in the mathematics content. Some participants in the bounded group described specific activities outside of the webinars that presented the

Figure 10

Line Graphs of Participants' Pre- and Post-Survey Scores by Value Facet: Bounded

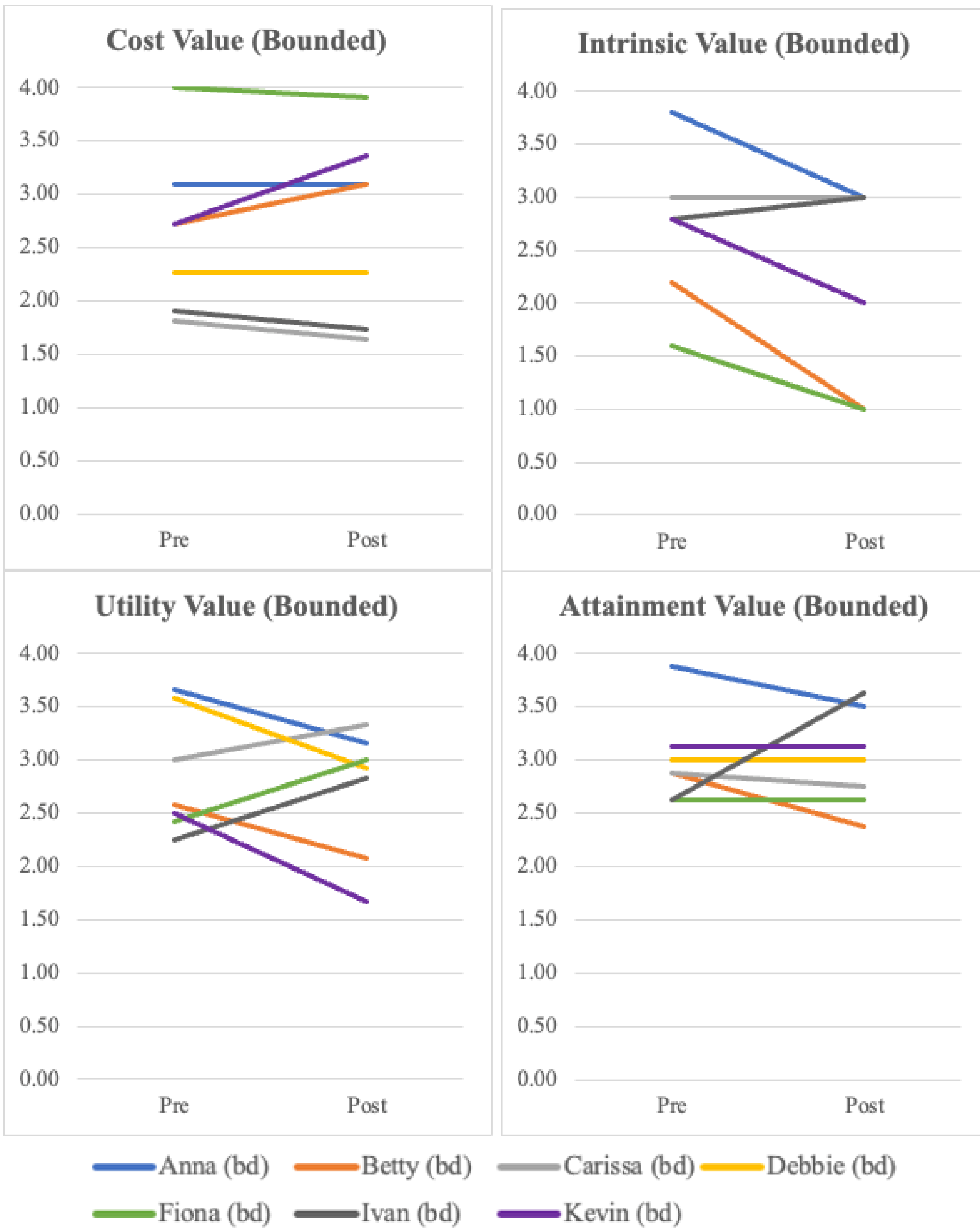
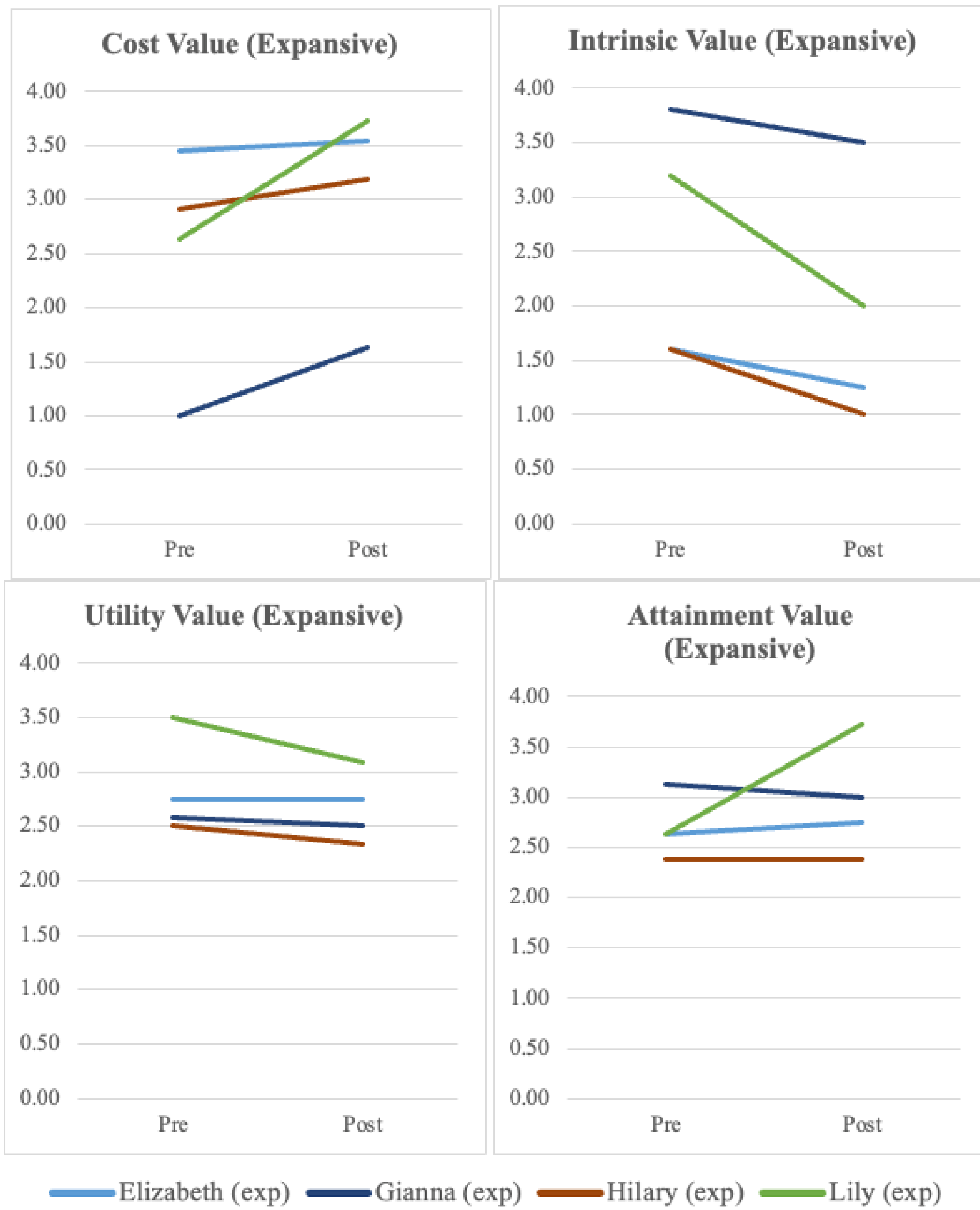


Figure 11

Line Graphs of Participants' Pre- and Post-Survey Scores by Value Facet: Expansive



utility value of mathematics to nursing, with one even referring to the webinars as a "waste of time." Finally, some students in the expansive group described the framing in the webinars as a source for seeing the utility of mathematics. In the sections that will follow I will present these results in more depth.

Bounded Group's Perceptions of Utility
Value: Useful Content

Carissa, Fiona, and Ivan were students in the bounded group that showed slight increases in their perceptions of utility, which was a theme reflected in their interviews. For example, Carissa (bd) showed an increase in perceptions of utility (pre 3.00; post 3.33). She called out specific College Algebra content – graphing – as being particularly useful in the nursing profession, saying:

> Right now [in algebra] we're learning how to properly read some graphs. And so that's another thing that's implied in nursing school. You know, I'm learning how to read a proper graph for a patient's chart. For example, I used it the other day at work for patients' vitals. We used the graph to look at what trends they're trending on, you know. Things like that. That's, that's very useful.

Fiona (bd) also showed an increase in utility value perceptions (pre 2.42; post 3.00) and credited the expansively framed extra credit assignments as aiding her in making connections between College Algebra content and nursing. She said:

> One of [the extra credit assignments] did have a square root involved. And I was like, Oh, wow! Like, you know, I never thought a square root of a number in this scenario would be in, you know, nursing. I'm like, okay, cool. Well, then, I guess square roots are in nursing. And I guess I should probably know this, too.

Ivan (bd) showed an increase in perceptions of intrinsic value (pre 2.80; post 3.00), utility value (pre 2.25; post 2.83), and attainment value (pre 2.63; post 3.63). Ivan (bd) was able to identify specific College Algebra topics as useful in both nursing and daily life.

Regarding nursing applications, he said:

> One application that we've learned in [College Algebra] so far…is looking at the rate of change over time. Now, if we have specifically a patient's lab values and we're trying to get their white blood cell count down, you know, we need to maybe look at, for instance, a specific antibiotic that's going to help to keep that bacteria in check. And then, looking at the rate of change, we can see that having this medication and knowing their white blood cell count, whether it's effective or ineffective. So that's one way that us as nurses can help quantify math in a very useful way that's applicable for patients and us in general as nurses.

He also identified ways that he used College Algebra topics in his daily life, commenting:

> I think that [College Algebra] is useful…not just in nursing, but home projects, for instance. I've already had to use some of those this year that I've learned from this class which has been fantastic. So this year my wife and I, we decided to landscape our entire backyard, and we needed to look at that surface area of the material that we're taking out, and then also to bring back in material to fill that void. We were able to calculate almost down to the exact yard on how much that we needed using math specifically from this class. We also had built an awning on to our house, and we wanted to know the specific rise over the run, and we were able to calculate that this year as well. And so those are just two small useful tips that we've been able to use from this class so far this year.

Bounded Group Named Activities Beyond the Webinars

Bounded group participants Debbie, Kevin, and Ivan made comments about the instruction and how it influenced their perceptions of the utility value of algebra for nursing. Debbie (bd) showed an increase in intrinsic value (pre 2.80; post 3.00) but a decrease in utility value (pre 3.58; post 2.92). One of her interview responses diverged from her survey result. In her interview, Debbie (bd) called out the expansively framed extra credit assignments as a classroom activity that improved her perceptions of utility in the nursing field. She commented:

> I've done a few [extra credit] problems in my algebra class right now, like calculating BSA [body surface area] and calculating a person's BMI [body mass

> index] and calculating like, dosage calculations. Like the exam that we had…[the instructor] incorporated med math, and that included, like administering medications to a pediatric patient versus administering medication to an adult patient, and those are two different formulas. So, if you choose one formula, and it's not correct for that specific patient, then your calculation would be wrong. I feel like, just like math, like you do need to really pay attention to the question, and if you don't, then you could get the wrong answer, and that can affect somebody's life.

Ivan (bd) mentioned that the webinars were not particularly helpful in identifying the value of mathematics, but he did specify the weekly “Why Should I Care” announcements as eye-opening:

> Personally, I didn't realize that there are so many different variations of algebra that were incorporated into the nursing field until taking this class, especially when [the instructor] is sending out emails [announcements] to tell you each week how this applies to the nursing field, which, I think, is fantastic.

Kevin (bd), a participant in the bounded group, followed the overall group trend of an increase in the negative value perception of cost (pre 2.73; post 3.36) and a decrease in the positive value perceptions of intrinsic (2.80 pre; 2.00 post) and utility (2.50 pre; 1.67 post). His interview responses converged with these perceptions, and he frequently referred to College Algebra and the weekly webinars as a “waste of time” and “something that you just have to go through in order to get where you want to go.” In contrast, Elizabeth (exp) showed a marginal increase in attainment value perceptions (pre 2.63; post 2.75) while utility value perceptions remained steady (pre 2.75; post 2.75). She called out expansively framed content in the webinars as being helpful in improving her general outlook on the value of mathematics:

> [The instructor] would use some scenarios [in the webinars]. And it helped. It helped make me feel a little better about my outtake on math because when you, when you make comparisons or relate relations to stuff that we do on the daily. It's like okay, I know I need to grasp this concept because I'm going to actually

use it. And I want to make sure I'm good at it so that I am good in my profession.

Julian (exp), a participant in the expansive group, also expressed changes in mindset based on the expansively framed webinars. He commented:

> I didn't know if algebra was actually going to be helpful before nursing school. You know, [the instructor] puts it in a different perspective. She does it in like clinical applications. So, I didn't even realize that algebra really is everywhere, almost as if, like chemistry. I forgot like, even stoichiometry, algebra has correlations with chemistry. I think that my thoughts about algebra and just math in general kind of expanded with, just like how [the instructor] explains it and puts it into clinical applications.

Unfortunately, Julian's (exp) quantitative data was eliminated from the analysis due to straight-line survey responses, so it was not possible to compare his quantitative data to these interview comments.

