

Developing Pre-Service Teachers' Understandings of Mathematical Mindsets: Influences of an
Online Gamification Tool

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DEDICATION

This dissertation is dedicated to my kids, Mary Jacqueline and Patrick.

To my daughter, Mary Jacqueline, your kind, loving heart and strong, outgoing personality that turns heads everywhere we go is what helped me accomplish this goal. You are the reason I started this doctoral journey and you helped me stay focused on the big picture. During times of challenge and struggle, all it took was a few minutes with you to turn my day around. Thank you for your beautiful smile, contagious laugh, and all the stickers and crayon marks on my papers.

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ABSTRACT

The purpose of this study was to examine preservice teachers' (PSTs) understandings of mathematical mindsets after using an online gamification tool (OGT). Drawing on a situated learning perspective, this study explored how and in what ways PSTs engaged with an OGT as they learned about mathematical mindsets. In particular, the aspects PSTs found benefiting and limiting to their understandings of mathematical mindsets were examined. The participants included 10 secondary mathematics PSTs who are part of an undergraduate program for mathematics majors to also obtain an education minor. Data was collected through interviews and student work completed using the OGT. As for data analysis procedures, a process of coding methods was utilized that drew heavily on suggestions from Saldaña (2013) and Charmaz (2000) to analyze PSTs' experiences and perceptions using the OGT. This inductive approach emphasizes the development of themes from data provided by the participants to better understand their conceptualizations and experiences learning about mathematical mindsets. The three themes identified regarding PSTs' understandings of mathematical mindsets were 1) Providing Challenging Learning Experiences and Tasks, 2) Sending Growth Mindset Messages, and 3) Valuing Mistakes. The four themes for benefiting aspects were 1) Experiential Learning, 2) Social Interactions, 3) Autonomy, and 4) Engagement. As for limiting aspects, the three identified were 1) Time Constraints, 2) Clarity of Game Structure, and 3) Development of Some Critical Understandings. Overall, the PSTs appeared to develop a better understanding of how to support student growth mindsets and what that looks like in math classrooms. Across their interviews, PSTs described teaching practices that they believed foster a growth mindset. Therefore, using the OGT seems to have provided contexts that helped make PSTs' understandings of mathematical mindsets more concrete.

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CHAPTER 1

INTRODUCTION

The learning experiences provided to students can have a powerful impact on their development. These experiences impact not only their understanding of academic concepts and skills, but also the beliefs they develop about their ability to learn. As defined by Dweck (2014), a growth mindset is the belief that through hard work one can learn and grow his/her abilities. In the area of education, a serious consideration is how to support teachers in fostering their students' growth mindsets for confidence and perseverance. The study examined one approach to supporting pre-service teachers' (PSTs) understanding of mindsets using an online tool that incorporates gamification. Gamification involves the addition of game-like elements to the learning process (Deterding, 2012).

Dweck's original work on mindsets published in 2006 describes the importance of students experiencing struggle, perseverance, and success to foster a growth mindset (Dweck, 2006). Boaler (2016) more recently extended these ideas to look specifically at ways to teach mathematics for a growth mindset. Boaler emphasizes the power of mistakes and struggle and advocates for students to have opportunities to question, critique, share ideas, make connections, problem solve, and think slowly and deeply about mathematical concepts (Boaler, 2016). These core ideas of teaching for a growth mindset have been seen in recommendations from Dewey over 100 years ago (Dewey, 1916). Before looking forward, it is worth looking back and delving into Dewey's recommendations more deeply to provide the context for this study.

According to Dewey's (1916) experiential learning theory, people learn through actively engaging in meaningful learning experiences. He posits:

To ‘learn from experience’ is to make a backward and forward connection between what we do to things and what we enjoy or suffer from things in consequence. Under such conditions, doing becomes a trying; an experiment with the world to find out what it is like; the undergoing becomes instruction—discovery of the connection of things (Dewey, 1916, p. 164).

More extensive ideas are formed through vital experiences that require learners to make judgements and connections (Dewey, 1916). Dewey (1916) noted, “An ounce of experience is better than a town of theory simply because it is only in experience that any theory has vital and verifiable significance” (Dewey, 1916, p. 169). In addition, creating experiences that connect to students’ past experiences allows them to assimilate new knowledge in a context that is meaningful to them (Dewey, 1938). This approach to learning generates observation, ideas, and assimilation of knowledge resulting in a more active and meaningful learning experience.

Another important component in the process of experiential learning is reflection (Dewey, 1922). Dewey emphasized the importance of active experiences followed by reflection to create meaning from those experiences. As he notes, reflection is the intellectual component of experience. Dewey (1933) described reflection as an, “active, and careful consideration of any belief or supposed form of knowledge in light of the grounds that support it and the further conclusions toward which it tends” (p. 7). Discovery from experiences provokes thinking or an experiential reflection of connections between the activity that lead to further explanation and knowledge. In summary, Dewey (1916) encouraged a more student-centered approach for learning that involves the three following components: 1) active engagement, 2) meaningful and relevant experiences focused on student needs, and 3) time for deep thinking through reflection.

As I noted previously, these components relate to the core ideas of teaching mathematics for a growth mindset.

In the area of mathematics education, one's belief about his/her math ability is especially important considering many people's words, actions, and attitudes related to mathematics reflect more of a fixed mindset rather than a growth mindset (Boaler, 2016). A fixed mindset in mathematics includes beliefs that one has little or no control over his/her success or lack of success in mathematics. A fixed mindset in mathematics includes the idea that one is born with or without math ability. These beliefs about mathematics can likely lead to less persistence in STEM (science, technology, engineering, and mathematics) disciplines (Rittmayer & Beier, 2009) since math is a critical component of all these content areas. The U.S. Bureau of Labor projects there will be more than nine million occupations related to STEM by 2022, which is an increase of about one million STEM jobs since 2012 (Vilorio, 2014). This increase speaks to the growth and the rapidly changing nature of STEM professions. A focus on mathematics makes sense given its role in STEM fields of study and professions. The following quote captures the role of mathematics in STEM:

Mathematics is the technical foundation for science, engineering, and technology. The work often involves finding patterns in data or abstract logic. These patterns can be used to draw general conclusions about data, to test mathematical relationships, and to model the real world. (Vilorio, 2014, p. 5)

This description of mathematics aligns with teaching practices that Boaler (2016) notes as developing a *mathematical mindset*, which involves seeing “mathematics as an open, growth, learning subject” and students seeing “themselves as powerful agents in the learning process” (Boaler, 2016, p. 171). Boaler advocates for students to have opportunities to play with

numbers, look for patterns, and think about their ideas in math. Given these points, it is important for educators and researchers to understand how to develop students' growth mindsets in mathematics classrooms in order to address the fixed mindset beliefs that many students hold, as well as to increase students' willingness to pursue STEM careers of the 21st century workforce.

The ideas of Dewey can inform the learning experiences of PSTs to develop an understanding of mathematical mindsets and how to support K-12 students' mathematical mindsets. First, actively engaging activities can create opportunities for exploring, discovering, and sharing ideas. Second, time for reflection is crucial for one to think deeply about his/her learning experiences and make further connections and discoveries. Third, an important component of creating meaningful and relevant educative experiences is connecting to students' past experiences, as well as their future goals. Connecting to past experiences allows PSTs to assimilate new knowledge in a context that is meaningful to them (Dewey, 1938) and connecting to future goals provides a more relevant experience such as learning tasks similar to what in-service teachers do. As we consider the past experiences and future needs of PSTs, the greater use of technology today should be of focus considering how these technology tools have dramatically transformed how we communicate and carry out daily tasks (Lave & Wenger, 2001).

The prevalence of technology in the world today has resulted in many young adults, including current PSTs, having more experiences using technology. Most PSTs today are considered 21st century students because their entire formal education experience has taken place in the 21st century. In turn, today's PSTs will also teach 21st century students. It is important to consider the different experiences of these students compared to past students in order to design

effective instruction. Of young adults 18 to 24, 80% use Facebook, 94% use YouTube, and 78% use Snapchat (Pew Research Center, 2018). In addition, American teenagers consume media an average of nine hours per day (Common Sense Media, 2015; Tsukayama, 2015) and 95% of teens have access to a smartphone and 88% have access to a computer (M. Anderson & Jiang, 2018). It's important to note these students' access to technology varies greatly by income level (M. Anderson & Jiang, 2018), as well as those with access vary in how they use it (Bennett & Maton, 2010; Green & Hannon, 2007). However, with the vast majority of 21st century students having access to technology, many students engage in activities using technology they find enjoyable and interesting such as playing video games (Perrin, 2018), posting, texting friends, watching videos, and creating music playlists (Tsukayama, 2015). Given what we know about 21st century students, we can leverage their past experiences and provide a meaningful context by integrating similar uses of technology into their learning activities. In addition, there is a growing number of online tools and resources available for educational purposes; therefore, it is beneficial for PSTs to learn how to use these tools effectively in classrooms.