Qualitative and quantitative data were used to answer the research question, "How does expansive versus bounded framing of mathematics influence how nursing students perceive mathematics value, and in particular, mathematics utility and relevance?" Some of the data converged. For example, students in the bounded group showed slight increases in utility value perceptions, and their interviews explained this through their own identification of relevance of the content and their naming of activities outside of the webinars (e.g., announcements, extra credit assignments). Though the overall quantitative analysis showed that there was no significant difference between the bounded and expansive group, a more fine-grained analysis revealed that bounded participants benefited from classroom activities outside of the webinars and expansive participants benefited from the framing used in the webinars. In other words, participants in the expansive group credited the webinar content for shifting utility value perceptions in comparison to the bounded group, which indicates that Expansive Framing positively influenced the way nursing students perceive mathematics utility and relevance.

Research Questions #3 and #4: Qualitative Analysis

To answer research questions #3 and #4, I undertook a reflexive thematic analysis (Braun & Clarke, 2022) of qualitative data. Phrases that included terms like *apply, transfer, use, outside of school, on the job,* or *everyday life* (RQ3), and *do/don't see connections, relationships*, or references to moments in the webinar that helped students make those mental connections (RQ4) were coded to help answer these research questions. After an intensive analysis process that involved numerous passes through the data to refine codes (detailed in the Methods section), 642 instances of 29 first-round codes were ultimately condensed into three themes and two subthemes.

Overall, the reflexive thematic analysis showed that the instructor's framing in webinars, as well as other instructor-created activities (e.g., weekly announcements, extra credit assignments) helped to create intercontextuality and led to improved perceptions of transferability. The results in this section are organized according to the themes and represent the qualitative results from analysis of interview transcripts (n = 10; six from bounded group and four from expansive group) and open-response survey items (n = 11; seven from bounded group and four from expansive group).

Theme 1: Nursing Students Believe that Content's Value and Transferability Should Be Made Explicit

The first overall theme that emerged from the analysis was that participants emphasized the importance to clearly see that the mathematics they are learning is useful because seeing value provoked them to work harder to master it. Transferability emerged in students' responses when they used phrases such as "the future," "applied to daily life," or "benefit me in my career." For example, Debbie (bd) commented, "I think it's super important, just because it gives you motivation to know that you're not doing it just to do it. Like, you're doing it as motivation to help you in the future," and Elizabeth (exp) said, "It's hard for me to learn something [when] I don't see the relevance in real life." Intercontextuality appeared in students' statements when they used phrases like "how math and nursing work together." For example, Betty (bd) commented:

> I think it would be…helpful to understand exactly how [math and nursing] work together versus … right now if there's assignments that I'm struggling with, I start to feel like, I'm not even going to use this in my nursing career. Like, why do I need to learn this?

Further, participants voiced that their value perceptions were strengthened when transferability and intercontextuality were made explicit in instruction. Many students named the instructor as important in helping them see the transferability and utility value. Gianna (exp) stated that it's important for learners to see value in what they're learning. She expounded, "If it's something that can be applied to daily life, and our educators have the possibility to let us know… how we can use that, I think that's awesome because lots of people think math is pointless." Fiona (bd) discussed her need for reassurance that the content she is learning would be beneficial to her future:

> I know it's it should be already reassuring that I would need it because it's a requisite for my nursing degree. But also, to just to remind myself that this isn't a waste of time that this is going to benefit me in my career. I do believe that it is important, but I feel like just a reassurance of explaining how this, you know, particular chapter that we're working on is implemented in nursing.

Gianna (exp) stated, “I think it is important for us to be *told* why it's relevant…And I think it's awesome that…all of you guys are trying to make us feel like this stuff is relevant with nursing” and Ivan (bd) said, “If you don't know how the math is being used unless someone else points it out to you, that's not something that's going to be apparent for every single person to see.” Kevin (bd) mentioned:

> I think that would be important for some people, for…the teachers to…focus more on useful things, or even show how something could be used in life. That way people aren't like, oh I'm just learning this because I have to and not because it's actually used.

Hilary (exp) affirmed the importance of teachers making transferability explicit and called out expansive webinar content as a way this occurred in her course:

> I do enjoy when [the instructor] does the real-life examples, like when she is talking about something specific and then she can tell you, this is where it applies. I think that's better than just saying blanket, you know, this is what we're doing and we're doing it because you have to and not really giving any reason.

However, when transferability and intercontextuality were not made explicit, many expressed the feeling that algebra is useful for other careers but not for nursing. For example, Kevin (bd) said:

> As far as nursing goes, I already work in the field [and] the only things that you…need to know is your basics like division, subtraction, addition, multiplication. As far as like, graphs and statistics and those kind of things, those things aren’t really used so much in an average person's life. Those things are more so used for somebody who's either working with some type of job that deals with spreadsheets, or maybe even an engineering job. It doesn't really correlate well with nursing so much.

Kevin (bd) went on to explain that he chose nursing as a career because it did not involve much math, saying, “Prior to nursing, I wanted to be an architect and I realized math wasn’t my thing, so I chose not to be an architect. That’s why I’m going into nursing.”

Ivan (bd) corroborated this attitude when he said, “I don't think that the entire whole of the class is useful in nursing. But outside of nursing in different fields of building or…civil engineering, things like that. Yeah, it can be very, very useful.” Kevin (bd) and Ivan’s (bd) statements provide insight into students’ view about what kind of mathematics is transferable to nursing versus other careers, and Kevin (bd) in particular distinguished the usefulness of algebra from other kinds of mathematics for the career of nursing.

Theme 2: Nursing Students’ Perceptions of Medical Math and Algebra and Their Value

Kevin (bd) and other students named some of this other kind of mathematics “basic” or described it as medical math (med math). Most participants recognized that they needed to learn basic mathematics calculations to be successful in medical mathematics, which is mathematics used specifically in healthcare applications. For example, Hilary (exp) commented that the mathematics she views as important to learn consists of “medication calculations, weight-based dosing. You know, the things that nurses use.” Debbie (bd) said:

> I feel like nurses should at least learn the basics to math, because there's so much basic math involved in nursing as well. I know that [nurses] do med math, and I know that that's very important, especially when drawing and administering medications. The slightest incorrect dosage…that you calculate can really affect somebody's life. So, I do think that when nurses go into the nursing program, like they should really be aware of at least their basic math skills.

Kevin (bd) wrote in his post-survey that “basic math is only needed [for nursing]. I feel like the only thing a class like [College Algebra] does is help in my ability to learn and think critically.” Betty (bd) commented in her interview, “I don't feel like I’ll use [algebra] very much, I mean, I know, like adding, subtract, subtracting, like simple math. But I don't feel like the stuff that I'm learning right now really pertains to my personal life.”

Though most nursing students saw value in learning basic mathematics calculations and applying them in medical computations, many did not see value in learning algebra or other advanced mathematics and thought the College Algebra course would mostly not be useful to them. For example, Gianna (exp) wrote in her post-survey:

> Passing algebra is great because it shows the school and employers that you can do basic algebraic computations, which means you have some of the mental processing power/intelligence that should be required of a nurse. But I don’t think that most of the formulas and objectives we learn during algebra will actually be applicable in our nursing careers. So, I would think taking algebra is not worth it but nevertheless it’s required so I like to think that the board at [the college] knows better and wouldn’t be making us take this class for nothing.

When asked if algebra is important to learn, Kevin (bd) responded:

> The basics, you know, like…if you're calculating BMI and stuff like that, I mean, it's basic division, multiplication. Like, if you want to change someone's pounds to kilograms…you just do times 2.2. So those are like really basic equations…in comparison to what's taught in math classes to where I think math classes overreach the intended subject of what nursing is really going to [need].

Ivan (bd) identified the topic of quadratic functions as unimportant in the nursing profession and elaborated, “I don't necessarily think that's super important to learn, because the chances of having to set that type of problem up in nursing is a severe outlier. Learning those is not always going to be the most important thing.” However, Hilary (exp) identified the real-life examples in the expansively framed webinar on quadratic functions as helpful in creating intercontextuality between content and real life. She explained:

> [The instructor] was talking about real life applications…like, the water going up and then going back down. She was talking about as we were graphing [quadratic] functions, how they make the arches. And then she was talking about all the different ways that it was [in real life]. Like when you hit a golf ball…[the function] tells you what height it is at which second.

Other participants were able to perceive transferability from abstract algebra content learned in class to more practical applications in both nursing and real life. Students mentioned concepts like ratio, measurement, rate of change, and graphing as highly transferrable. Elizabeth (exp) said, "I think that with dosage calculations…understanding how much medication will be administered, like the ratios [in algebra] is important" and Anna (bd) wrote in her pre-survey, "Algebra is used in calculating the correct dosage and can involve determining the flow rate of a drug that is delivered intravenously." Julian (exp) commented:

> I think I appreciate math even more now. Just seeing that like, when I go to the farmers market, you know, they're like, 25% off, or you know I go to the store. I'm doing a lot of like budgeting now. I've been doing so much more math than expected, compared to before, where last year I was just unprepared. And then this year I just feel like I you know, I'm doing great. I think I appreciate I really appreciate math more now.

Julian (exp) also mentioned using graphing in his job as a dialysis technician. He said:

> Seeing the graph [in algebra] really helps me with like, oh, that's where it peaks, and that's where it declines. In dialysis we use a thing called crit line, which basically measures the blood, and how much oxygen is in there and it measures even how much fluid is in the patient. So, I'm just better at looking at the crit line and looking at the graph and seeing, oh, okay, well, now that there's less fluids in the patient, and I'm still taking out this much. The patient might crash, and I might need to do CPR, which I don't want to do. So, a lot of the graphing stuff really helps me.

Ivan (bd) wrote in his pre-survey, "Nursing field uses in my opinion very few College Algebra equations. However, converting units would be the biggest area of applied algebra besides simple math calculations you might need which can mostly be done in your head." In his post-survey, Ivan's opinion had changed. He wrote, "There is a direct correlation with algebra and nursing in medical dosage calculations. I had not realized prior to this class that the conversions were from algebra formulas, rather than from chemistry." Interestingly, Ivan was in the bounded group, and in an analysis of other portions of his writing and interview, he attributes his thinking about value and transferability to the announcements and extra credit, which is tied to Theme 3 and will be discussed further below. Ivan's (bd) comments begin to move beyond basic math or med math and discuss the applicability of algebra to nursing. However, many students perceived algebra as transferable to "thinking" and "problem solving" more generally rather than practical nursing skills.

Subtheme 2a: Nursing Students' Perceived Value for Learning Algebra for Mathematical Practices

Many participants saw value in learning algebra for mathematical practices, such as developing problem solving and critical thinking skills, or attending to precision. Kevin (bd) stated, "I think it's important to have an open mind and just appreciate the value of hard work and using your critical thinking to discover things that you probably didn't know before. I think that's the value of the class" and Julian (exp) wrote in his pre-survey, "The most important connection between algebra and nursing is the act of problem-solving. It is important to critically think through your problems and solve it in a step-by-step manner." In his post-survey, he stated, "It is important to be precise and accurate when it comes to dealing with numbers because any minor changes can cause an adverse effect on the patient's plan of care."

Other participants commented on algebra being useful in furthering their academic career. For example, Anon2 (exp) wrote in their survey, "If I advance my career in the nursing field or even a nurse anesthetist, I will have to advance further in math than just algebra." Anon1 (exp) wrote, "I want to eventually go enter a master's program…so I think knowing and being good at algebra will be extremely helpful." Fiona (bd) said:

> If your knowledge is limited, your opportunities are limited as well. But if you have education, and you know more than just what the basic…whatever gets you through life, it's limited. So, I do believe that the more you know, in math and in general…it is better, for [your life], later down the line and in whatever profession you decide to go into.

Some students mentioned algebra being useful in family life. Betty (bd) said, "I do think it is important, especially having kids. I think it's good to understand math, especially for when they get older and are in the same classes" and Debbie (bd) commented, "I have younger cousins and they always ask me for help with their homework, and this would be something that I can help them with." Others mentioned personal satisfaction and confidence building as another perceived benefit of learning algebra. Ivan (bd) said, "Doing well in algebra not only is a personal satisfaction, but I think it makes you more efficient and confident to go into various problems that you encounter" and Kevin (bd) remarked, "If you're able to get through something that's hard for you and…you face the stigma of, I'm not going to use this, but yet you push yourself to get through it…it's going to build your confidence for sure."

In his interview, Julian (exp) credited the webinar lectures as strengthening his value for learning algebra for mathematical practices. In reference to the lectures, he said, “I was like, oh, okay, that's a really smart way to solve that. I would have never thought that. And I think that would translate to nursing…thinking outside the box on how to solve problems and patient interventions.” He later went on to describe additional perceived value in learning algebra:

> I think that based on what I learned so far, it's like really that critical thinking part of algebra not just with the numbers, but how you solve things in an orderly manner…and then also double checking the work like plugging the answer back into *x* or *y* and making sure it equates to each other. I think that's really beneficial with nursing. In nursing you do a lot of like, second checks and third checks.

However, some who perceived value struggled to identify transferability. For example, Anon2 (exp) wrote in their post-survey, “It’ll help with the classes that need the basic math knowledge but not for anything else.” In her post-survey, Gianna (exp) wrote:

> I think both [algebra and nursing] require a certain amount of intelligence to run smoothly. But algebra is about memorizing equations and plugging in arbitrary numbers. It essentially tests how well you can memorize and follow instructions. So, I guess in THAT sense I can see how it relates to nursing; nurses follow doctors’ instructions and memorize medical terms. Besides that, though, I don’t really see a connection.