One teaching approach used to reach today's students is game-based learning (GBL), which involves learning a skill or a concept through a game. The idea behind GBL is to connect to students' experiences playing games outside the classroom, especially video and online games for 21st century students. In 2006, the educational research community received a mandate from the National Summit on Educational Games to increase empirical investigations targeting how and under what conditions games can be used to maximize learning potential (Federation of American Scientists, 2006). One of the assumptions that members of the Summit made was that students "acquire new knowledge and complex skills from game play, suggesting gaming could help address one of the nation's most pressing needs— strengthening our system of education

and preparing workers for 21st century jobs” (Federation of American Scientists, 2006, p. 3).

The considerable amount of research on GBL has shown that it is a promising teaching approach that can enhance student engagement (Huizenga, Admiraal, Akkerman, & Dam, 2009; Hwang, Shih, Ma, Shadiev, & Chen, 2016; Ke & Abras, 2013; Marino et al., 2014; Sáez-López, Miller, Vázquez-Cano, & Domínguez-Garrido, 2015), motivation (Hays, 2005), learning (Hamari et al., 2016), collaboration (Ke & Abras, 2013), and self-efficacy (Meluso, Zheng, Spires, & Lester, 2012). Moreover, GBL can heighten students’ enjoyment (Ke & Abras, 2013; Marino et al., 2014; Sáez-López et al., 2015), concentration, and interest (Hamari et al., 2016).

Few studies have examined a situation involving both GBL and the development of mathematical mindsets. One such study was conducted by Boaler, Bryant, and Klein (2018). The researchers examined how a digital math game with personalized mindset messages influenced engagement, challenge seeking, persistence, and mastery. They found that students receiving mindset coaching during game play were significantly more successful in their engagement, challenge seeking attitudes, persistence, and level of mastery. Students received mindset coaching throughout the game that encouraged them to choose appropriate challenges, so they worked at the optimal difficulty level. Boaler et al. (2018) highlighted the importance of students being challenged appropriately: “In my work as a teacher I see repeatedly that the most wonderful learning moments come when students experience the right level of challenge – when they find something hard but within their grasp” (p. 3). Appropriate challenges are important for students to experience struggle. Findings from this study indicate that moments of struggle are critical for students’ development of growth mindsets, and struggles can be designed with intentionality for this purpose. Students learn to value struggle and mistakes when they receive strategic messages during these moments that they are learning with these kinds of experiences

and that their brains are becoming stronger in the process. Moments of struggle can provide valuable experiences for students to learn to persist through challenges. Understanding factors that impact students' beliefs about their learning ability such as challenge and struggle are critical to effective teaching and therefore should be of focus in teacher preparation programs.

Dewey's beliefs about teacher preparation programs supports developing PSTs' understanding of mindsets and the impact mindsets have on student thinking and learning. He believed that teacher preparation programs should focus on the mind-activity of students, as well as the idea of becoming a life-long learner more so than practical matters such as lesson planning and classroom management. Dewey noted, "Unless a teacher is such a student, he may continue to improve in the mechanics of school management, but he cannot grow as a teacher, an inspirer and director of soul-life" (National Society for the Study of Education, McMurray, & Dewey, 1904). Involved in the mind-activity of students are their beliefs about their abilities. Therefore, it is essential for teachers to be aware of mindset beliefs and how they impact both teachers' and students' learning. Looking forward, what would Dewey's ideas look like today with the greater use of technology in and outside the classroom?

Figure 1.1 illustrates how the ideas discussed in this chapter connect. As noted previously, ideas from Dewey's experiential learning theory support the core ideas of teaching for a growth mindset, connecting to learners' past experiences and future goals, and creating engaging learning experiences. Thus, an online gamification tool that incorporates actively engaging, meaningful and relevant learning experiences followed by reflections has the potential to be an effective approach to develop 21st century PSTs' understanding of mathematical mindsets. An online gamification tool that incorporates actively engaging, meaningful and relevant learning experiences followed by reflections has the potential to be an effective

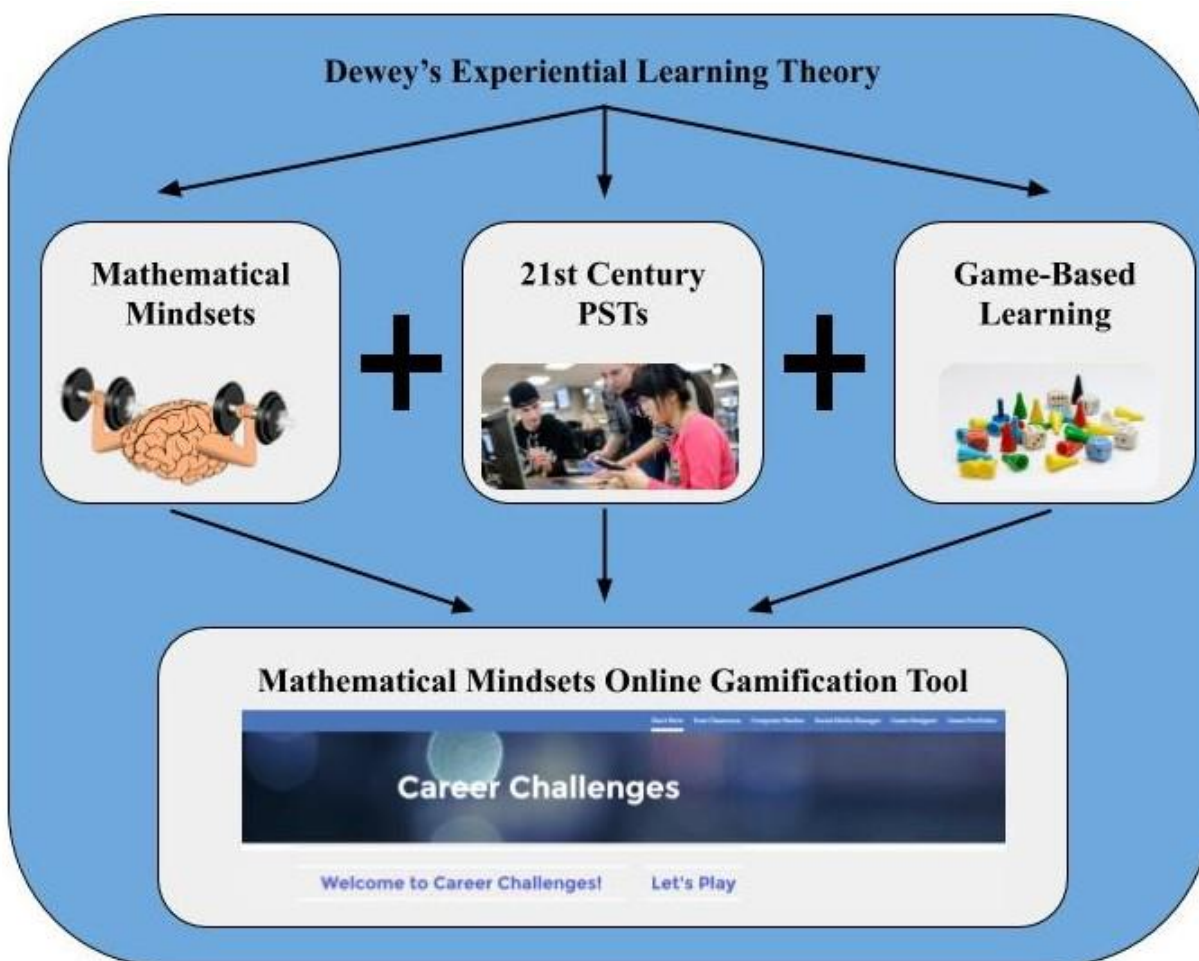


Figure 1.1. Concept map summarizing connections among study fields

approach to develop 21st century PSTs' understanding of mathematical mindsets. This online format would also provide a forum to reach a broader group of PSTs. The purpose of gamification is to take advantage of game elements that enhance educational experiences. From the limited research on gamification, positive impacts on students' educational experiences have been found (Bellotti et al., 2013; Deterding, 2012). These positive impacts include increasing student motivation (Glover, 2013), enjoyment, and quality of work (Kingsley & Grabner-Hagen, 2015). Merely the action of playing an online educational game does not guarantee quality

learning. The design of gamification is critical to positive outcomes. This calls for more research to understand what aspects are most beneficial to incorporate in gamification, in light of the limited literature in this area (Glover, 2013; Hanus & Fox, 2015).

Problem Statement

The fixed mindset beliefs commonly held about mathematics are problematic because they lead students to think they can do little to change their ability related to mathematics. These beliefs cause students to think of mistakes as failures and give up when experiencing challenges because they see little or no value in putting forth effort (Dweck, 2007). Boaler (2016) posits that there are common misconceptions that people hold that serve as the basis for their negative feelings about mathematics. Two of these misconceptions are that math is all about a) rules and procedures and b) right or wrong answers. Individuals likely formed these misconceptions because this is how they experienced learning mathematics in the classroom through their K-12 experiences (Boaler & Greeno, 2000; Hiebert et al., 2005). Math classrooms that emphasize rules and procedures with little conceptual understanding can cause some students to find mathematics meaningless and confusing (Boaler, 2016). Consequently, some of these same students identify as “not being a math person” (Anderson, 2007; Boaler & Greeno, 2000). In addition, teaching mathematics with a focus on procedures, speed, and accuracy sends fixed mindset messages to students because they either know the answer or they don’t (Boaler, 2016). Clearly, many students may not experience mathematics as something that they work toward understanding at some point during their K-12 education.

Given that many students are likely learning mathematics with an emphasis on procedures (Boaler & Zoido, 2016; Hiebert et al., 2005; Stigler & Hiebert, 2009), many mathematics classrooms are likely not providing access to the development of growth mindsets

to many students. Due to many mathematics teachers having more fixed mindsets (Jonsson, Beach, Korp, & Erlandson, 2012) and their practices reflecting their conceptions of students and mathematics (Horn, 2007; Stipek, Givvin, Salmon, & MacGyvers, 2001), many PSTs likely learned in an environment that did not foster a growth mindset in mathematics. The PSTs that participated in this study are majoring in mathematics and pursuing a secondary mathematics teacher certification. It is expected that they likely feel confident in mathematics or at least have positive dispositions towards the subject. However, do they feel everyone can learn mathematics at high levels? In other words, do they have a growth mindset related to mathematics? It is quite possible that some or even many PSTs believe they are “math people,” but do many hold beliefs that everyone can become a math person? Dweck (2006) found high-achieving girls were some of the students most negatively impacted with fixed mindset beliefs. Their actions and language reflected less of a willingness to engage with more challenging tasks in fear of making mistakes and not being viewed as smart by others (Boaler, 2016; Dweck, 2006; Halvorson, 2011). If these PSTs have received messages such as “they are smart at math” then they may have developed fixed mindsets towards the subject believing some can do math and some cannot. In short, being successful or confident in mathematics does not necessarily go hand in hand with holding a growth mathematical mindset.

Studies indicate that mathematics teachers commonly have fixed mindset beliefs about their students’ abilities to learn mathematics (Horn, 2007; Stipek et al., 2001; Sun, 2018). Yet, it is possible for teachers’ mindsets to shift and change toward growth mindsets (Dweck, 2006). In one study, a group of teachers showed change in their teaching practices, reflecting more growth mindsets after participating in a training focusing on teacher mindset beliefs (Seaton, 2018). Research indicates that teaching practices and experiences teachers provide students have a

greater impact on students' mindsets than whether or not a teacher holds a growth or fixed mindset (Haimovitz & Dweck, 2017). Therefore, this study focused on developing PSTs' understandings of mindsets and of teaching practices that foster student growth mindsets in mathematics.

Purpose of the Study

The purpose of this study was to explore how PSTs' understandings of mindsets in mathematics are influenced by using an online gamification tool. Research indicates teachers who hold a growth mindset can positively impact their students (Anderson, Boaler, & Diekmann, 2018). To leverage these 21st century students' past experiences, this study employed an online gamification tool. This approach provided PSTs authentic learning opportunities as they learned about mindsets and ways to foster students' growth mindsets in mathematics by using defining tools of their generation and completing tasks similar to those of in-service teachers. This study is situated at the intersection of mathematical mindsets, gamification, and the context of 21st century learning. The following three research questions guided this study:

1. What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?
2. What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?
3. What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?

Previous studies found gamification to be a beneficial teaching approach (Bellotti et al., 2013; Kingsley & Grabner-Hagen, 2015). Therefore, this study's online gamification tool has the

potential to positively influence PSTs' understanding of mathematical mindsets and ways to foster students' growth mindsets.

Need for the Study

This study is needed from a practical and a theoretical perspective. From a perspective of practice, the study is positioned to be significant to informing teacher and student learning in a number of ways. First, examining aspects of the online gamification tool that PSTs find are and are not helpful contributes to a better understanding of effective online instruction in teacher education programs. Secondly, findings from this study can guide future implementations of online professional development for K-12 teachers. The sample in this study comprises PSTs who have grown up in the 21st century with technology saturated in their lives. PSTs are our future teachers. Therefore, understanding their experiences learning with an online tool can benefit not only teacher education programs, but also professional development for K-12 teachers. Lastly, all students currently in K-12 classrooms are 21st century students, so the findings from this study can provide a better understanding of effective online instruction for K-12 students. Thus, the results of this study may be useful for future designs of online instruction for PSTs, in-service teachers, and K-12 students.

This study also addresses the problematic and prevalent fixed mindset beliefs about mathematics. Many teachers hold fixed mindsets in mathematics (Jonsson et al., 2012) and have fixed mindset beliefs about their students' ability to learn mathematics (Horn, 2007; Stipek et al., 2001; Sun, 2018). Thus, this study is significant for mathematics teacher education programs seeking to promote effective strategies in fostering students' growth mindsets. In addition, contributions from this study may also be transferred to professional development training that aims to develop teachers' understanding of mathematical mindsets and encourage practices that

foster student growth mindsets. The literature indicates there is a disconnect between teachers having a growth mindset and those beliefs transferring to their teaching practices (Haimovitz & Dweck, 2017). Thus, the activities used in this study's online gamification tool emphasize teaching practices that foster students' growth mindsets in mathematics.

Limitations

As is true with most qualitative studies, the unique learning contexts examined in this research is not necessarily generalizable on a large scale. The sample of participants was drawn from two teacher education courses at a university in the Southeastern United States, and therefore did not allow for a diverse or large collection of data, limiting the generalizability of the study's results. However, the purpose of qualitative research is not to generalize but instead explore individual meaning and the complexity of a situation (Creswell & Creswell, 2018). With this in mind, the results of this study can be used to inform future research related to online instructional tools and to the development of educators' understanding of mathematical mindsets. Furthermore, the study's findings can provide an understanding of what did and did not work in this particular situation, which can guide future designs and implementations of online instructional tools.

As the researcher, my relationship with participants may also be a limitation of the study. I was the facilitator for the mindset module, so participants may have viewed me as a figure of authority. Furthermore, my beliefs related to mindsets and effective teaching practices were likely expressed from my role as the facilitator, consequently sending specific messages to participants that may have affected their responses on data collections. However, I was not the course instructor and did not make any decisions on their performance in the course such as

assigning grades. By not having a pre-existing relationship with the participants, the risks of influencing their responses were likely reduced.

Delimitations

This section provides details of the delimitations that may have impacted the study's findings. These delimitations are characteristics of the research design chosen by the researcher to set boundaries for the study. First, this study is delimited by the collection of self-report data to analyze participants' experiences using the online gamification tool. Self-report data raise an important concern because participants may not answer honestly to items. Thus, their responses may not reflect their actual thinking, feelings, or behaviors (Christenson, 2012). Students may be influenced by social demands to answer in a certain direction especially under some conditions such as responding without anonymity. Although there was the risk of dishonest responses, interview and reflections allowed the collection of data on participants' subjective perceptions. This type of data was necessary to learn about participants' experiences using the online gamification tool including their perceptions of aspects of the tool that were and were not helpful.

This study's findings are also delimited by the online gamification tool only being implemented for one topic in the course. This short time span provided a very specific situation, which was the purpose of this qualitative study. These boundaries were appropriate given this study's focus on mathematical mindsets and an online gamification tool. In addition, these boundaries were set for manageability of the study, as well as accessibility to the classroom.

Assumptions

A few assumptions are wrapped up in this study. First, I believe teachers should be supported in using practices that foster students' growth mindsets; therefore, I assume these are

effective teaching practices. In addition, I believe incorporating technology based on student-centered approaches is most effective. I took these beliefs into the study. However, the design of the study including the activities in the online gamification tool and questions asked during interviews were based on research evidence. Lastly, I assumed students responded honestly on all reflections and interview questions. Student identifiers were replaced with pseudonyms to ensure confidentiality. With these efforts to keep participants' information confidential, it was assumed students felt comfortable to respond honestly.

Definition of Terms

This section provides definitions for key terms regarding how they were used and applied in this study.

21st century learning – learning related to developing the skills needed to be successful in the 21st century where one is likely to have several careers and face new challenges. Learning for the 21st century means mastering content while also developing 21st century skills that include producing, problem solving, collaborating evaluating information, and lifelong learning. Furthermore, the technological tools and their benefits for learning are part of the 21st century learning context (Partnership for 21st Century Learning, 2007).