Many participants indicated that though they perceived importance in learning algebra for mathematical practices in general, math that was clearly practical for their career was more important to them. Hilary (exp) remarked, “I don't mind math when there's a practical application. If it's something that I'm not going to use, then it's harder for me to really get into it and learn it. Then it's not really very valuable to me.” Ivan (bd) noted that algebra could be more useful in a nursing school if problems were put into nursing contexts. He said, “I don't necessarily need to know that George is driving a car and he's going to Seattle. But…if George is working in a hospital and he encounters an IV drip rate problem, that's something that's directly related to nursing."

Participants who were already working in some capacity in the medical field, or who have had conversations with those who do, reported an inability to see how algebra is directly transferrable. Kevin (bd) wrote in his pre-survey, "As an LVN dealing with nursing and shadowing RN's I rarely see any kind of math. If any math is used it is basic math and conversions, nothing like algebra and statistics." In his post-survey, it appeared that his opinions had not changed. Kevin (bd) wrote, "I…have discussed this with RNs and many state basic math is the only thing needed for the job such as addition, subtraction, multiplication, and division. Majority of the math required won't be used in the nursing field." Fiona (bd) agreed in her pre-survey. She wrote, "I've worked on the ambulance for 13 years now and I have not had to use math like this at all in the field." However, after the intervention, Fiona (bd) seemed to be entertaining the possibility that she may use more algebra than she previously thought. She said:

> I'm still you know, questioning and stuff. But the more I do the math, and you know, my [instructor]…sometimes writes notes on the assignments and stuff like that, or especially the extra credits, of like, how this would pertain to nursing. And so that's kind of helping me, you know, open my mind up a little bit more and just get my wheels turning about this question.

Hilary (exp) mentioned in her interview that she had worked in the medical field for 18 years. This in-practice experience seemed to influence her value perceptions for algebra, and she frequently indicated that she was only interested in learning what was directly practical for her career. For example, she said, "I can see what [the instructor] is doing with trying to relate everything back to nursing, but…some of the stuff she's talking about, like…calculating certain drips for medications…that's done by the pharmacist, it's not done by the nurse." She also said she did not see value in knowing mathematics beyond the basics because, "It's so easy now to use the internet. If you had to convert between…teaspoons and cups…it's easy to get on the internet and punch it in. You're going to get an accurate answer and not have to do anything."

Elizabeth (exp) also acknowledged that she saw little value for learning contrived mathematics:

> It's hard for me to grasp a concept when it's…not realistic like for me to like… Why do I need to understand how fast the train is going at *x* miles per hour, and how long it's going to take to get to Toronto. Why do I need that know that? And so I think the reasoning behind it for me is hard to grasp the concept, because I'm not understanding how can I apply this in real life?

She went on to describe how intercontextual content proved helpful in improving her value perceptions. She said, "However, seeing how it correlates…is helpful for me, because I feel like, my learning style…it's difficult for me to grasp the concept when I can't see the reasoning in real life. So, I think that is helpful for me."

While participants unanimously agreed that basic calculations and medical mathematics are important for nurses to understand, they often struggled to see practical value for algebra, though many named mathematical practices such as problem solving and critical thinking as valuable outcomes for algebra. However, some participants described the instructor's role in webinars and other classroom activities as helpful in improving their value perceptions for algebra beyond simply mathematical practices. The role of the instructor and classroom activities will be discussed in the next section.

Theme 3: The Instructor Played a Role in Creating Intercontextuality and Shaping Students' Perceptions of Value and Transferability

The third theme that emerged from the analysis was that students remarked on certain instructor-created classroom experiences, including webinars and other activities, as being influential in creating intercontextuality. This section centers on participant views on webinars, which was the focus of the intervention. Participants articulated differences in their experiences with the webinars based on their treatment group, and in particular, the expansive framing group participants could describe intercontextuality.

Bounded Framing Group Stated Lack of Connections between Math and Nursing in Webinars

Many participants in the bounded framing group commented that they did not see connections made to nursing or to real life during instruction. When asked what (if anything) the instructor did to help students see connections, Betty (bd) said, "I didn't get that much from the webinar" and specified disconnected content from the lecture, "Right now, one thing that I'm struggling a little bit with is like, the function of a specific letter…I've actually been struggling this last week or so on how it's going to be useful in my everyday life." Fiona (bd) corroborated Betty's views when she said, "Maybe [the instructor] might have mentioned a couple of times in the webinars like, how it's going to you know, play within my nursing career. I mainly remember it off the extra credit. Not so much on the webinars."

Ivan (bd) agreed with other participants in the bounded framing group that the webinars lacked helpful connections. He said, "I feel more that we're learning about the specific functions versus the application within nursing [in the webinars] …I wouldn't say that [the instructor] has shown us exact nursing examples within those webinars personally, that I can recall." Kevin (bd), another participant in the bounded group, remarked:

> For the most part the webinars were geared to get you to understand what the assignments were, which is okay, that's typically what most classes are like. But, like I said before, I wish maybe there was a way to make it a little more exciting by stating…like, these types of equations that we're learning this week is something that an engineer would know, or architect would know, just to make it more like to where you're like, wow, okay, these are actual things that some people use.

It appeared that the bounded webinars did not improve participant perceptions of mathematics utility, relevance, or transferability to their own lives or future careers.

Expansive Framing Group Named Connections between Math and Nursing in Webinars

In contrast, many of the participants in the expansively framed webinars expressed that the intercontextuality created during the lecture was helpful in improving their perceptions. For example, Elizabeth (exp) stated, "Sometimes [the instructor] will relate things to our everyday life, or just put things more in layman's terms. So that's more understandable with an example, maybe not necessarily nursing, but just in our everyday life, too." The interviewer followed up with, "And did that help you see connections between mathematics and nursing?" Elizabeth (exp) responded, "Yeah, that helps."

Hilary (exp) reported that she did not see how algebra would help in her everyday life, but when asked whether she sees connections between the College Algebra class and the nursing profession she answered affirmatively. Gianna (exp) also expressed, "[The instructor] has…showed us like a medical problem, and like a graph or something of how we could be applying that knowledge we're learning that week to this patient or whatever. So, more of that would be interesting." Julian (exp) mentioned that he enjoyed the clinically based examples in the expansively framed webinars and commented:

> I [want] just more examples… I mean, [the instructor] was really creative, but I think just more examples per content…I just want like a clinical application each week. Then I think it would really stick to me. Oh, this is why we're learning about quadratics or combining like terms.

When Julian (exp) stated that he wanted a clinical application "each week" he may have been referring to the webinars outside of treatment weeks (Weeks 6, 9, and 10) which were all taught using bounded framing and thus had no clinical applications. Finally, Anon2 (exp) wrote in their post-survey that they found the expansively framed classroom activities as more valuable than the homework, which primarily used bounded framing. They wrote, "The real life examples and the extra credit is useful because it ties in more work related examples. However, the everyday homework does not."

Overall, results indicated that participants in the bounded framing group did not experience improvements in their value perceptions from attending webinars. However, some participants in the expansive framing group noted that they picked up on the intercontexuality in the webinars, and they described changes in their attitudes toward mathematics utility, relevance, and transferability. This suggests that intercontextuality is indeed a driver of perceptions of value and transferability (RQ4) and that expansive versus bounded framing does influence how nursing students perceive transferability of mathematics (RQ3).

Subtheme 3a: Other Classroom Activities (Unplanned Expansive Framing) Emerged as Influential in Creating Intercontextuality

Certain classroom activities emerged as effective in creating intercontextuality through expansive framing. Due to the focus on webinars in this study, these activities were unanticipated sources of intercontextuality, but many participants articulated that the activities helped them make connections across contexts and improve value perceptions of mathematics. These activities were standard class routines and assignments, so they were common to both expansive and bounded framing groups.

One of the activities that participants frequently named was the extra credit assignments as described in the Methods section of Chapter III. The topics included in extra credit assignments included nursing applications such as calculating BSA (body surface area), finding pediatric medication dosages, converting units using ratios, and calculating the frequency of treatment for a burn patient using a formula. In the post-survey, Elizabeth (exp) indicated that she felt some of the skills she learned in College Algebra were transferrable and named specific content from the extra credit. She wrote, “I will apply some of these skills in nursing when calibrating and converting vitals (height, weight, BSA, units, etc.).” Anon3 (exp) also mentioned BSA as a useful skill learned in College Algebra. When asked what specific content they found useful from the course, Julian (exp) said, “Body surface area is really helpful, medications, infusion rates of medications, how long it remains in the bloodstream” and Hilary remarked, “Bits and pieces, like the weight-based calculations and drug calculations are good.” Both of their comments refer directly to skills learned and practiced on extra credit assignments. Betty (bd) said:

> Like for our extra credits…we get these problems that are like, real life situations. You're given these formulas and different patients, and you have to know how to work the formula, and without understanding math and like, how formulas work, you wouldn't be able to know why you're getting the answer you're getting or how to do the formula, like how to plug different things in. So, I do think [algebra] is important for nursing.

Here Betty (bd) specifies that the intercontextuality created through the extra credit assignment was helpful in connecting algebra to nursing in her mind.

Another classroom routine that many students mentioned was the weekly “Why Should I Care?” announcements (detailed in the Methods section). It should be noted that some participants described these announcements as an email because the announcements are automatically sent to their school email when they are posted. For example, Ivan (bd) said:

> I didn’t realize that there's so many different variations of algebra that were incorporated into the nursing field until taking this class especially when [the instructor] is sending out emails to tell you each week how this applies to the nursing field, which, I think, is fantastic.

Fiona (bd) also mentioned this activity when she said, “The professor always posts announcements every week how what we are working on that week will show up in nursing. That is helpful.” Betty (bd) commented:

> I do think it helps every week that our professor sends out an email that's just stating how what we're learning for the week could be used in the nursing field. I think that definitely helps being shown specific examples of how what we're using correlates into a nursing career.

As a participant in the bounded group, Betty (bd) went on to say that she “didn’t get that much from the webinars” but that she found the connections were made “more so from the weekly announcements.”

Finally, participants named the study itself as being a reason they found more value in the course content. Gianna (exp) was asked why she thinks it’s important to see the value in what she is learning. She responded, “I guess it's showing us we're not wasting our time…you want to understand why it's relevant to your job. And I think it's awesome that…all of you guys are helping us feel like this stuff is relevant with nursing.” Fiona (bd) called out the survey and interview as opening her mind to ways that mathematics could be applicable. She said:

> Up until now…I was more close-minded. But now that I'm part of this…survey and questionnaires and stuff like that, it's really making me think. And yeah, I kind of appreciate it because then I can start seeing life in a different way, which is also good, because if you only look at life in one certain way then that's all you're used to, and you might feel trapped. But if I can learn…how College Algebra is used in the daily life, you know, that would be kind of cool. I wouldn't be opposed to learning and listening about that. So I do actually appreciate being part of this, and I appreciate you guys picking me for this interview. Because I am starting to see a different side of education. And honestly it is making me feel more confident about myself, because I really lack confidence.

The qualitative data presented in this section were used to answer the research questions, “How does expansive versus bounded framing of mathematics influence how nursing students perceive transferability of mathematics?” and, “In what ways is intercontextuality the driver of perceptions of value and transferability?” Participants revealed that seeing value in the content they learn motivated them to master it, but some did not see practical value in learning algebra for nursing. However, the instructor’s framing in the webinars and other activities was effective in creating intercontextuality, which influenced participant views on other types of value for mathematics. For example, students expressed value for learning med math, and that they felt algebra was useful for mathematical practices such as critical thinking and problem solving, which were seen as skills directly transferable to nursing. This indicates that EF was effective in creating intercontextuality, and intercontextuality was effective in improving views of value and transferability.

Summary

This chapter presented three major findings. First, the quantitative analysis revealed that in general, positive value perceptions declined slightly or remained steady, while negative value perceptions increased slightly or remained steady. However, quantitative tests did not produce statistical significance for any value facet. Second, the convergence of quantitative and qualitative data helped to provide a closer look at individual value perceptions. This fine-grained analysis showed that participants in both groups did benefit from expansively framed activities, though the expansive group discussed the webinars positively while the bounded group did not find the webinars helpful. Third, the qualitative data showed that nursing students saw importance in seeing the value in what they learn, and that those value perceptions were reinforced when transferability and intercontextuality were made obvious in instruction. Further, the data revealed that nursing students perceived the most value for learning basic calculations and medical math but saw little practical value for learning algebra. However, EF did emerge as an effective way to improve nursing students' value perceptions for learning algebra, and students' reasons for this were about improving one's ability to think and problem solve. The form of EF varied; while expansively framed webinars showed some influence on perceptions of value and transferability, other expansively framed classroom activities were identified as beneficial to both groups for improving perceptions of value and transferability. Overall, intercontextuality was an apparent motivator of changes in value and transferability perceptions.

CHAPTER V

DISCUSSION

The purpose of this study was to examine how nursing students perceived value for learning mathematics, and whether those value perceptions were influenced by creating intercontextuality through EF. The research questions were:

1. How does expansive versus bounded framing of mathematics affect nursing students' perceptions of mathematics value?
2. How does expansive versus bounded framing of mathematics influence how nursing students perceive mathematics value, and in particular, mathematics utility and relevance?
3. How does expansive versus bounded framing of mathematics influence how nursing students perceive transferability of mathematics?
4. In what ways is intercontextuality the driver of perceptions of value and transferability?

In this chapter I will provide context for, and interpretation of the results presented in Chapter IV. I will also discuss limitations and recommendations for instruction and future research and revisit the conceptual framework. This section is organized by research question. I will first delve into quantitative results, then the convergence of quantitative and qualitative, and end with discussing qualitative results. Finally, I will provide suggestions for using EF in instruction, discuss limitations to the current study and recommendations for future research, and offer a modified conceptual framework.