21st century students – These students are those whose formal education experience has mostly taken place in the 21st century. Most of these students have increased access to technology (Pew Research Center, 2018); therefore, they have different experiences from past generations of students.

21st century skills – 21st century skills are the skills “students should master to succeed in the work and life in the 21st century” (Partnership for 21st Century Learning, 2007, para. 5). Partnership for 21st Century Learning (P21) has identified three categories of 21st century skills:

life and career skills, learning and innovation skills – 4 Cs, and information, media, and technology skills. This study focused on the learning and innovation skills by integrating the 4 Cs into the gamification activities, which are critical thinking, creativity, communication and collaboration.

Fixed mindset – One with a fixed mindset believes abilities, qualities, and intelligence are stable and cannot change or can change only a little (Dweck, 2006)

Game-based learning – Game-based learning involves learning a skill or a concept through a game. A game is “an immersive, voluntary and enjoyable activity in which a player pursues a challenging goal based on the game rules” and “provides a safe environment for taking chances and the opportunity to develop the knowledge and refine the skills required to succeed” (Kinzie & Joseph, 2008, p. 644).

Gamification – Gamification incorporates game elements such as points, levels, and challenges in non-game contexts (Simões, Redondo, & Vilas, 2012) such as learning activities. Gamification involves the teacher teaching a concept using game elements to increase student engagement (Kingsley & Grabner-Hagen, 2015).

Growth Mindset – One with a growth mindset believes abilities, qualities, and intelligence can grow and develop through hard work and persistence (Dweck, 2006)

Mathematical Mindset – One with a mathematical mindset has growth mindsets beliefs toward mathematics including seeing “mathematics as an open, growth, learning subject” (Boaler, 2016, p. 171).

Mindset – the beliefs people possess about their capacity to grow their abilities, qualities, and intelligence (Dweck, 2014). This study focuses on beliefs about mathematics and the implicit beliefs about whether our math ability is malleable or fixed.

STEM – a field in the 21st century workforce that involves using “knowledge of science, technology, engineering, or math to try to understand how the world works and to solve problems” (Vilorio, 2014, p. 3) that also involves technology and other tools.

Organization of the Study

As with other work of this nature, this dissertation is organized into five chapters. The current chapter introduces the study with general information including the statement of the problem, the purpose of the study, the need for the study, limitation, delimitations, assumptions, and definition of terms. The remaining chapters are organized in the following manner. The second chapter presents the theoretical framework for this study, as well as the review of literature that is relevant to mindsets, 21st century learning context, and educational gamification. The third chapter describes the research methodology including the research design, participant selection, data collection, and data analysis procedures. The fourth chapter details the results from data collection and how the data helps answers the research questions. The final chapter discusses the conclusions and implications based on the findings from this study.

CHAPTER 2

LITERATURE REVIEW

“If we teach today’s students as we taught yesterday’s, we rob them of tomorrow.”
John Dewey

The 21st century workforce is changing so quickly that research predicts 65% of today's grade schoolers will hold jobs that do not exist yet (World Economic Forum, 2018). Our rapidly changing world can be put into perspective by how “the top ten in-demand jobs in 2010 did not exist in 2004” and “the US Department of Labor estimates that today's learner will have 10 to 14 jobs by the age of 38” (Lopez-Claros, 2011, p. 59). In addition, human knowledge is increasing exponentially with knowledge doubling approximately every 13 months (Schilling, 2013) and with information changing so quickly, half of what a student learns in the first year of a technical degree program is predicted to be outdated by his/her third year of study (Lopez-Claros, 2011). Given these points, people need to be able to adapt in this quickly changing world to be successful in the 21st century workforce.

As I made clear before, it is important to possess a growth mindset, which is the belief that one can improve and learn through hard work (Dweck, 2006), in order to navigate the 21st century. Moreover, mathematical mindsets are particularly significant with the growing number of STEM jobs (Vilorio, 2014) and the prevalent fixed mindset beliefs towards mathematics (Boaler, 2016). A student’s experiences learning mathematics can influence his/her mathematical mindset, one’s belief about his/her math ability. Thus, it is critical for teachers to use classroom practices that foster student growth mindsets. A serious consideration for teacher education programs is supporting pre-service teachers’ (PSTs) understanding of mindsets, as well as reaching these 21st century students who have grown up in a world saturated with

technology (Hicks, 2011). Using gamification, adding game-like elements to the learning process (Deterding, 2012), is one approach that can potentially support PSTs' understanding.

In this chapter, I will discuss the theoretical framework and relevant literature that informed this study. The theoretical framework will be explained first. Next, a review of literature is provided in three areas of research: mathematical mindsets, preparing 21st century PSTs, and game-based learning (GBL). A review of the most relevant research is provided to gain a better understanding of the situation in which this study took place. Mindsets regarding intelligence are detailed with a focus on mindsets in mathematics. To gain a better understanding of how to teach and prepare 21st century PSTs, research related to skills needed in the 21st century, educational benefits of technology, and characteristics of 21st century students are discussed. Finally, research in GBL with attention to gamification is presented.

Theoretical Framework

Situated learning theorists posit that learning is tied to the context in which it takes place including the tools and resources available (Brown, Collins, & Duguid, 1989; P. Cobb & Bowers, 1999; Lave & Wenger, 2001; Putnam & Borko, 2000; Saivyer & Greeno, 2009). The studies of Lave and Wenger (2001) and Putnam and Borko (2000) provide illustrations of four foundational ideas of situated learning that provided this study's theoretical framing. First, *legitimate peripheral participation*, devised by Lave and Wenger (2001) with their emphasis on the whole person acting within a social world is a key idea to this study's theoretical framework. The work of Putnam and Borko (2000) who explored teacher learning with a situated perspective provided the following three foundational ideas: "that cognition is (a) situated in particular physical and social contexts; (b) social in nature; and (c) distributed across the individual, other persons, and tools" (p. 4). These ideas will be detailed in the following paragraphs.

First, the notion of *legitimate peripheral participation* (Lave & Wenger, 2001) involves one's participation in communities. This idea emphasizes the "whole person acting in the world" (Lave & Wenger, 2001, p. 49), as well as the social world and how it impacts learning, rather than only the immediate context typically considered by most theories. Influences from the social world involve technological tools and how these tools impact participation such as functions they fulfill and interactions among people (Lave & Wenger, 2001). These ideas are evident in this study examining how PSTs learned using an online gamification tool. In understanding the whole person with this study's participants, it is important to consider today's PSTs have grown up in the 21st century where technology has been immersed in every facet of their lives (Hicks, 2011). This technology immersion affects how they learn and the social world they live and participate within. Therefore, the characteristics of 21st century students and their experiences need to be considered in order to plan effective situated opportunities for PSTs to learn. Given these points, this study attempted to situate professional learning for PSTs within an effective context by using an online gamification tool.

A second foundational idea is that cognition is situated in particular physical and social contexts. Learning and knowledge involve more than acquisition of facts. How people acquire knowledge and the physical and social contexts in which it takes place is fundamental to what is learned (Putnam & Borko, 2000). In other words, how individuals participate and interact with each other, as well as the tools and resources they utilize play an integral part in their learning. For example, learning with authentic activities situates cognition within contextual features that will likely lead to successful use of these skills outside the classroom. Authentic activities are similar to what practitioners do or they "foster the kinds of thinking and problem solving skills that are important in out-of-school settings" (Putnam & Borko, 2000, pp. 4-5). Authentic

contexts can positively influence learning by making what is learned more meaningful to students' lives outside the classroom.

A third idea for this study's situated perspective is that cognition is social (Putnam & Borko, 2000). Social interactions play a significant role in how learning takes place within a community. All members' ideas and ways of thinking contribute to how and what is learned. From a social situated perspective, one central goal of education is to equip students with the ability to use their knowledge and interact with others in various communities. Therefore, activities designed for participation in professional communities or that develop lifelong learning such as opportunities "to question and extend their knowledge in various domains" (Putnam & Borko, 2000, p. 5) will likely lead to more successful application of what is learned later in their lives.

The final idea is that cognition is distributed across people and resources (Putnam & Borko, 2000). Learning is not something that happens in isolation. It takes place with the contributions of other people and resources such as technological tools. Most have experienced feeling stuck while trying to complete a difficult task and persevered through the challenge by using resources available such as getting help from a colleague or conducting research on the internet. Members of a community extend capabilities beyond what would be possible for any individual community member. Furthermore, opportunities to access other people and tools while learning is more representative of how we learn outside the classroom and therefore, it makes sense to incorporate "tool-aided" and "socially shared" learning tasks in classrooms to prepare students for successful participation in society (Putnam & Borko, 2000).

These ideas related to a situated perspective (Lave & Wenger, 2001; Putnam & Borko, 2000) provided the lens from which to examine PSTs learning in this study. Next, I will present

relevant literature regarding PSTs' learning about mathematical mindsets using an online gamification tool.

Mathematical Mindsets

In Dweck's frequently cited work (2006), she explains how mindsets are more than beliefs: "Mindsets frame the running account that's taking place in people's heads. They guide the whole interpretation process" (p. 215). As Dweck notes, mindsets guide how people constantly interpret their experiences and make decisions. One's mindset can fall between two ends of a spectrum, with a fixed mindset on one end and a growth mindset on the other end. These mindsets are two different pathways people can create for their learning, but it is important to recognize that mindsets are not a dichotomy, but rather individuals show up along a continuum from a more fixed to a more growth mindset (Dweck, 2014). Someone with more of a fixed mindset views intelligence as stable with little ability to change, whereas someone with more of a growth mindset believes intelligence is malleable and can substantially improve through hard work. Boaler (2016) has taken Dweck's ideas about mindset and examined it specifically for mathematics. Mathematical mindsets involve beliefs about the ability to persevere in solving challenging math task. One with a growth mindset believes he/she can learn and grow in mathematics (Boaler, 2016).

Although, there is a larger research base in the areas of mindsets and mathematical mindsets, I draw mostly from Dweck and Boaler as they are the primary and most influential researchers regarding these concepts. Dweck has pioneered a field of research about fixed mindsets and growth mindsets, "now widely-used concepts that Dweck defined and elucidated" (SAGE, 2018, para. 2). Boaler collaborated with Dweck to extend her ideas and study how mindset beliefs are infused in mathematics as they both agreed that "math was the subject most

in need of a mindset makeover” (Boaler, 2016, p. ix). Boaler has contributed extensive research to provide better understanding of how teachers can foster growth mindsets in mathematics.

The topic of mathematical mindsets is important for a number of reasons. First, the general public reflects more fixed mindsets about mathematics (Boaler, 2016). Discourses surrounding mathematics are often negative, reflecting dislike and a lack of identification (Gresalfi & Cobb, 2006; Ladson-Billings, 1997). Patterns in dispositions towards mathematics seem to be very different from other subjects such as language arts or social studies (Boaler, 2016). These views beg the question of why people hold negative dispositions towards mathematics. Boaler (2016) describes this idea as being “embedded deep in the American and British psyche” (p. xii). People believe mathematics is different from other subjects and many misconceptions about mathematics have been constructed including: math is about right or wrong answers, math is about rules and procedures, men are better at math than women, and people who can do math are the smartest people (Boaler, 2016). These beliefs reflect a more fixed mindset about mathematics. In contrast, learning mathematics should encourage a growth mindset through “reasoning, creativity, connection making, and interpretation of methods” (Boaler, 2016, p. xii). Math is constantly changing, and learning authentic mathematics involves diverse ways of thinking and different pathways of problem solving.

In the last decade, advances in technology have afforded the ability to look at brain activity and brain growth. Findings in the area of “brain plasticity” reveal that the brain has the extraordinary capability of growing and changing in a short period of time¹ (Abiola & Dhindsa, 2011; Woollett & Maguire, 2011). It was previously believed that the brain could not be changed (Cajal, 1959; Fuchs & Flugge, 2014). New findings show the brain can grow and

change, which means the vast majority of students have the potential to learn mathematics at high levels (Boaler, 2016).

Can one actually develop a different mindset? Multiple studies confirm that mindsets are not permanent and can be changed (Blackwell, Trzesniewski, & Dweck, 2007; Dweck, 2006; Seaton, 2018). When students' mindsets change from more fixed to more growth-like in their approach, learning becomes more positive and successful (Blackwell et al., 2007). People can change their mindsets by developing an understanding of the two mindsets, growth and fixed. For example, *Brainology*, a program to teach students about their brains and the growth mindset has been found to be successful in changing the mindsets of students and teachers (Dweck, 2006). Seaton (2017) found that a training program on mindsets impacted teachers' mindsets and sustained change in their instructional practices. These studies reveal mindsets are malleable and when people are made aware of the two mindsets and the characteristics of each, they can choose how they want to believe.

Some strategies have been identified in the literature as effective in developing a growth mindset in mathematics. One idea is that it is beneficial for teachers to help students view mistakes positively and as opportunities to learn and grow (Allen & Schnell, 2016). Mistakes have been found to create more brain activity than the process of solving problems correctly (Boaler, 2016; Moser, Schroder, Heeter, Morgan, & Lee, 2011). This point emphasizes the power of mistakes for brain growth. Other strategies to develop growth mindsets in mathematics are to encourage students to play with numbers, look for patterns, and think about their own ideas (Boaler, 2016). Opportunities to problem solve has been found to contribute to students' persistence (Middleton & Spanias, 1999; Suh, Graham, Ferranone, Kopeinig, & Bertholet, 2011) and those who have good problem solving skills have a mathematical disposition with "a

willingness to pit themselves against difficult mathematical challenges under the assumption that they will be able to make progress on them, and the tenacity to keep at the task when others have given up” (Schoenfeld, 2007, p. 60). In addition, fostering communication through conversations in pairs, small groups and whole class have been found to be beneficial to expanding students’ views of what it means to be competent in mathematics (Cohen & Lotan, 2014; M. Smith & Stein, 2011). Such experiences provide opportunities to allow students to develop beliefs about mathematics as a “subject of growth and their role is to learn and think about new ideas” (Boaler, 2016, p. 34). Furthermore, the verbal messages students receive have great impact on their mindsets. With effective teaching, messages, and support, teachers can promote more growth mindsets in their students (Haimovitz & Dweck, 2017).

One central consideration for developing growth mindsets in mathematics is the tasks provided to students during mathematics lessons. These mathematical tasks can communicate a more fixed or growth mindset (Boaler, 2016). Tasks that promote procedures, accuracy, and speed will develop more fixed mindsets in which students focus on their ability, whereas tasks that involve collaboration, making connections, creativity and multiple access points provide opportunities to develop growth mindsets in mathematics. Boaler (2016) suggests six ways teachers can draw on mathematical tasks to support the development of a growth mindset: 1) select an open task to encourage multiple methods, pathways, and representation 2) provide inquiry 3) pose problems before teaching the method to solve them 4) add a visual component 5) make tasks have a low floor and high ceiling and 6) require convincing and reasoning. Allen and Schnell (2016) offer similar suggestions for mathematics tasks with “multiple access points that benefit from nonalgorithmic approaches and diverse problem-solving strategies” (p. 403).

Providing mathematical tasks with these characteristics can increase the potential of building a growth mindset and developing deep understanding in mathematics.

Students' Mindsets

About 40% of students have fixed mindset beliefs, another 40% have a growth mindset, and 20% waver between the two mindsets (Dweck, 2006). A considerable proportion of students have damaging beliefs about their intelligence, believing their intelligence cannot grow or can only grow a little (Dweck, 2006). These beliefs appear to have concrete implications for how students approach learning and challenges. In this section, I discuss the important impacts of students' mindsets.

Those who possess more fixed mindsets feel it is crucial to always be perfect (Dweck, 2006), they prioritize performance over learning (Donohoe, Topping, & Hannah, 2012), and they view mistakes and effort as lack of ability (Dweck, 2007). On the other hand, those with more growth mindsets believe “you can always substantially change how intelligent you are” (Dweck, 2006, p. 17), which creates a focus on learning. So, those who reflect growth mindsets value effort, learn from mistakes (Dweck, 2007), seek challenges, persevere, and have higher intrinsic motivation (Donohoe et al., 2012). Consequently, overall, such individuals achieve at higher levels (Boaler, 2016). Given these points, the two mindsets have very different effects on how students interpret and respond to their experiences, which is described in the remaining paragraphs of this section.

Research on students' mindsets regarding intelligence has found that students with more fixed mindsets overly focus on their ability (Dweck, 2014). They care about looking smart, which results in their avoidance of taking risks in fear of “looking dumb.” This also results in students focusing too much on grades or evaluations (Dweck, 2006). For example, Dweck

(2006) examined how students responded when told there was a test inside a box that measured an important school ability. The study found that students with a more fixed mindset believed the test could measure how smart they were and how smart they would be when they were adults. Their fixed mindsets were reflected in their beliefs that their own intelligence could change very little over time. Mueller and Dweck (1998) also conducted a study of fifth graders solving intriguing puzzles. In this study, students were divided into two groups. One group was praised for ability and the other was praised for their effort. Those praised for their ability described their intelligence as a fixed trait and when the puzzles became harder, they no longer enjoyed solving them. However, the same fifth graders did enjoy feeling successful as they solved the easier problems (Dweck, 2006). This study revealed those with fixed beliefs did not want to put forth more effort to solve the puzzles. As reflected in this study, students with more fixed beliefs see little or no value in working hard to overcome a challenge because they believe one either has the ability or one does not.