Inconclusive Quantitative Results Yet Evidence of Intercontextuality's Influence

The quantitative data was used to explore the first research question about how expansive versus bounded framing affected perceptions of mathematics value. Analyses included descriptive statistics, boxplots, and a Wilcoxon Signed Rank test, which showed that perceptions of positive value beliefs generally declined slightly, while negative value beliefs increased slightly across both treatment groups. However, none of these measures yielded statistical significance. Thus, based on available quantitative data, the answer to RQ1 is inconclusive.

Some of the difficulty with quantitative data arose from having a small sample size. Overall, this study suffered from relatively unsuccessful recruitment and a low number of participants, potentially due to students simply not reading recruitment announcements and emails. Further, many interview participants expressed that they were overwhelmed by the load of the College Algebra course itself, and as such other students perhaps did not feel capable of taking on additional, optional tasks such as participation in the research. Consequently, the sample size ended up being much smaller than expected; a larger sample size would have yielded more statistical power and conclusive results.

It is also possible that the three-week intervention was simply not intensive enough for participants to experience a change in perception based on webinars alone. Interviews took place during Week 12 of the semester; at that point, learners had watched 12 webinars with only three of them being part of the treatment. The other nine webinars were taught the same across both treatment groups with no lean toward bounded or expansive framing during instruction. The conceptual framework (Figure 4) suggests that a lack of intercontextuality breaks the connection that leads to improved perceptions of value and transferability, so the intercontextuality that nine of 12 webinars lacked may have prevented those connections from being made. This view is strengthened by participants such as Julian (exp) who mentioned in his interview that his value perceptions benefitted from the clinical applications that the instructor included in the expansively framed webinars. He commented that he wanted those applications *every week* to help him make deeper connections. This indicated that the expansively framed webinars were helpful in improving his perceptions, but the greater quantity of standard webinars (which lacked intercontextuality) may have overshadowed any positive effects the expansive webinars produced. Further compounding this issue is that many participants did not watch all the webinars as required. For example, Ivan (bd) said in his interview, "I've only been able to watch one or two of the webinars." It is possible that the lack of exposure to the framing intervention in the webinars, due to either too few treatment webinars or participants simply not watching, caused a lack of quantifiable changes.

It is also necessary to look at sources of bounded or expansive framing in classroom activities other than webinars, particularly because some of these activities emerged as being influential in changing value perceptions. One major source of bounded framing in normal classroom activities was the weekly homework. These assignments were completed through the Knewton adaptive learning program and comprised a large portion of the exposure to mathematics that students received. The homework assignments were almost exclusively presented devoid of contextual links (and thus using bounded framing). Again, the conceptual framework would suggest that the lack of intercontextuality in the homework assignments would disconnect the link that leads to improved value perceptions and perceptions of transferability. Indeed, many interview participants mentioned that they did not see the value in most of the homework. For example, Anon2 (exp) wrote in their post survey, “The real-life examples and the extra credit is useful because it ties in more work-related examples. However, the everyday homework does not.” This confirms that the bounded framing in the homework assignments was at best ineffective, but at worst detrimental, in helping learners make connections and see more value and transferability in what they learn.

The present study is consistent with previous research (e.g., Gaspard et al., 2021) since adult students perceived low positive value beliefs for learning mathematics, yet diverged from other research (e.g., Hulleman et al., 2017; Kosovich et al., 2019) in that the value intervention did not yield definitive quantifiable improvements in value perceptions. However, this study contributes to this field of study by putting forward intercontextuality as a motivator of value changes, and while quantitative-only results were inconclusive, combining quantitative data with qualitative data helped to crystallize study outcomes. I will present these results in the next section.

Broad Framing and Integrated Activities as Strategies for Creating Intercontextuality

I combined quantitative and qualitative data to answer the second research question, which dealt with how nursing students perceived mathematics value with a focus on mathematics utility and relevance. Quantitative data consisted of line graphs and qualitative data was made up of written survey responses and transcripts of participant interviews. I created line graphs for individual participants and this fine-grained quantitative analysis paired with qualitative data produced a new perspective. While some individuals showed declines in perceptions of positive value facets and an increase in perceptions of negative value facets (consistent with the group quantitative analysis), others showed improvements in specific positive value facets and/or declines in negative value facets. Utility value perceptions varied across groups as well; in both groups, some individuals showed improvements in while others showed declines. However, a closer look at specific participants in both groups who showed improvements revealed that they described changes in value beliefs based on various classroom activities; those in the expansive group named both webinar content and other activities such as announcements and extra credit (e.g., Elizabeth (exp)), while those in the bounded group named only announcements and extra credit in helping shape perceptions (e.g., Ivan (bd)). This indicates that the conceptual framework (Figure 4) is accurate in showing the connection between broad framing of context and content and intercontextuality, which results in improved perceptions of value and transferability. The source of that intercontextuality varied between groups (webinars versus other expansively framed activities) but the contrast between groups showed that intercontextuality was responsible for improving students' perceptions of the transferability of mathematics.

Further, many participants were able to see value in specific College Algebra content regardless of which group they were in. For example, Carissa (bd) perceived value in learning about graphs because of its application to tracking patient vitals, and Gianna (exp) perceived value for learning rational expressions because of how often nurses use ratios in dosage calculations. However, other participants called out the same content as not useful (for example, Hilary (exp) not seeing value in learning graphs). The source of the disconnect between why people in the same group ended with different value for specific content while others did not remain unclear. However, light bulb moments that students experienced may provide some insight, such as when Fiona (bd) described the expansively framed extra credit assignment as helping her see value for learning square roots. Julian (exp) also described a light bulb moment in realizing that algebra can be found everywhere, and he credited the webinars as creating that intercontextuality for him. Again, this is consistent with the conceptual framework (Figure 4), showing that intercontexuality is what led to both Fiona and Julian's revelations about the value of algebra.

This study's findings support previous research showing that broad framing resulted in greater perceived relevance (e.g., Lam et al., 2014). However, this research goes one step further by identifying unexpected sources of EF's influence on perceived relevance. While my focus was on contextual framing during instruction, classroom activities also emerged as being influential (expansive framing in extra credit and announcements) or not influential (bounded framing in homework) in creating intercontextuality. This opens the discussion on best practices for using EF in instruction, and further research is needed to identify the most effective ways to produce intercontextuality via EF teaching techniques.

Intercontextuality Leads to Improved Perceptions of Transferability and Value

Qualitative data were analyzed to answer the third and fourth research questions, which considered how nursing students perceived transferability of mathematics, and in what ways intercontextuality served as the motivator of any perception changes. One major result that emerged was that participants in both groups were more motivated and interested when they saw value in what they were learning, which is consistent with previous research (e.g., Durik & Harackiewicz, 2007; Priniski et al., 2018). While this study confirms the importance of students seeing value in what they are learning, it also introduces intercontextuality as the driver of value changes. When intercontextuality was apparent, value perceptions improved. For example, Betty (bd) spoke to the importance of intercontextuality ("how math and nursing work together") and Gianna (exp) said that she appreciated when her instructors clearly identified transferability and created intercontextuality, and that this study was "awesome" for "trying to make us feel like this stuff is relevant with nursing." In contrast, Kevin (bd) emphasized that the content was not relevant or useful for nursing, potentially due to the lack of intercontextuality created in the bounded webinars. These findings support the conceptual framework by demonstrating that when intercontextuality is present, it leads to improved perceptions of value and transferability.

However, it is unclear whether intercontextuality was the sole source of improved perceptions of value and transferability in this study. While students did credit webinars, extra credit, and announcements as helpful in shaping viewpoints, some were also able to see connections even when they were not explicit in instruction. For example, Ivan (bd) noted that he was able to use algebra concepts in a building project, even though this connection had not been made clear in the class. It could be that Ivan had taken similar College Algebra courses multiple times at multiple other institutions (a fact he discussed during his interview) and his background and other experiences with mathematics likely shaped his opinions. Thus, while this research showed that intercontexuality does have a role in shifting opinions, the magnitude of its role remains unclear, especially for adult students with a significant amount of mathematical experience. EF may need to be part of a broader culture of teaching at the institutional level to be significantly influential.

Another outcome of this study was that students largely viewed their future work in the medical field as being non-mathematical, aside from basic calculations. This result converges with previous research (e.g., Hoyles et al., 2001), but adds to the discussion by showing that EF has potential as a utility value intervention through building intercontextuality in something as simple as broad framing of content and context. The conceptual framework suggests, and this study confirms, that utility value interventions help nursing students view their future work as requiring more mathematics than just simple calculations. Fiona (bd) spoke to this when she mentioned her mind opening based on expansively framed activities, and other students mentioned specific concepts like ratio, measurement, rate of change, and graphing as highly transferrable (e.g., Carissa (bd) and Gianna (exp)). This research shows that EF holds potential for opening minds to the relevance of mathematics and changing perceptions of its value.

Implications for Using Expansive Framing in Design and Practice

When I created the lessons to use in this study's intervention, my focus was on engaging in contextual framing through the language used during instruction. Engle et al. (2011) spoke to the ease of contextual framing as one of the strengths of using EF in practice because very little content knowledge is required to frame across contexts. A secondary focus in the lesson plans involved connecting topics or content areas (mathematics and nursing) through enhanced integration. This type of EF requires more knowledge of both content areas and is arguably more difficult to employ during instruction. However, participants foregrounded content-based elements in their interviews when they discussed perception changes. While contextual framing may have played a role in shifting their views, participants did not seem to pick up on this contextual framing as often as they identified the content-based framing. Thus, seeking opportunities to frame broadly across both context and content is essential in creating intercontextuality.

Using Expansive Framing in Curricular Design

The emergence of unexpected sources of EF (e.g., classroom activities like extra credit and announcements) speaks to the importance of incorporating EF into the curriculum and not just during instruction. This view is further reinforced because nursing students perceived the most value for medical math. Thus, it would be beneficial to nursing students' perceptions to incorporate medical math more seamlessly into the regular curriculum rather than divorcing College Algebra content from anything directly applicable to the medical field. In this study, the homework assignments represented most of the mathematics exposure that students received. Because the homework was almost entirely bounded and many participants did not see the value in it, it is important to seek opportunities to improve this element of the curriculum. Broadly, I recommend a shift away from bounded, calculation-focused assessments and a transition into a problem-solving approach (e.g., Hmelo-Silver, 2004).

Ideally, schools should consider a holistic institution-wide curriculum that employs EF across all content areas. However, this is no small feat and requires intense collaboration between course instructors and curriculum experts. When a complete overhaul of the curriculum is not reasonable, there are still opportunities for smaller improvements that would foster intercontextuality in the course content. For example, instructors may consider additional tasks beyond the homework such as contextual problems that link content areas (e.g., the extra credit assignments in this study) or online forums for students to discuss connections between mathematics and other content areas. This study shows that content-based supports for EF need not be complicated or difficult to implement, and small and simple activities still provide benefits to learners. While contextual framing can be achieved solely through the instructor's word choices, the curriculum itself also provides an opportunity for broad framing across content areas through integration.

Using Expansive Framing in Instruction

Broad framing across context during instruction is one of the most straightforward ways to promote intercontextuality (Engle et al., 2011). While this study shows that individual teachers can effect change on a course level, it would be worthwhile to seek professional development opportunities for all instructors to gain knowledge of the techniques and benefits of this mode of instruction to implement EF teaching more broadly across the institution. In an asynchronous online course format such as the one in this study, teachers can easily achieve expansive framing of context, but they may need to be creative in finding ways to frame across roles by promoting student authorship.

Engle et al. (2012) identified five explanations for how EF may foster transfer (Figure 2). This study focused on connecting settings during instruction and deemphasized student authorship. Because the framing of student roles is an important part of EF, an asynchronous webinar format may not be as conducive to a framing intervention as an in-person or synchronous webinar format. The lack of interpersonal interaction in an asynchronous webinar makes it difficult to foster this type of transfer. Thus, instructors of asynchronous webinar formats may consider focusing on mathematical practices as an anchor topic (Beck et al., 2024) to promote broad framing of student roles. Several students expressed viewing algebra as important to critical thinking and problem solving, and instructors may consider framing these mathematical practices as essential skills for nurses. Instructors could also ask students to complete activities such as interviewing a nurse to find out how they use mathematics in the field or researching and writing about connections between nursing and algebra. These activities will encourage individual student authorship and ownership of their new knowledge in an asynchronous course format.

Limitations and Recommendations for Future Research

I made many of the study design choices based on participant and resource availability due to the authentic classroom context as the setting for this research. Due to these choices and a smaller-than-expected sample size, there are inherent limitations and threats to validity and reliability. First, the small sample size and non-probabilistic convenience sample used in this study do not allow for generalizations (Capraro et al., 2019). Further, Capraro et al. explained the internal reliability of an instrument is dependent on the sample that was used to validate it. Thus, the sample used in this study will not yield the same reliable results as the original study on the Value Beliefs instrument (Gaspard et al., 2015), which was conducted on a large population of high school students and not a small population of adult learners. The sample size in this study was also not large enough to conduct a Confirmatory Factor Analysis on the survey used in this context. Further, while the Value Beliefs instrument had acceptably high Raykov's ρ numbers for almost all survey items, the prompts addressing personal importance and utility for school had numbers slightly below ($\rho = 0.65$) the acceptable range of $\rho > 0.7$. This may weaken the instrument's ability to identify the effect of the intervention on these categories. Further, Sloane and Wilkins (2017) advocated against single-unit quantitative studies, such as one classroom or an isolated period. Ideally, this study should be replicated and expanded longitudinally among multiple classroom conditions.