On the other hand, students with a more growth mindset often experience more enjoyment from learning and desire to take on challenges and put forth greater effort (Dweck, 2006). Furthermore, having a growth mindset predicts higher academic achievement (Blackwell et al., 2007). Research suggests holding a growth mindset supports individual's resilience, perseverance, and motivation (Donohoe et al., 2012; Seaton, 2018). Dweck (2014) described students with a growth mindset as having more "grit" because they put forth effort, they persevere through challenges, and learn from mistakes. She found in the study of fifth graders solving puzzles that those with a growth mindset seized opportunities to solve more difficult puzzles (Dweck, 2006). They were motivated by the challenge and some even wanted their parents to buy similar puzzles for them to do at home. The students reported feeling smart when

they had to work harder to figure something out. It was about learning something through hard work, progress, and confronting a challenge, but at the same time they enjoyed learning.

Students' mindsets are also reflected in how they respond to failure and mistakes (Allen & Schnell, 2016; Boaler, 2016; Dweck, 2006, 2014). Students with more fixed mindsets often hide from mistakes because they feel measured by them; whereas, students with more growth mindsets consider their mistakes as opportunities to learn (Dweck, 2014). Dweck (2006) examined how seventh graders would respond after receiving a poor test grade. Through interviews with the students she found that those with a growth mindset would study harder for the next test. Conversely, those with a fixed mindset said they would study less and even consider cheating (Dweck, 2006). These students saw mistakes as embarrassing and representative of their inability. Brain research indicates that mistakes make synapses fire and our brains grow (Allen & Schnell, 2016; Boaler, 2016) and therefore, should be viewed as learning opportunities to grow and as an essential part of the learning process.

Finally, students' mindsets seem to impact how they respond to feedback they receive from teachers (Dweck, 2006). Students with more growth mindsets use the feedback to improve and grow. However, students with a fixed mindset view feedback as an attack and do not learn from the feedback. The kind of feedback we give children also influences their mindsets. It is more effective to give feedback that focuses on process and improvement rather than ability. Dweck (2006) found praising students for ability pushed them into a fixed mindset. As a result, it appeared they did not want to complete difficult tasks to expose their imperfections. Yet, students who received praise for effort revealed a growth mindset and wanted to complete challenging tasks. Additionally, The feedback and language students receive in the classroom is very important from the impact it has on their mindset (Seaton, 2018). Given these points, the

mindsets students develop directly influence their learning experiences and how they respond to challenges and opportunities to learn and grow.

The Role of Teachers' Mindsets

Given the positive effects of growth mindsets on academic behaviors and achievement, it is important to understand the role of the teachers in supporting students' development of more growth mindsets in mathematics. Is it critical for a teacher to hold a growth mindset towards himself/herself and mathematics in order to support students' growth mindsets? I address this question in the following paragraphs.

Like students, a teacher's mindset has a significant influence on his/her own learning. Teachers who hold more growth mindsets about teaching value learning over their reputation. As an illustration, Dweck (2014) found teachers with a growth mindset engaged in more professional development, observed other teachers, and they specifically asked for feedback. Further, Dweck found that these same teachers did not care about being viewed as perfect. Instead, they sought to continually improve, so they confront problems in their teaching practices, persevered through struggles, and strived to reach all their students by learning from their students (Dweck, 2014). These behaviors are reflective of teachers with a growth mindset.

Some studies indicate teachers' mindsets transfer to their practices and influence students' mindsets (Rattan, Good, & Dweck, 2012; Seaton, 2018). Dweck noted, "teachers with more fixed mindsets engage in more ability grouping and create more self-fulfilling prophecies when it comes to student achievement (Dweck, 2015, p.11). Grouping students by ability, communicates lower expectations for lower performing students and higher expectations for higher performing students (Haimovitz & Dweck, 2017), which supports opportunities to develop more fixed mindsets in classrooms. However, others suggest teachers who have a

growth mindset do not necessarily pass it to their students (Haimovitz & Dweck, 2017). It was believed teacher mindsets would influence their students' mindsets through their behaviors or teaching practices. Some researchers (Haimovitz & Dweck, 2017; Schmidt, Shumow, & Kackar-Cam, 2015) posit that beliefs about motivation instead of abilities may have more influence on teachers' practices than their mindsets. Another consideration is that teachers' self-reported mindsets did not predict their actual mindsets or their students' perceptions of their mindsets (Haimovitz & Dweck, 2017). Though, when teachers reported how they would respond to a struggling student through open-ended prompts, their responses were more aligned with their students' perceptions of the teachers' mindsets. This indicates a disconnect between teachers' self-assessment of their mindset and what kind of mindset is actually reflected through their teaching practices.

The teaching practices and experiences teachers provide students appear to have more influence on student mindsets than a teacher's own mindset. Haimovitz and Dweck (2017) found in their review of research that teachers who used performance-oriented practices in class seemed to have students with more fixed mindsets. On the other hand, teachers who supported the development of growth mindsets engaged in the following teaching practices: teaching for understanding, encouraging students to explain their thinking, giving feedback that deepened students' understanding, and using process praise (Haimovitz & Dweck, 2017). These teachers also communicated explicitly that struggle and learning from mistakes is an important part of the learning process. Further, they allowed students to revise their work to demonstrate their deeper understanding. Based on the study conducted by Haimovitz & Dweck, these teaching practices foster a growth mindset culture for students to learn.

Teaching practices have the potential to create classroom opportunities for students to develop more growth mindsets. Therefore, it would be important for teacher education programs and professional development for teachers to encourage teaching practices that promote student growth mindsets (Haimovitz & Dweck, 2017). Anderson, Boaler, and Diekmann (2018) found an online course designed for teachers to learn about mindsets contributed to significant positive improvements in teacher instructional practices and student beliefs about their abilities in mathematics. In this study, participants learned about what Anderson et al. (2018) refer to as the Mathematical Mindsets Approach that combines learning about mindsets, the new brain science, myths about math, and effective mathematics teaching strategies. Promoting growth mindset beliefs in mathematics can help confront the obstacles and misconceptions involved in learning mathematics (Boaler, 2016). Furthermore, a growth mindset will better serve students overall in the 21st century as they face new challenges and situations in which they are constantly a learner.

Preparing 21st Century Pre-Service Teachers

Today's learners need more than an education focused on mastery of content and acquisition of facts to be prepared for this rapidly changing world. The Partnership for 21st Century Learning (P21) brought together educators, business, community and government leaders to discuss the knowledge and skills needed to succeed in the 21st century. This framework identified learning and innovation skills which are increasingly recognized for better preparing students for complex jobs in the 21st century workforce (Partnership for 21st Century Learning, 2011). Learning and innovation skills include the four Cs: creativity, critical thinking, communication and collaboration. In addition, this framework identified the ability to utilize technological tools as an important skill for the 21st century. Integrating technology has multiple benefits for learning, which will be presented next.

Benefits of Technology for Learning

Meaningful technology integration supports 21st century teaching and learning (Tondeur et al., 2017) and develops 21st century skills such as the four Cs (Partnership for 21st Century Learning, 2007; President's Panel on Educational Technology, 1997). The 21st century learning framework is not the first to advocate for meaningful integration of technology. Others have advocated for high-level (Ertmer, 1999), student-centered (President's Panel of Educational Technology, 1997) or constructivist (H. J. Becker & Riel, 1999) uses of technology. All these terms can be used interchangeably (Ertmer et al., 2016) and refer to meaningful learning experiences enhanced by technology. The benefits of technology are detailed in this section including how it develops 21st century skills and provides access to information, personalized learning, enhanced feedback and assessment, and increased motivation and engagement.

Develops 21st century skills. Technology can provide opportunities to develop the 21st century skills of collaboration, communication, creativity, and problem-solving (Falloon, 2015; Herro, Kiger, & Owens, 2013; McKnight et al., 2016). Many technological tools are designed for collaboration and communication such as collaborative documents and video conferencing, as well as virtual classrooms, discussion boards, blogs (Falloon, 2015; McKnight et al., 2016) and text messaging (Kolb, 2011). These tools allow students to communicate ideas and make comments thereby promoting collaboration with peers by sharing and receiving feedback. Furthermore, face-to-face collaboration between students while using mobile devices supports high levels of conversations and content creation (Kearney, Burden, & Rai, 2015). Students working collaboratively with laptops can prompt discussion by comparing information on the screen, helping each other problem-solve, asking and answering each other's questions and sharing ideas (Fonkert, 2010). Furthermore, interactive whiteboards, document cameras, and

computers can facilitate collaboration and communication (D. Wolf, Lindeman, Wolf, & Dunnerstick, 2011) by allowing students to present and share assignments and projects. For example, one teacher had students use mobile devices while working in teams to gather and analyze data, create simulations and then make presentations (Bray & Tangney, 2016). This use of technology enables learning environments to become more socially interactive making rich connection between people (Kearney, Schuck, Burden, & Aubusson, 2012) where students are collaborating and learning from each other. Technological tools can create a collaborative learning environment and provide learning experiences that are impossible without them.