I chose to include qualitative data in addition to quantitative to better identify and more deeply explain constructs in the data set (Simon, 2019) as well as include both written and verbal formats for students’ responses. However, there are some important considerations that come with qualitative methods. Bhattacharya (2017) cautioned against using the quantitatively based terms *validity* and *reliability* and instead suggested *academic rigor* and *subjectivities.* Academic rigor can be maximized by employing multiple coding passes completed by multiple scholars and checking inter-rater reliability, which is recommended for future research. Researcher subjectivity must also be minimized when interviewing. Patton (2015) recommended that qualitative researchers remain empathetically neutral with their participants yet noted that “neutrality is not detachment” (p. 58). Reflexivity, which is the process of identifying and interrogating one’s biases and assumptions, as well as how the research process itself has affected the researcher, is essential in qualitative research (de Freitas et al., 2017), particularly in this study, where the researcher is also the course instructor. Consequently, a research assistant was employed to conduct interviews, a positionality statement has been included in Chapter I, and I have remained aware throughout the research of how my positionality influenced my attention, coding, and interpretations. Braun and Clarke (2022) asserted that reflexive thematic analysis is inherently subjective, and as such there is inevitable bias influencing the qualitative interpretation. I attempted to mitigate this bias by designing a study with both quantitative and qualitative data sources and by anchoring my interpretations in the existing literature and my conceptual framework.

The varying mathematical content from one week to the next is another shortcoming of the study design. This potential confounding variable can be minimized in future studies by incorporating multiple sections of the same course, alternating bounded and expansive conditions by week and by classroom, and comparing across classrooms. This would also help mitigate potential carryover and/or maturation effects. Future research should also include more bounded/expansive lectures – ideally, covering the entire course – to create a more comprehensive intervention. Research across different age ranges, classroom settings, and cultural groups is also recommended, as well as research to explore the mechanism through which this enhanced integration and framing intervention changes perceptions of mathematics value. An expanded qualitative analysis with a larger number of participants is the recommended approach for research in this vein.

This study also did not seek to disentangle the effect of specific contextual elements (e.g., time, place, people, roles, or topics) on perceptions of value or transferability. While enhanced integration is inherent in Engle et al.'s (2012) conception of EF (namely, broad framing across topics), it remains unclear whether this type of framing through integration was effective than other types of framing across settings (time, place, or people). Thus, future research is necessary to further sort out the magnitude of individual roles of connecting settings (time, place, people) versus enhanced integration (topics) versus student authorship (roles).

Finally, an issue that this research brings to light but does not directly address is that while many participants saw value in learning algebra for mathematical practices (critical thinking, problem solving, etc.), many nursing students reporting seeing little value in pursuing a mathematical education unless it involves practical mathematics. This brings up the question of whether it is beneficial or detrimental to tailor a mathematics curriculum to include only the content that will be directly appliable to the learners' future careers or lives. This is a theoretical discussion that should be explored further in future research on mathematics for nursing and other careers.

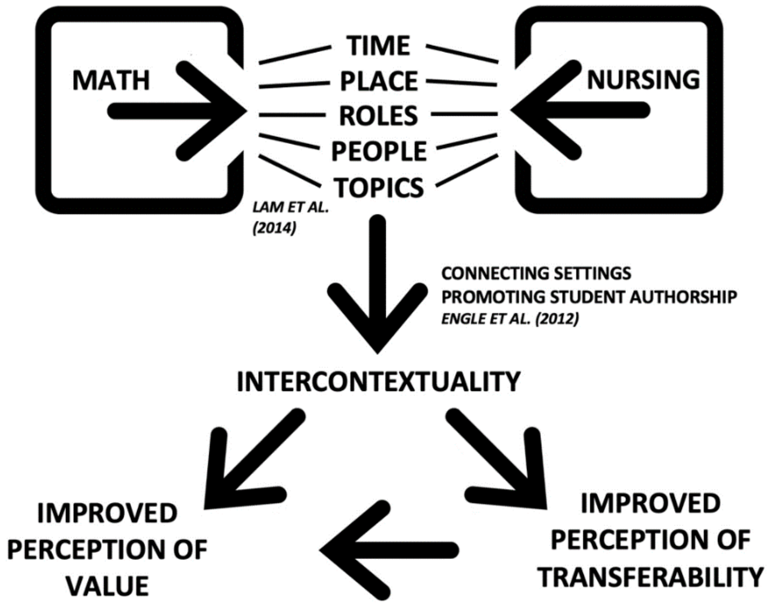
Revisiting the Conceptual Framework: Implications for Expansive Framing Theory

The conceptual framework (Figure 4) represents the relationships between the foundational constructs in this dissertation. In this conception, intercontextuality created through EF results in two hypothesized outcomes: improved perceptions of mathematics value and improved perceptions of mathematics transferability. While this study showed that intercontextuality does indeed lead to improved perceptions of value and transferability, I also noticed that some participants described that their views on value improved only after their views on transferability improved. Thus, I suggest the following modified conceptual framework (Figure 12).

In Figure 12, the addition of the arrow from "improved perception of transferability" to "improved perception of value" depicts the relationship for participants whose value perceptions were tied to their transferability perceptions. In other words, when some students saw that what they were learning was applicable (transferable) to the nursing profession, they saw more value in learning it. For instance, Gianna (exp)

Figure 12

Modified Conceptual Framework



described the intercontextuality created through medically based examples as transferrable to nursing ("how we could be applying that knowledge") and then stated that "more of that would be interesting," indicating that she found value in learning more of this type of mathematics. However, other students (e.g., Kevin (bd)) were able to find value in learning algebra for reasons such as improving their mathematical practices, even when they did not view it as transferrable to nursing. The directional flow of the arrows in Figure 12 depicts both routes that students take to find value in learning mathematics through EF.

This study informs the theory of Expansive Framing in several important ways. While prior research on EF focused primarily on transfer, the construct of transferability is subtly different and speaks more to how students perceive the future applicability of what they are learning. In other words, while previous research (e.g., Engle et al., 2012) shows that EF fosters transfer across systems, this study shows that it also fosters the *perception* of transferability before the transfer occurs. This research also extends the discussion on value perceptions and confirms that EF is an effective value perception intervention. Finally, EF is a theory that has not yet made broad inroads in the field of mathematics education, even though its basic tenets can apply to any knowledge domain. This research puts forward EF as a valid and valuable theory that merits future research specifically within the sphere of mathematics education.

What I Learned from the Study as a College Algebra Instructor and a Researcher

I initially began my exploration of Expansive Framing as it applies to fostering transfer across systems. At the same time, I found myself troubled by the number of College Algebra students I taught who did not find what they were learning to be worthy of their time and energy. I was intrigued by EF's capacity for improving a student's ability to transfer what they learn to another context, and I wondered whether EF might also, in addition to fostering transfer, be an effective value intervention for adult learners.

I find mathematics fascinating but believe most mathematics curricula do not convey its true significance. Mathematics is often taught in a highly bounded manner, isolated from other topics and contexts aside from a few improbable story problems at the end of a lesson. Students are primarily evaluated based on their ability to run algorithms and calculate the "right" answer. Calculation-focused teaching is inherently bounded and as Jo Boaler said, “Maths isn’t just about calculations. They may be the least interesting part. It’s actually about patterns and space, seeing things differently, and making connections” (YouCubed at Stanford, 2023). EF is one way to help mathematics learners make these connections. Recognizing and understanding relationships between content areas is vitally important to appreciate the interdependent complexities of knowledge. This study is only the first step in exploring the link between intercontextuality through EF and perceptions of transferability and value, yet it shows that EF holds potential for opening minds to how mathematics fits within the complex, interconnected world around us.

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APPENDICES

Appendix A

IRB Approval Letter

Research UtahStateUniversity

Notification of Protocol Approval

From: Ronald Gillam, Ph.D.
Chair, Institutional Review Board

Nicole Vouvalis, J.D.
Director of Human Research Protections

To: Jessica Shumway
Date: 2023-08-07
Protocol #: 13479
Title: Nursing Students' Perceptions of Mathematics Value and Transferability: A Mixed Methods Investigation

Your proposal has been reviewed by the Institutional Review Board and is approved under Expedited procedure(s) Expedited Category 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 (e.g., cognition, motivation, identity, communication, culture, social behavior) or research using methods such as survey, interview, oral history, program or human factors evaluation, etc.

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.

Appendix B

Sample Lesson Plans

Week 6 Bounded Webinar Lesson Plans

Weekly Learning Objectives:

- Learn how to evaluate and simplify rational expressions
- Perform operations on rational expressions
- Learn how to simplify complex fractions
- Learn how to solve proportions and applications with proportions
- Learn how to solve rational equations

Slide Number	Lecture	Bounded Context Notes
1	Welcome to the Week 6 Webinar. As a reminder, you should only watch this provided webinar and do not share links with any other learners. Please be sure to watch the entire webinar.	Same across both lectures
2	Week 6 Checklist	Same across both lectures
3	Upcoming reminders	Same across both lectures
4	This week we will be talking about rational expressions. We'll be performing operations, simplifying complex fractions, and solving rational equations. We'll also look at solving proportion equations.	
5	Knewton defines a rational expression as the ratio of two polynomials, which means it's basically just a fraction. All of the fraction rules apply. (Give some examples of context-free rational expressions.)	
6	Dividing by zero is not defined in math, so when we're working with rational expressions we need to make sure we're not using any values that make an expression undefined. Example: $\frac{10c+6}{7c-5}$ Find all values for which expression is undefined.	
7	This week a big focus is learning how to simplify rational expressions. We want to make sure we always factor first. Example: $\frac{20d^2+44d+24}{100d^2-144}$	
8	Now let's look at multiplying two rational expressions. We talked about simplifying rational expressions, so let's simplify these expressions first before we multiply. Remember your fraction rules for multiplication.	

	Example: $\frac{q^2+5q+6}{6q+18} * \frac{9q+27}{q^2+8q+15}$	
9	Now let's look at dividing two rational expressions. Again, let's simplify these expressions first before we divide. Remember your fraction rules for division. Example: $\frac{4x+28}{12x+72} \div \frac{x^2+10x+21}{x^2+14x+48}$	
10	What if you are presented with a problem that has both multiplication and division? In that case, just follow these steps. (Read through steps 1-4.) Example: $\frac{3q^2-12q}{3q-3} * \frac{q^2+q-2}{q^2+q-6} \div \frac{3q^2+31}{3q-6}$	
11	Attendance access code	Same across both lectures
12	Now let's look at adding two rational expressions. Again, let's simplify these expressions first before we add. Remember your fraction rules for addition. Example: $\frac{6}{45u^2v^2} + \frac{7}{9u^3v}$	
13	Now let's look at subtracting two rational expressions. Again, let's simplify these expressions first before we subtract. Remember your fraction rules for subtraction. Example: $\frac{3z-1}{z+4} - \frac{2}{z-4}$	
14	Complex fractions are defined as rational expressions that have fractions in the numerator, denominator, or both. We have two methods to solve. (Read steps of each.) I'm going to use Method 1 first. (Solve the problem using Method 1.)	
15	Now let's solve the same problem using Method 2. (Demonstrate steps of Method 2.)	
16	We're done talking about operations with rational expressions. Let's spend some time talking about proportions. Here are the steps to solve proportional equations. Let's use the steps to solve these two equations. Example: $-\frac{5}{x} = \frac{1}{21}$ Example: $\frac{3m+8}{8} = \frac{m-1}{3}$	

17	We're done talking about proportions. To finish up, let's go through an example of solving rational equations. Here are the steps to solve rational equations. Let's use the steps to solve this equation. Example: $\frac{-8}{3x} - \frac{5}{6x} = 2$	
18	We're done learning about rational expressions and equations. Just a few reminders before I end the recording.	Same across both lectures

Week 6 Expansive Webinar Lesson Plan

Weekly Learning Objectives:

- Learn how to evaluate and simplify rational expressions
- Perform operations on rational expressions
- Learn how to simplify complex fractions
- Learn how to solve proportions and applications with proportions
- Learn how to solve rational equations

Webinar Structure:

Slide Number	**Lecture**	**Expansive Context Notes**
1	Welcome to the Week 6 Webinar. As a reminder, you should only watch this provided webinar and do not share links with any other learners. Also, you must watch the entire webinar to qualify for payment at the end of the study	Same across both lectures
2	Week 6 Checklist	Same across both lectures
3	Upcoming reminders	Same across both lectures
4	In the past few weeks we've been learning about polynomials and breaking them down using factoring. We're continuing to build on that knowledge this week as we learn about rational expressions. We'll apply some of this knowledge to learning about proportions. Next week is your midterm but after that you'll continue to build on what you're learning here by looking at some different types of polynomials.	Time
5	What is a rational expression? A rational expression is a ratio. It is comparing two quantities. (Give examples shown by pictures on slides.) In particular, a rational expression is the ratio of two polynomials. That means it's a fraction with a numerator of a polynomial and a denominator of a polynomial. You know quite a bit about fractions already. (What do you know? Go over some fraction rules.)	Topics Time
6	Where do you see rational expressions in medicine? Who might use rational expressions in the medical field? (Provide examples.)	Topics People
7	One thing we need to be careful of is dividing by zero. We've discussed this idea before – why can't you divide	Time

	by zero? What value would make the denominator zero in this rational expression? (Work through example problem.)	
8	A pharmaceutical company found that when a patient is administered medication via injection, the concentration of the drug in the bloodstream can be modeled by the function $y = \frac{20x^2+44x+24}{100x^2-144}$. Let's simplify the rational expression. Think back to last week when we learned about factoring. Let's factor first.	Time Topics
9	When you are performing dimensional analysis for dosage calculations, you often need to multiply fractions. (Review how to multiply fractions.) Let's apply what you know about multiplying fractions for dosage calculations to this model where we have some unknown variables. Example: $\frac{q^2+5q+6}{6q+18} * \frac{9q+27}{q^2+8q+15}$	Time Topics
10	Division is multiplication of the reciprocal so we can use very similar techniques on this division problem. Again, let's simplify these expressions first before we divide. Example: $\frac{4x+28}{12x+72} \div \frac{x^2+10x+21}{x^2+14x+48}$	
11	What if you are presented with multiple a problem that has both multiplication and division? As you know, when doing dosage calculations, you often have to both multiply and divide so you need to keep order of operations in mind. Example: $\frac{3q^2-12q}{3q-3} * \frac{q^2+q-2}{q^2+q-6} \div \frac{3q^2+31}{3q-6}$	Topics
12	Attendance access code	Same across both lectures
13	We know that rational expressions represent complex proportional relationships, and sometimes we may need to combine quantities. Let's look at adding two rational expressions. Example: $\frac{6}{45u^2v^2} + \frac{7}{9u^3v}$	
14	Now let's look at subtracting two rational expressions. Again, let's simplify these expressions first before we	

	subtract. Example: $\frac{3z-1}{z+4} - \frac{2}{z-4}$	
15	As you know, the human body is incredibly complex, and sometimes we have processes that are best modeled by fractions stacked upon fractions. Complex fractions are rational expressions that have fractions in the numerator, denominator, or both. This article shows an interesting application of complex fractions. It describes a pharmacological approach to treating cancer that involves complex fractions of large numbers of molecules in the drug.	Topics People Place
16	Consider this complex fraction. This models the molecular makeup of a drug. If we want to simplify it, remember that you already know how to do fraction division. (Demonstrate how to simplify.)	Topics
17	Proportions are an application of rational expressions. They use an equals sign to compare two rational expressions. There are so many real life applications of proportions, particularly in the medical field when you work with comparisons of quantities. (Work through examples).	Topics
18	What if we make that proportion slightly more complicated by putting together subtraction of rational expressions in an equation? (Demonstrate example.) Example: $\frac{-8}{3x} - \frac{5}{6x} = 2$	
19	Today we've discussed rational expressions. This builds on what we've learned about polynomials, factoring, and solving equations. Now we know how to identify a rational expression and work with them in many ways. We'll continue learning about different types of expressions and functions throughout the semester. You'll also use many of these ideas when you take statistics and you'll definitely see things like proportions in the nursing practice. Email me if you have any questions or see any other applications of rational expressions in real life!	Time People Topics Place
20	Reminders	Same across both lectures

Week 9 Bounded Webinar Lesson Plan

Weekly Learning Objectives:

- Solve quadratic equations using factoring and the square root property.
- Learn the quadratic formula.
- Learn how to solve applications with quadratic equations.
- Solve higher order equations with factoring.
- Find the domain and range.
- Determine if a graph is a function by using the vertical line test.

Slide Number	**Lecture**	**Bounded Context Notes**
1	Welcome to the Week 9 Webinar. As a reminder, you should only watch this provided webinar and do not share links with any other learners. Remember that you must watch the entire webinar.	Same across both lectures
2	Week 9 Checklist	Same across both lectures
3	This week we will be learning about quadratics. You will see a few strategies on how to solve quadratic equations. We will also talk about some more general features of functions and find things like domain and range.	
4	Today we'll look at three methods for solving quadratic equations: 1. Square root method 2. Factoring 3. Quadratic Formula	
5	Let's start with the Square Root method. Solve $2x^2 = 72$ Show procedure of solving using Square Root Property step by step. My answer is ± 6.	
6	This one can also be solved using the Square Root method. Solve $(x+3)^2 = 4$ Show procedure of solving using Square Root Property step by step. My answer is -1 and -5.	
7	We're done learning about solving using the Square Root Property. Let's move on to the factoring method. Solve: $m^2 - 18m + 81 = 100$	

	Show procedure of solving using factoring step by step. My answer is 19 and -1.	
8	We're done with the factoring method. The last method we'll talk about today is the Quadratic Formula. The Quadratic Formula is $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$ and we're going to use it to solve this equation. Solve $d(4d+5)-8=0$ Show procedure of solving using Quadratic Formula step by step. My answer is $\frac{-5\pm3\sqrt{17}}{8}$.	
9	How many real number solutions are possible? $-x^2+2x-3=0$ The discriminant is the piece of the Quadratic Formula under the square root and it can tell us how many solutions we can expect. (Work through example problem.) My answer is that this problem has no real number solutions.	
10	Solve $y=-x^2+6x$ Ask viewers to consider which method might be best to solve this equation. Solve using multiple methods.	
11	Attendance Access Code	Same across both lectures
12	Let's talk about a completely different topic now: functions. According to Knewton, a function is "a relation that assigns a single element in the range to each element in the domain."	
13	You can identify a function based on a table by looking at the inputs and outputs. It's a function if every input has one and exactly one output. (Work through example of identifying function based on table.)	
14	We can also use the Vertical Line Test to determine whether a graph is a function or not. (Explain Vertical Line Test and work through example of identifying functions based on graphs.)	
15	The way we represent a function is using function	

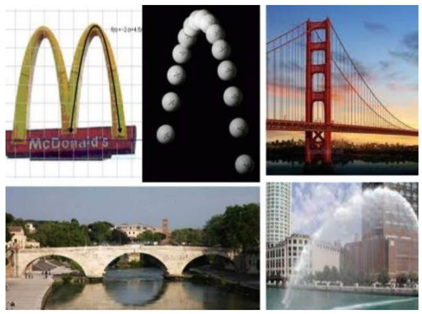
	notation. (Explain how to read function notation.) Work through example problem: Find the value $C(-2)$. $$C(t) = t^2 - 2t - 4$$	
16	Work through example problem: For $h(c) = 8c^2 - 41c$, Solve $h(c) = 42$. Solve $h(2)$.	
17	One concept of functions is domain and range. Give definitions for each. Find the domain and range of the function represented in the set $\{(4,7), (8,-12), (9,-7), (3,11)\}$	
18	Find domain of a function given an equation. Now that we know how to read and work with function notation we can consider inputs that do or not work for this function. Find the domain. $$f(x) = \sqrt{-2x + 20}$$	
19	We're done learning about quadratic equations and functions. Just a few reminders before we end the recording.	

Week 9 Expansive Webinar Lesson Plans

Weekly Learning Objectives:

- Solve quadratic equations using factoring and the square root property.
- Learn the quadratic formula.
- Learn how to solve applications with quadratic equations.
- Solve higher order equations with factoring.
- Find the domain and range.
- Determine if a graph is a function by using the vertical line test.

Slide Number	**Lecture**	**Expansive Context Notes**
1	Welcome to the Week 9 Webinar. As a reminder, you should only watch this provided webinar and do not share links with any other learners. Also you must watch the entire webinar to qualify for payment at the end of the study.	Same across both lectures
2	Week 9 Checklist	Same across both lectures
3	Anchor idea: it’s all about relationships! Math helps us define relationships. In nursing we look for relationships (if I change x in my care, how will that affect my patients?). In nursing school, you are learning about how different aspects of nursing care can affect your patients positively or negatively. An understanding of different types of functions helps us represent those relationships and quantify them. We have been learning about different types of expressions and equations. For example, last week we learned about radical equations, and in Week 6 we learned about rational equations. Today we’re extending that discussion to include quadratic expressions and equations, and we’ll have our first introduction to the concept of functions, which is an important idea to link these together and help us define relationships.	Topics Time Participants
4	What kind of relationships can quadratic	Topics

	functions represent? Show image and discuss parabolas. Can you think of any other real-life relationships that could be modeled using a parabola? 	Place
5	Medical examples of quadratics • Research study on left (quadratic function modeled relationship between markers of Alzheimer's severity and brain activation) • Graph on right (healthy average systolic blood pressure based on age)	Topics Place
6	Solve $2x^2 = 72$ This is a relationship that says when I plug in some value for x it gets squared, then doubled. I want a specific number for x that tells me what will equal 72 when I do those operations. Remember last week when we learned about square roots? We are going to be returning to those concepts here. (Demonstrate solving equation.) My answer is ± 6. Return to anchor idea of relationships by discussing how ± 6 are the two numbers that make this relationship true; any other values would invalidate the relationship's definition.	Time
7	Solve $(x + 3)^2 = 4$ Again, we're returning to what we have learned about square roots and we're continuing to expand our view of square roots here. (Demonstrate solving equation.) My answer is -1 and -5. Return to anchor idea of relationships by discussing how -1 and -5 are the two numbers that make this relationship true; any other values would invalidate the	Time

	relationship's definition.	
8	Solve $$m^2 - 18m + 81 = 100$$ Remind students of two previously learned concepts: factoring perfect square trinomials and Zero Product Property. This may look familiar. (Demonstrate solving equation.) My answer is 19 and -1. Return to anchor idea of relationships by discussing how 19 and -1 are the two numbers that make this relationship true; any other values would invalidate the relationship's definition.	Time
9	Solve $x(4x+5) - 8 = 0$ You're continuing to add tools to your tool kit to solve complex mathematical relationships. Quadratic Formula is a tool to help us solve these, but it's not the only way. This is a tool you should have in your tool chest to help you sort out more complex relationships. (Show formula and give brief history on how it's derived.) Each of these variables (a, b, c) represent a different piece of this relationship, and changing any one of them will affect the entire system. (Liken this to a medical relationship: respiratory rate affects the heart rate which affects patient's level of stress, etc.) The quadratic formula represents a complex relationship between these different variables. (Demonstrate solving equation.) My answer is $\frac{-5\pm3\sqrt{17}}{8}$. Return to anchor idea of relationships by discussing how $\frac{-5\pm3\sqrt{17}}{8}$ are the two numbers that make this relationship true; any other values would invalidate the relationship's definition. Remind students how to check answer.	Topics Time Place
10	How many real number solutions are possible? $$-x^2 + 2x - 3 = 0$$ We've already added several tools to our tool kit	Topics Time

	(remind students of methods we've learned). If you were asked to find the solutions to this problem, where would you start? Let's start working through it together. (Demonstrate problem; pause when you get to the negative number under the square root.) Think back to when you've seen negative numbers as the radicand. We talked about how these are called imaginary numbers and we learned how to simplify them. The term "imaginary" is a bit misleading since they do have real-life applications (for example, electrical circuits). They're also useful in determining how many real number solutions a quadratic has. (Present terminology *discriminant*.) My answer is that this problem has no real number solutions. (Show a graph of what this looks like and what that tells us about the function.)	
11	Solve: The amount of medication in Kelly's blood is represented by the relationship $y = -x^2 + 6x$ where y is the amount of medication and x is the number of hours after the medication is taken. After how many hours will the medication leave Kelly's bloodstream? Here we see a medically based example of a mathematical relationship. This relates the amount of medication in Kelly's bloodstream to the amount of time that has passed. Try pausing the video and solving this using the one of the methods we've discussed. See if you can explain what your answer means in context of the problem. (Demonstrate how to solve and interpret answer.)	Topics Participants Place
12	Webinar Access Code	Same across both lectures
13	We've talked about so many different ways to relate variables and we're continuing to learn	Topics Time

	about these relationships. Some of these relationships fall into the family of functions, which are a special type of relationship. "In an OR, a disinfectant is diluted with water. For each x mL of disinfectant, you need 2.5 times as much water. This relationship is an example of a function and can be represented as w(x)=2.5x." We will return to this function a bit later and explore it more deeply.	Place
14	In a lot of medical research, relationships are represented by functions. Identifying how you know you have a function is important. This can help identify whether you have a unique relationship or not. We can identify whether we have a function based on a table of data like this one. This table shows the relationship between a woman's weight and the calories burned while jogging. Let's determine whether it falls into the special category of a function. (Work through example of identifying function based on table.)	Topics Place
15	We can also identify whether a relationship is a function by looking at its graph. (Work through first three graphs.)	
16	This graph shows a patient's white blood cell count from the day of hospital admittance to the day of discharge. Is this a function? How would it look different if it was not a function? (Explain.)	Topics
17	In this class we've been learning to speak the language of mathematics, much like you're learning to speak the language of nursing in your nursing courses. Reading advanced research and literature on nursing and medicine requires you to speak both languages fluently. Using function notation is one way relationships are represented. (Explain how to read function notation.) Work through two example problems:	Time Topics Participants

	First example: For $h(c) = 8c^2 - 41c$, Solve $h(c) = 42$. Solve $h(2)$. (Briefly explain what answers mean in context of the relationship presented by the function $h(c)$.)	
18	Second example: For $C(t) = t^2 - 2t - 4$, find $C(-2)$. (Briefly explain what answers mean in context of the relationship presented by the function $C(t)$.	
19	An important part of relationships – especially real-life relationships - is to know their limits. For example, in the example of the disinfectant we discussed earlier, is it reasonable to say that we can add an infinite amount of disinfectant to water? Or do we need to limit the amount based on the size of the bottle of disinfectant? This refers to the idea of domain and range of functions. Let's say our bottle of disinfectant is 200 mL. That means the largest amount of water I will need to dilute this bottle is 2.5*200=500 mL of water. Domain: [0,200] Range: [0,500]	Topics Place Time
20	Let's continue exploring domain and range with this function. $$f(x) = \sqrt{-2x + 20}$$ Find domain and range. We will return to this idea of domain and range in future weeks as well, and you'll revisit this idea of limits in other classes.	Time
21	Today we've discussed quadratic equations and functions. This builds on what we've learned previously about other types of functions – lines, rationals, polynomials, etc. Now we know how to identify a function and work with function	Time Topics Place Participants

	notation. We'll continue expanding our vocabulary of functions next week when we discuss operations and composition of functions, and we'll learn about some other functions like exponentials and logarithms later in the semester. You'll also learn about functions when you take statistics. Be on the lookout for math relationships in your everyday life and email me with what you find!	
22	Reminders before we end the recording.	