Technology can also promote the development of creativity skills. For example, cameras in devices and various mobile apps can allow students to create screencasts or recordings of their work (Ingram, Williamson-Leadley, & Pratt, 2016). Students can then create artifacts such as storyboards (Kolb, 2011) and video projects which requires problem solving, critical thinking and application of content knowledge (Morgan, 2013). Soto and Ambrose (2016) investigated the use of creating screencasts in math classrooms and found benefits from capturing student explanations when problem solving because they could better assess their understanding. Bray and Tangney (2016) also had students create projects through problem-based tasks where they created games and group presentations of projectile motion simulations. Another example of students' creativity is computer programming of animations when learning transformations and translations of figures (Fonkert, 2010). These types of projects allow students to develop creativity skills and feel a sense of accomplishment when they see their final products.

Access to information. Mobile technologies provide students and teachers with more access to information (Thomas & O'bannon, 2013) in classrooms, which provides many opportunities that would not be possible without technology. Students have access to the internet

where they can do research and gather data (Kolb, 2011; Roschelle, 2003). With the portability of devices today, teachers and students have access to information anywhere and anytime (Kearney et al., 2012; Thomas, O'Bannon, & Bolton, 2013) allowing more learning to be extended beyond the classroom. It is reported that 95% of teens use the internet, 78% have cell phones, and 80% have a desktop or laptop computer (Rainie, 2014). This prevalent access to technology provides teachers and students access to information and online resources that can personalize learning, which will be described next.

Personalized Learning. Using technology in classrooms allow teachers to personalize instruction based on students' learning needs and interests (Harper & Milman, 2016). One study (Hutchison, Beschoner, & Schmidt-Crawford, 2012) used iPads to personalize learning by aligning content to students' learning goals. Other uses of technology to personalize instruction include supplementing previous skills learned by allowing students to go back and practice (Milman, Carlson-Bancroft, & Vanden Boogart, 2014), differentiating for foreign language learning (Steele, 2012), and modifying digital resources to meet the individual learning styles of students (Bray & Tangney, 2016; Fraser & Garofalo, 2015; Ingram et al., 2016; D. Wolf et al., 2011). Devices can be customized by downloading applications for specific needs or interests of individual students (Cumming, 2013); thus, providing more personalized lessons (Mouza & Barrett-Greenly, 2015). Teachers reported "all students could work on the same activity while accessing it at an individualized level that fits their own particular needs, interests, and skills" (McKnight et al., 2016, p. 202). Technology provides many options to individualize learning based on students' needs and interests thereby providing a more personalized and meaningful learning experience (Gonzalez, Sharma, & Galleta, 2012).

Enhances assessment and feedback. Many tools are available for teachers to quickly assess students' understanding through online quizzes and classroom response systems (Roschelle, 2003) providing more efficient and effective assessment and feedback. Screencasts and recordings through mobile apps like Show and Tell afford the opportunity to capture the process of solving problems to better assess students' understanding (Soto & Ambrose, 2016). Recordings of student work provide formative assessments of learning during the process of solving problems as well as their ability to make connections between concepts. Others also discussed how teachers can more easily obtain formative assessments with technology (Fraser & Garofalo, 2015; Muir & Geiger, 2016; Roschelle, 2003). Fraser and Fraser and Garofalo (2015) described one teacher's use of formative assessment where he displayed tasks on an interactive whiteboard and students selected the answer on their *ActiVote* student response remote. The teacher could instantly know when all students had completed the task, see how many responses were correct and incorrect, and anonymously display this to the class. This provided instantaneous feedback to the teacher and students on what students did and did not understand.

The interactivity of technology allows teachers the benefit to provide greater and ongoing feedback (Markett, Sanchez, Weber, & Tangney, 2006; McKnight et al., 2016). Teachers can provide feedback through text messaging (Kolb, 2011) and other technological tools. In addition, students can receive more feedback through the anonymity nature many tools have (Roschelle, 2003) like online survey tools. Students can instantly see where they and peers share misunderstandings without the embarrassment of others knowing they answered a question incorrectly. In one study (Falloon, 2015), the use of Google Docs allowed the teacher to provide feedback to students during the process of them working on assignments. This real-time feedback allowed students to make adjustments and improve their work before the assignment

was due. Without technology, teachers typically give feedback after students have completed and submitted the assignment. Technology affords the ability for students to receive feedback during the process of completing assignments, providing more effective and productive learning experiences. Thus, access to a variety of technological tools enables teachers to more effectively assess students and provide immediate feedback.

Increases engagement and motivation. Students' engagement and motivation has the potential to increase with effective integration of technology. Technology integration can facilitate student-centered instruction where students are more actively engaged and motivated (Harper & Milman, 2016). Students revealed increased motivation when using technology to actively engage in meaningful problems. For example, one activity involved a Barbie bungee where students used smartphones and video analysis to obtain accurate measurements and create spreadsheets, tables, scatter plots, lines of best fit and linear functions (Bray & Tangney, 2016). Engagement and motivation are also enhanced through opportunities to be creative while using technology in classrooms. In one study (Grant et al., 2015), teachers reported that students were more engaged and motivated using technology because it allowed them to be more creative and show what they had accomplished. In another study (Mouza & Barrett-Greenly, 2015), students reported they enjoyed using production apps where they could be creative in different ways. Furthermore, students get excited and motivated to share their final products with the class (Bray & Tangney, 2016; Fonkert, 2010; Soto & Ambrose, 2016). Technology can provide enjoyable learning experiences with opportunities for students to be creative, pursue their interests, and share their products, which increases engagement and motivation.

21st Century Students

Students of the 21st century live in a world where technology is fully integrated into their everyday lives. These students are also known as digital natives or the net generation because they have been immersed in technology since birth (Hicks, 2011). Technology's ubiquitous presence has normalized it for 21st century students and created very different learners from in the past: "The saturation of technology in students' lives has produced an entirely different type of student, shaping the way they think, learn, and experience the world around them" (Hicks, 2011, p. 188). According to Prensky (2001a), students today have changed radically from past students because of the rapid dissemination of technology. With technology fully integrated into 21st century students' lives, they have different experiences from past students. Their different experiences include receiving information fast, multi-tasking, seeing graphics before text rather than vice versa, having random access to information, being networked, playing digital games and receiving instant gratification and frequent rewards (Prensky, 2001a). Due to their different experiences using technology, 21st century students' thinking and processing has changed compared to past students.

Moreover, neurobiology and social psychology provide further indication that 21st century students think differently. Research in neurobiology has revealed that the brain changes and constantly reorganizes itself based on inputs it receives, a phenomenon called neuroplasticity (Prensky, 2001b). Instead of the number of brain cells being fixed like previously thought, research shows that brain cells are constantly replenished. Physiological differences of the brain likely exist between students today and in the past due to different experiences causing areas of the brain to grow and develop more or less. Furthermore, social psychology provides strong evidence that one's experiences influence his/her thinking patterns. One example is how people

from different cultures think differently: “We now know that brains that undergo different developmental experiences develop differently, and that people who undergo different inputs from the culture that surrounds them think differently (Prensky, 2001b, p. 3). This indirect evidence from neurobiology and social psychology indicates 21st century students likely have physically different brains causing them to think and process differently. An example of students processing differently is how they develop “hypertext minds” where they leap around accessing information randomly based on their own preference creating more parallel, rather than sequential cognitive structures (Prensky, 2001b). In summary, 21st century students’ thinking has changed compared to students in the past based on their very different experiences using technology.

However, not everyone has agreed that 21st century students’ thinking is radically different, and instead Bennett and Maton (2010) claimed their experiences with technology are more varied. After researching students’ access and use of technology, findings suggested that students have varied levels of access and uses of technology and, thus, different opportunities. More frequent uses of technology involve communication and accessing information, and less student engagement in activities to create or play games suggesting that 21st century students’ experiences with technology are more diverse than homogeneous. Green and Hannon (2007) also found students use of technology varied and suggested the following technology user types: digital pioneers, creative producers, everyday communicators, and information gatherers. Students were also found to be a combination of these user types. These studies’ findings indicate that today’s students have diverse experiences with technology with many of these experiences occurring at home. These diverse experiences at home led Bennett and Maton (2010) to question how skills developed at home can be transferred to academic contexts. Their

point was “that everyday technology-based activities may not prepare students well for academic practices” (Bennett & Maton, 2010, p. 325) because academic uses of technology are different from everyday uses.