Week 10 Bounded Webinar Lesson Plan

Weekly Learning Objectives:

- Determine intervals of increase and decrease
- Determine average rate of change
- Find local extrema
- Perform operations on functions
- Evaluate composite and one-to-one functions
- Identify inverse functions and find the inverse to a function
- Represent linear functions in a table
- Graph linear functions and interpret slope as a rate of change

Slide Number	**Lecture**	**Bounded Context Notes**
1	Welcome to the Week 10 Webinar. As a reminder, you should only watch this provided webinar and do not share links with any other learners. Remember that you must watch the entire webinar. At the end of the lecture you'll have an opportunity to participate in a paid research opportunity so be sure to keep an eye out for that.	Same across both lectures
2	Week 10 Checklist	Same across both lectures
3	This week we will be learning about functions and how to add, subtract, multiply, and perform composition of functions. We'll also look at graph behavior and look at inverse functions.	
4	Let's start with a graph. On this graph we want to figure out where it is increasing and find the local maximum and minimum. (Work example problem.)	
5	This is the rate of change formula. It helps us find the average rate of change of a function on a given interval. (Work example problem.)	
6	You're done learning about analyzing functions for intervals of increase/decrease and finding local extrema. Now we are going to discuss how to perform operations on functions, starting with addition. (Work example problem.)	
7	Here we are going to be doing something called function composition, which is where one function is the input of the other function. This screenshot from Knewton tells us how to read $f \circ g$. For this example, we are going to find $(f \circ g)(x)$. (Work example problem.)	

8	This is a similar problem but notice our input is 5 instead of a function. We can either find $g(5)$ first, then use that as the input into $f(x)$ or we can find $f(g(x))$ first, then use 5 as an input. (Demonstrate both ways.)	
9	Attendance Access Code	Same across both lectures
10	We're done learning about operations and composition of function, so let's turn our attention to finding the inverse. The basic steps of finding inverses are shown here. (Work example problem.)	
11	Additional example problem of finding inverses	
12	It's time to close the chapter on working with functions and move on to a different topic which is modeling with lines. You've seen these line formulas before. (Conduct brief review of line formulas.)	
13	Demonstrate how to find a linear function using a table of values	
14	The slope tells us a lot about a linear function. You can tell whether a line is increasing, decreasing, or neither based on the slope. (Give an example of each.)	
15	We can tell whether these examples are increasing, decreasing, or neither (constant) based on their slope. (Work through each example.)	
16	In a linear model, slope can be conceptualized as rate of change. (Review slope as change in output/change in input and work example problem.)	
17	We're done with our Week 10 content, but you do have an extra credit opportunity this week. (Go over EC expectations.)	
18	EC example problem	
19	We're done learning about operations with functions, inverses, and linear models. Just a few reminders before we end the recording.	

Week 10 Expansive Webinar Lesson Plan

Weekly Learning Objectives:

- Determine intervals of increase and decrease
- Determine average rate of change
- Find local extrema
- Perform operations on functions
- Evaluate composite and one-to-one functions
- Identify inverse functions and find the inverse to a function
- Represent linear functions in a table
- Graph linear functions and interpret slope as a rate of change

Slide Number	**Lecture**	**Expansive Context Notes**
1	Welcome to the Week 10 Webinar. As a reminder, you should only watch this provided webinar and do not share links with any other learners. Remember that you must watch the entire webinar. At the end of the lecture you'll have an opportunity to participate in a paid research opportunity so be sure to keep an eye out for that.	Same across both lectures
2	Week 10 Checklist	Same across both lectures
3	This week we're continuing our discussion of relationships. Last week we discussed quadratic relationships and just touched on some function basics. We're continuing to learn about functions this week and we'll look at some practical applications of functions.	Time
4	Function in Real Life • Mixer is our "function machine" or rule • Cookie ingredient input, cookie output • Bread ingredient input, bread output • Depending on what you put in, you get a unique output. You can't input cookie ingredients and expect a loaf of bread to come out.	Topics Place
5	Function in Real Life • Vending machine (input specific button (like A5), output specific snack) • Blood pressure (input BP meds, output lower BP – blood pressure is a function of medication dosage)	Topics Place
6	Intervals of Change and Local Extrema When we're examining a function, it can tell us a lot about the situation it models if we know where the maximums	People Topics Place

	and minimums occur. For example, this graph shows the blood glucose levels for three different people based on time passed after a meal. (Point out the local extrema.) This is useful information to me to be able to see where these three people will experience high and low blood sugar levels. (Point out the intervals of increase and decrease.) This is useful information to me to be able to see how long it takes for blood sugar to ramp up and come back down.	
7	Let's look at this graph and figure out where it is increasing and where to find the local extrema (maximum and minimum). (Work example problem.) Depending on what this graph models, knowing the maximum, minimum, and intervals of change can tell me a lot.	
8	Understanding the rate of change can deepen our understanding of functions. Rate of change refers to how quickly the function changes over time. We can look at a specific interval of the function. For example, on this function, we are going to look specifically at the interval [0,2]. Notice that in the rate of change formula uses function notation which we started learning about last week. (Demonstrate example problem.)	Time
9	An example in real life could be a patient with diabetes who is monitoring their blood sugar levels. Let's say you record their blood sugar levels at two time points: 0 minutes (before a meal) and at 30 minutes (shortly after a meal). What is their rate of change over this interval? (mg/dL = milligrams per deciliter) $$\frac{170-150}{30-0}=\frac{20\ mg/dL}{30\ min}=0.67\frac{mg}{dL}/min$$	Topic People Place
10	Now sometimes we'll have two different functions that we need to combine in different ways, such as addition or subtraction. An example would be calculating the number of calories burned in two separate workouts. The first function represents calories burned on a morning jog, while the second function represents calories burned on an evening walk. We walk to add them together to figure out how many calories are burned altogether. (Demonstrate example problem.)	Topic People Place
11	Function composition also allows us to combine functions but in this case we're taking a function of a function.	Topic People

	(Demonstrate hamster example problem.)	Place
12	Let's look at a similar problem but with a different input. (Note the difference in input and demonstrate example.)	
13	Attendance Access Code	Same across both lectures
14	Finding inverses – give a few real-life examples (listed on slide) and then go through process of finding inverse	Topic People Place
15	Another inverse example	
16	We're continuing to build our concept of functions, and one very important and commonly used model of a function are lines. We've worked with lines earlier in the semester and you've seen these formulas before. Now we're going to apply them to our ever-growing conception of functions.	Time
17	Pay in nursing – discuss linear model of a travel nurse's pay and work through example on slide	Topics People
18	We've discussed slope before, but what practical information could slope tell us about a linear model? (Go over positive/increase, negative/decrease, zero/constant.) This graph shows a person's heart rate over time. Notice that it is made up a bunch of tiny lines. (Discuss trend lines and noticing when heart rate is increasing or decreasing.)	Topics Time People
19	Based on a given function, we can tell whether it's increasing, decreasing, or remaining constant based on the slope. (Work given examples.)	
20	Earlier we talked about finding rates of change and how quickly something is changing. (Remind them of blood sugar problem on slide 6.) In a linear model, the slope is what tells us our rate of change. (Review slope as change in output/change in input and work example problem.)	Topics Time
21	What's next?	Time
22	You have an extra credit opportunity this week where you'll be exploring a function that calculates body surface area. (Discuss EC expectations.)	Same across both lectures
23	EC example problem	Same across both lectures
24	Wrap-up and reminders	Same across both lectures

Appendix C

Content-Based Pretest

Pretest

Name:

This assessment does <u>not</u> count toward your grade in MAT100.
Choose the best multiple-choice option on each question.

1. Determine the value(s) for which the rational expression $\frac{10c+6}{7c-5}$ is undefined.
   Answer: $c = \frac{5}{7}$

2. Simplify $\frac{2x-20}{5x-50}$
   Answer: $\frac{2}{5}$

3. Multiply $\frac{9w}{w^2+9w+14} * \frac{w^2-4}{9w}$
   Answer: $\frac{w-2}{w+7}$

4. Find the least common denominator for $\frac{3}{z^2+15z+56}$ and $\frac{9z}{z^2-49}$
   Answer: $(z+7)(z+8)(z-7)$

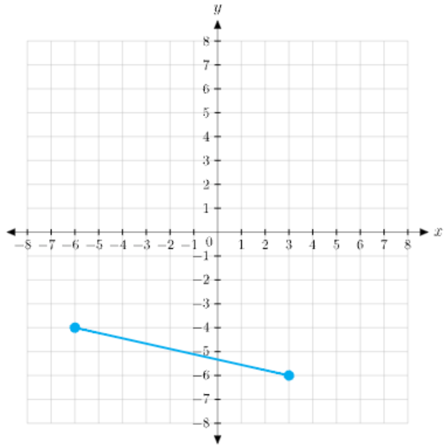
5. Solve $\frac{3n+10}{10} = \frac{n+3}{3}$
   Answer: $n = 0$

6. Solve $4x^2 = 36$
   Answer: $x = 3, -3$

7. Solve $2x^2 - 10x + 12 = 0$
   Answer: $x = 3, 2$

8. Evaluate $f(1)$ if $f(x) = -2x - 3$
   Answer: $f(1) = -5$

9. Identify the domain and range of the graph shown using interval notation.

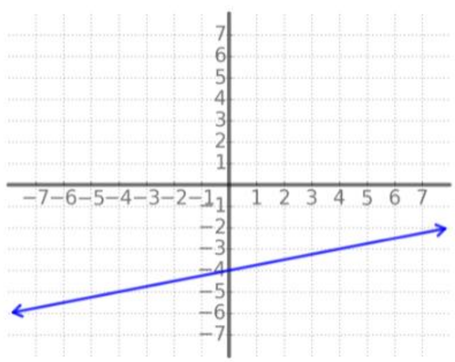


Answer: Domain [-6,3], Range [-6,-4]

10. For the functions $f(x) = 4x + 3$ and $g(x) = 2x^2 + 5x$, find $(f \circ g)(x)$.
Answer: $(f \circ g)(x) = 8x^2 + 20x + 3$

11. Find the inverse of $f(x) = 2x + 3$.
Answer: $f^{-1}(x) = \frac{x-3}{2}$

12. Find the equation of the linear function whose graph is given here.



Answer: $f(x) = \frac{1}{4}x - 4$

13. The population of a town is growing at a constant rate. The initial population is 1400 and after 3 years the population has grown to 1616. What is the rate (per year) at which the population is increasing?
Answer: 72 people per year

Appendix D

Value Beliefs Survey

Value Beliefs Survey

Name:

Mark each question based on how much you agree with the statement. Choices include *completely disagree, somewhat disagree, somewhat agree, and strongly agree.*

Intrinsic

1. Algebra is fun to me.
2. I like doing algebra.
3. I find algebra interesting.
4. I enjoy exploring mathematical topics in algebra.

Importance of Achievement

5. It is important to me to be good at algebra.
6. Being good at algebra means a lot to me.
7. Performing well in algebra is important to me.
8. Getting good grades in algebra is very important to me.

Personal Importance

9. It is important to me to remember what I learn in algebra.
10. Algebra is not meaningful to me.
11. I'm excited to learn a lot about algebra.
12. Algebra is very important to me personally.
13. To be honest, algebra is not important to me.
14. It is important for me to know a lot of algebra.

Utility for Nursing School

15. It is worth making an effort in algebra because it will save me a lot of trouble in nursing school as I finish my degree.
16. Being good at algebra will pay off because it is needed for my degree.

Utility for Daily Life

17. Understanding algebra has many benefits in my daily life.
18. Algebra comes in handy in my daily life.
19. Algebra is directly applicable in everyday life.

Social Utility

20. Being good at algebra will help me make friends with my classmates.
21. I can impress others with a good knowledge of algebra.
22. If I know a lot about algebra I will leave a good impression on my classmates.

Utility for Nursing Career

23. Doing well in algebra will be of great value to me when I am a nurse.
24. Learning algebra is worthwhile because it will improve my job and career opportunities.

General Utility for Future Life

25. Taking algebra classes will be useful in my life.
26. I will often need algebra in my life.

Effort Required

27. Doing algebra is exhausting to me.
28. I often feel completely drained after doing algebra.
29. Dealing with algebra drains a lot of my energy.
30. Learning algebra exhausts me.

Emotional Cost

31. I'd rather not do algebra because it causes me stress.
32. When I deal with algebra I get annoyed.
33. Algebra is a real burden to me.
34. Doing algebra makes me really nervous.

Opportunity Cost

35. I have to give up other activities that I like to be successful at algebra.
36. I have to give up a lot to do well in algebra.
37. I'd have to sacrifice a lot of free time to be good at algebra.

Adapted from Value Beliefs Instrument in Gaspard, H., Dicke, A.-L., Flunger, B., Schreier, B., Häfner, I., Trautwein, U., & Nagengast, B. (2015). More value through greater differentiation: Gender differences in value beliefs about math. *Journal of Educational Psychology, 107*(3), 663–677.

Open-Response Prompts

1. Do you believe that it’s worth your time to learn algebra in nursing school? Why or why not? Please explain.
2. How do you think you might apply what you’ve learned in this course (College Algebra) to the nursing profession? Please explain.
3. What connections do you see between this course (College Algebra) and the nursing profession? Please explain.

Appendix E

Interview Protocol

Interview Protocol

Thank you for meeting with me. As a reminder, your honest answers will not affect your course progress in MAT100 (College Algebra) or at the college and your name will not be used in any manuscripts that result from research. This interview will be audio recorded. Are you okay if we proceed?

RQ2: How does expansive versus bounded framing of mathematics influence how nursing students perceive mathematics value, and in particular, mathematics utility and relevance?

I'm going to ask you some questions about how you feel about math.

1. How do you feel about math in general?
    a. Probing: Why do you think you feel that way? Have you always felt that way? What experiences have shaped your feelings about math?
2. Do you believe that it's worth your time to learn math in nursing school? Why or why not?
    a. Probing: In what ways will doing well in College Algebra pay off?
3. Do you believe that this class (College Algebra) is useful for the nursing profession? For your everyday life? Why or why not?

RQ3: How does expansive versus bounded framing of mathematics influence how nursing students perceive transferability of mathematics?

Now I'm going to ask you some questions about using the math you are learning in College Algebra specifically.

4. How do you think you will use what you've learned in College Algebra in your job as a nurse?
    a. Probing: Do you think it's important that you can see how the math you are learning can be applied to your career? Why or why not?
5. How do you think you might apply what you've learned in College Algebra in your everyday life (outside of work/your career).
    b. Probing: Do you think it's important that you can see how the math you are learning can be applied to your life? Why?

RQ4: In what ways is intercontextuality the driver of perceptions of value and transferability?

6. Do you see any connections between what you learned in College Algebra and your everyday life? What are they? Can you give me some examples?
7. Do you see any connections between what you learned in College Algebra and the nursing profession? What are they? Can you give me some examples?
8. Thinking back to the webinars you had in your College Algebra class, did the instructor do anything in the webinars that helped you see the connections

between mathematics and nursing?

   a. Probing (if they answer yes): What did they do? Can you give me some examples? How did that help?
   b. Probing (if they answer no): What could your teacher have done to help you see connections between mathematics and nursing?

9. How do you think it would change your experience if College Algebra was integrated into your nursing classes instead of being taught as a separate class? What would be different?

CURRICULUM VITAE

KIMBERLY E. BECK
Layton, Utah | 801-682-6096 | kimberly.beck@usu.edu

EDUCATION

Ph.D. in Education **2024**
Specialization: Curriculum & Instruction
Concentration: Mathematics Education & Leadership
Utah State University, Logan UT

M.Ed. in Secondary Education **2012**
Specialization: Curriculum & Instruction
Concentration: Mathematics Education & Leadership
Utah State University, Logan UT
Teaching Certificate: Secondary Mathematics Level III

B.S. in Mathematics **2020**
Weber State University, Ogden UT

B.S. in Architectural Engineering **2005**
Emphasis: Structural Systems
University of Wyoming, Laramie WY

PROFESSIONAL HISTORY

Nightingale College, Salt Lake City Utah **2020 – present**

Faculty Supervisor, Mathematics *2024 - present*
Supervisor and mentor for five faculty members on Mathematics team. Main responsibilities include conducting regular teaching observations, providing instructional coaching, maintaining course curriculum, conducting staff meetings, acting as liaison between faculty members and leadership, and addressing student grievances.

Assistant Professor, Mathematics *2020 - present*
Teacher of mathematics courses for undergraduate nursing students. Main responsibilities include designing course materials for and teaching College Algebra and Intro to Statistics online courses, communicating frequently with students, and maintaining regular office and tutoring hours, with a teaching load of 12-15 credit hours per semester.

Utah State University, Logan Utah **2021 – 2024**

Graduate Research Assistant *2021 - 2023*

Research assistant on NSF-funded project on mathematics and computer science integration in elementary classrooms. Main responsibilities include communicating with teachers, planning and participating in design meetings, attending and contributing to research team meetings, literature reviews, data collection, and qualitative data coding and analysis.

Graduate Teaching Assistant *2023 - 2024*
Instructor of record for undergraduate elementary education mathematics methods courses. Main responsibilities include designing and implementing course materials and activities, demonstrating inquiry-based teaching strategies, and supervising and mentoring practicum students.

Johns Hopkins Center for Talented Youth, Online **2019 – 2020**

Instructor, Mathematics
Supervised progress of online students in accelerated gifted program. Communicated regularly with students and parents and held online office hours to provide additional guidance to students in Honors Algebra II course.

Weber State University, Ogden Utah **2015 – 2020**

Adjunct Instructor, Mathematics
Taught quantitative literacy mathematics courses, including both face-to-face and online formats. Worked closely with students to bolster mathematics skills and encourage progression toward a college degree. Maintained a collaborative learning environment where group work and other innovative teaching principles were employed regularly.

Academy at Solstice, Layton Utah **2009 – 2015**

Instructor, High School Mathematics
High school mathematics instructor at private residential treatment facility for at-risk teenaged girls. Designed curriculum for all mathematics courses taught at the academy. Worked closely with students' therapists and doctors to create an effective learning environment for at-risk youth.

Layton City, Layton Utah **2005 – 2009**

Civil Engineer, Water Resources
Designed and managed $7 million West Gentile Street Reconstruction Project, acted as Layton City Water Conservation Coordinator, directed design and construction of new wells and tanks, oversaw water sampling and safety programs, performed water modeling for new developments and to solve existing system deficiencies, managed City maps and database of infrastructure.

PUBLICATIONS

Journal Articles (Refereed)

Beck, K.E., Shumway, J.F., Shehzad, U., Clarke-Midura, J., & Recker, M. (2024). Facilitating mathematics and computer science connections: A cross-curricular approach. *International Journal of Education in Mathematics, Science, and Technology, 12*(1), 85-98. https://doi.org/10.46328/ijemst.3104

Book Review (Non-Refereed)

Beck, K. (2020). Achieving equity in the mathematics classroom [Review of the book *The impact of identity in K-8 mathematics: Rethinking equity-based practices*, by Aguirre et al.]. *Utah Mathematics Teacher, 13*, 100-104. www.utahctm.com/journal

UNIVERSITY TEACHING

Utah State University, Logan, Utah (2023-2024)

ELED 4062: Teaching Elementary School Mathematics II: Number, Operations, and Algebraic Reasoning

Students develop pedagogical content knowledge in number, operations, and algebraic reasoning for teaching grades preschool to grade six, including methods for designing and implementing mathematics instruction, assessment, remediation, and intervention.
Face-to-face on campus: Spring 2023, Fall 2023

Nightingale College, Salt Lake City, Utah (2020-present)

MAT100: College Algebra

This course provides knowledge of Intermediate Algebra and its applications. Emphasis is placed on algebraic techniques with polynomials, rational expressions, exponents, radical expressions and equations, factoring, linear and quadratic equations, inequalities, logarithmic and exponential functions, and solving systems of two or more linear equations.
Online: Spring 2021, Summer 2021, Fall 2021, Spring 2022, Summer 2022, Fall 2022, Spring 2023, Fall 2023

MAT220: Introduction to Statistics

In this course, learners will look at the properties behind the basic concepts of probability and statistics and focus on applications of statistical knowledge. Learners will learn about how statistics and probability work together. The subject of statistics involves the study of methods for collecting, summarizing, and interpreting data. Learners will learn how to understand the basics of

drawing statistical conclusions. This course will begin with descriptive statistics and the foundation of statistics, move on to probability and random distributions, the latter of which enables statisticians to work with several aspects of random events and their applications. Finally, learners will examine a number of ways to investigate the relationships between various characteristics of data.
Online: Spring 2021, Summer 2021, Fall 2021

Weber State University, Ogden, Utah (2015-2020)

MATH 0950: Pre-Algebra

An introduction to mathematical literacy including number sense, algebraic thinking, proportional reasoning, and math learning strategies. Topics include properties of and operations with whole numbers, integers, decimals, fractions and percent; introductory operations and applications with exponents, algebraic expressions, linear equations, and basic geometry.
Face-to-face on campus: Fall 2015, Spring 2016, Fall 2016, Spring 2017, Fall 2017

MATH 0970: Pathway to Contemporary Mathematics

This course integrates geometry, numeracy, proportional reasoning, algebraic reasoning, and topics in statistics and functions (linear, quadratic, rational, radical, exponential and logarithmic) using modeling, problem solving, and critical thinking.
Face-to-face on campus: Summer 2019, Spring 2020

MATH 0990: Beginning Algebra

An introduction to algebraic literacy using properties of real numbers, solving linear equations and inequalities, geometry, ratio and proportion, applications, graphing, solving linear systems, exponents, scientific notation, polynomials, factoring, and solving quadratic equations. Learning strategies for mathematics success, including development of a mathematical growth mindset are integrated into the course.
Face-to-face on campus: Fall 2015, Spring 2016, Fall 2016, Spring 2018 (2), Summer 2018

MATH 1010: Intermediate Algebra

Inequalities (including absolute value and systems), systems of equations, applications, functions (inverse, exponential, and logarithmic), variation, factoring, rational expressions, radicals, complex numbers, quadratic equations, parabolas, circles, quadratic formula, formulas, properties and applications of logarithms.
Face-to-face on campus: Fall 2019 (2)
Online: Fall 2017

MATH 1030: Contemporary Mathematics

Topics from mathematics which convey to the student the beauty and utility of mathematics, and which illustrate its application to modern society. Topics include geometry, statistics, probability, and growth and form.
Face-to-face on campus: Summer 2016, Fall 2016, Spring 2017, Summer 2017, Fall 2017, Summer 2018, Fall 2018, Fall 2019

CEPR 1494: Math 1030/1040 Prep

This abbreviated review course is for students that previously met the entrance requirements for Math 1030/1040 but the prerequisite has since expired.
Face-to-face on campus: Summer 2018, Spring 2019, Summer 2019

Guest Lectures

Guest lecture, ELED 4062 Teaching Elementary School Mathematics II (2022, Feb). For Dr. Jessica Shumway, Utah State University.

Guest speaker, TEAL 7551 Mathematics Education Research Foundations (2022, Dec). For Dr. Jessica Shumway, Utah State University.

GRANT-FUNDED RESEARCH PROJECTS

Collaborative Research: Supporting Rural Paraprofessional Educators and their Students with Computer Science Professional Learning and Expansively Framed Curriculum. (2021-current). My role: Graduate Research Assistant funded by National Science Foundation grant. Working on collaborative team to adapt existing fifth-grade computer science and mathematics curriculum to an integrated model. Assisting in creation of professional development for rural paraprofessionals and teachers. (with Principal Investigator, Dr. Mimi Recker, Utah State University, and Co-Investigators, Drs. Jody Clarke-Midura, Utah State University, Jessica Shumway, Utah State University, and Victor Lee, Stanford University.

AWARDS AND PROFESSIONAL RECOGNITION

Utah State University Kaysville Campus General Scholarship, 2020

University of Wyoming Trustee’s Scholarship (full academic scholarship awarded to top 1% of Wyoming high school graduates), 2001-2005

OUTREACH FOR PUBLIC SCHOOLS

Cache County School District, Logan, Utah. *Cache Code Math PD and Curriculum Planning*. (2021, February, June, August, and December; 2022, March, June, August, October, and December). Professional development and curriculum planning sessions for up to 10 teachers and two administrators as part of the Computer Science for Paraprofessionals NSF-funded research project. Included Scratch programming instruction, model lesson teaching, and curriculum co-planning (with Drs. Mimi Recker, Jessica Shumway, Jody Clarke-Midura, and Victor Lee).

PROFESSIONAL MEMBERSHIPS

Mathematical Association of America, 2021-present
National Council of Teachers of Mathematics, 2021-present
Special Interest Group Computer Science Education, 2021-2022

INTERNATIONAL PRESENTATIONS

International Congress on Mathematical Education (ICME)

Beck, K.E., & Shumway, J.F. (2024, July). *Expansive Framing of Mathematics and Computer Science: Supporting Paraprofessionals and Classroom Teachers in Cross-Curricular Teaching.* Paper Presentation, 15th International Congress on Mathematical Education, Sydney Australia.

NATIONAL PRESENTATIONS

American Educational Research Association (AERA)

Shehzad, U., Clarke-Midura, J., **Beck, K.E.**, Shumway, J.F., & Recker, M. (2023, April). *Rethinking Integrated Computer Science Instruction: A Cross-Context and Expansive Approach in Elementary Classrooms.* Paper Presentation, American Educational Research Association (AERA) Annual Meeting, Chicago, Illinois.

International Society of the Learning Sciences (ISLS)

Shehzad, U., Clarke-Midura, J., **Beck, K.E,** Shumway, J., & Recker, M. (2023, June). Integrated, Elementary-Level Computer Science: A Cross Contextual and Expansive Approach. *In Building Knowledge and Sustaining Our Community: The International Conference of the Learning Sciences (ICLS).* Montreal QC Canada: International Society of the Learning Sciences.

National Council of Teachers of Mathematics (NCTM)

Beck, K.E., & Shumway, J.F. (2023, April). *Geometry and Coding: Introducing an Integrated Mathematics-Computer Science Unit.* Workshop Presentation, National Council of Teachers of Mathematics (NCTM) Virtual Conference, online.

Beck, K.E., & Shumway, J.F. (2022, September). *Applying Expansive Framing to an*

Integrated Mathematics-Computer Science Unit. Paper Presentation, National Council of Teachers of Mathematics (NCTM) Research Conference, Los Angeles, California.

STATE AND REGIONAL PRESENTATIONS

Utah Council of Teachers of Mathematics (UCTM)

Beck, K.E., Shumway, J.F., & Clarke-Midura, J. (2022, February). *Mathematics from Scratch: Learning with Coding.* Workshop presentation, Utah Council of Teachers of Mathematics (UCTM) conference, Kaysville, Utah.

Welch Bond, L.E., **Beck, K.E.**, Basham, M., Shumway, J.F. (2023, March). *Math and Coding Connections in Elementary*. Workshop presentation, Utah Council of Teachers of Mathematics (UCTM) conference, Provo, Utah.

Utah State University Student Research Showcase

Beck, K.E. (2023, March). *The Valentine's Tea: A Cache Valley Rite of Passage.* Paper presentation, Student Research Showcase, Logan, Utah.