Despite whether or not 21st century students’ thinking is drastically different from students in the past, a common belief is they have shorter attention spans. Prensky (2001a) argues that attention spans of students today are not short which is evident in their ability to engage for long periods of time in activities outside of school. He described how students today are always doing something really engaging with a creative component (Prensky, 2005) such as playing video games, creating movies or downloading music playlists. One student reported: “On the Internet you can play games, you can check your mail, you can talk to your friends, you can buy things, and you can look up things you really like” (Prensky, 2005, p. 62). Outside of the classroom, students follow their interests and passions which is essential for engagement (Prensky, 2010). Engagement and motivation drive students to put in the effort necessary to learn well. Prensky’s (2010) interviews with almost a thousand students highlighted what they want in their education:

- They do not want to be lectured to.
- They want to be respected, to be trusted, and to have their opinions valued and count.
- They want to follow their own interests and passions
- They want to create, using the tools of their time.
- They want to work with their peers on group work and projects (and prevent slackers from getting a free ride).
- They want to make decisions and share control.

- They want to connect with their peers to express and share their opinions, in class and around the world.
- They want to cooperate and compete with each other.
- They want an education that is not just relevant, *but real* (p. 3)

Students today have short attention spans for traditional ways of teaching, and instead want to learn in an environment where they can pursue their interests and passions.

To reach 21st century students, teachers need to present content in different ways. These students have different past experiences and future job opportunities with different needs and, therefore, need to be taught in new ways. Prensky (2001a) referred to these new ways of teaching to reach 21st century students as “Digital Native” methodologies where teachers present content in a way that engage these students. For example, partnering pedagogy is one teaching approach to reach the needs of 21st century students. In this teaching approach, students predominantly use technology with the teacher coaching and guiding (Prensky, 2010). The teacher guides students learning through good questions, providing context and rigorous learning experiences. Another “Digital Native” methodology is GBL where digital games can be used to teach and engage 21st century students because they are familiar with playing games (Prensky, 2001b).

Game-Based Learning

Through playing video games and other entertaining games, many 21st century students have likely experienced the joy of completing challenges, as well as deep engagement that has motivated them to continue the game. Games, especially video games, are thought of as meaningless and a waste of time, especially in education (Prensky, 2005). However, educators might find some compelling characteristics to gaming that benefit and enhance learning

experiences. If educators use some of the elements commonly used in games, they may be able to reach 21st century students. This section describes the history of GBL, key GBL elements, and research of GBL in education.

History of GBL

Principles of GBL can be traced back two thousand years to Ancient Rome (Betrus & Botturi, 2010). Romans incorporated games in their culture and celebrations through sport competitions and gladiator fights. These concepts have moved through history to education with pedagogical approaches such as the Montessori Method from the early 1900s (Betrus & Botturi, 2010). More recently, GBL has evolved to include modern day technology. This section will focus on two influential educators of GBL. First, Quintilian, a Roman rhetorician from the first century AD who identified components of GBL in his multi-volume work on oratory will be presented. Then, how an innovative Italian educator named Maria Montessori in the early 19th century promoted similar approaches to teaching children will be discussed.

Quintilian: Ancient Rome. Ancient Roman life revolved around working and earning money for a living, but there were also a variety of leisure activities including games (Betrus & Botturi, 2010). Any activity that was not related to work was considered leisure activities such as swimming, athletics, and entertainment. The Latin word for “game” and “playing” is *ludus*, which was part of leisure activities in Ancient Rome. *Ludus* was also used for places people were trained for sports and games. Additionally, when public schools were founded, they were called “*ludus*”. Therefore, the same term was given to games and school as both were part of what the Romans considered leisure activities. Conversely, today studying and going to school is viewed as work rather than leisure (Betrus & Botturi, 2010). However, if we look at learning

and games from the perspective of Quintilian and the roots of the Roman Empire, games have the potential to enhance learning experiences.

Quintilian's work, *Institutes of Oratory*, included 12 volumes and is considered the "highest summary of Roman education" (Betrus & Botturi, 2010). He opened the first public rhetoric school around AD 70 that was funded by the state treasury. From his experiences as an educator, he wrote the school's method for the fundamental education of an orator. This was significant in Rome at the time because before any man could participate fully in civil life, he had to be an exceptional orator. In his work, Quintilian (1856/2006) promoted the relationship between amusement and learning:

For it will be necessary, above all things, to take care lest the child should conceive a dislike to the application which he cannot yet love and continue to dread the bitterness which he has once tasted, even beyond the years of infancy. Let his instruction be an amusement to him. (book 1, chapter 1, paragraph 20)

Quintilian valued the need to enjoy learning for students to develop motivation and a desire to learn in the future. Furthermore, Quintilian (1856/2006) described elements that motivate learning:

Let him be questioned and praised; let him never feel pleased that he does not know a thing; and sometimes, if he is unwilling to learn, let another be taught before him, of whom he may be envious. Let him strive for victory now and then, and generally suppose that he gains it; and let his powers be called forth by rewards such as that age prizes. (book 1 chapter 1, paragraph 2)

According to Betrus and Botturi (2010), these elements today are described as feedback (be praised/never feel pleased), competition (let another be taught before him/strive for victory), and

rewards. Additionally, one could infer Quintilian is also describing challenge, feeling successful, and learning socially.

Quintilian (1856/2006) also refers to the importance of games having structure: “There must, however, be bounds set to [play], lest the refusal of it beget an aversion to study, or too much indulgence in it a habit of idleness” (book 1, chapter, 3, paragraph 10). Children learn through play, but for games to create purposeful learning, structure is necessary. Goals, rules, and feedback are game elements that contribute to the overall structure of the game to create environments where students are learning through play with purposeful learning objectives.

Maria Montessori: Early 1900s. The concept of learning through play was also promoted by Maria Montessori in her book *The Montessori Method* (Montessori, 1964). This method was first implemented in the Children’s House in Rome and then spread throughout Europe, North America, and worldwide. Maria Montessori has continued to be influential today with at least 4,000 certified Montessori schools in the United states and 7,000 worldwide (Montessori.edu, 2018). Additionally, other schools have adopted pedagogical approaches based on Montessori’s methodology.

The main goal of the Montessori Method is to nurture children’s natural desire to gain knowledge and learn from curiosity. Some elements of this method include self-paced and self-directed learning, hands-on and sensory education to foster experimentation, community of learners, and active learning in an ordered way (Betrus & Botturi, 2010). When children are given choice of activities to pursue, they become motivated from the feeling of success or power (Montessori, 1964). According to Maria Montessori, children learn through play. However, to ensure purposeful learning that fuels children’s desire to gain knowledge, they need a structured environment (Betrus & Botturi, 2010). Playing through a structured environment is very similar

to the idea of playing games. Like Quintilian, Montessori obviously saw the value of games creating this environment because one of the primary tools used in Montessori schools is purposeful play through educational games with structure (Betrus & Botturi, 2010).

Another significant insight from Montessori is that teachers must choose game activities that convey meaningful information (Betrus & Botturi, 2010). Activities designed for children to gain meaningful information as they learn through play or games sustain their engagement and motivation to continue. For example, Montessori observed students become more engaged by the gain of knowledge than by an external motivation (Montessori, 1964). During her observations, children played a card game to help them learn to read. Each card had a word of a toy item for students to silently read and then identify. If children correctly identified the toy, they could play with it as long as they wanted. The fascinating discovery was that children did not care to play with the toys. They preferred to continue drawing cards one after the other to identify the items (Montessori, 1964). Knowledge and accomplishment was the reward that motivated the children, instead of the external reward of playing with toys. Dignan (2011) also emphasized the importance that “the core experience of an activity matters, and a veneer of gameplay isn’t going to change that” (p.3). Thus, the activities and content must be meaningful and allow children to feel successful. Students’ engagement will be sustained through the meaningful and rewarding learning experiences.

Key GBL Elements

A game is defined as “an immersive, voluntary and enjoyable activity in which a player pursues a challenging goal based on the game rules” and “provides a safe environment for taking chances and the opportunity to develop the knowledge and refine the skills required to succeed” (Kinzie & Joseph, 2008, p. 644). Prensky (2001) proposed “digital game-based learning” as the

use of computers in delivering educational games. GBL involves learning a skill or a concept through a game. The key elements of GBL is what enhances learning experiences. The history of GBL revealed multiple game elements. Quintilian identified feedback, competition, rewards, and structure as key elements to GBL (Betrus & Botturi, 2010). Montessori also contributed structure, as well as active learning and autonomy as other elements. GBL also comprises challenging activities and experiences of success and enjoyment (Dignan, 2011). Therefore, this section will discuss the following GBL elements: challenging core activities, autonomy, and structure that comprises goals, feedback, and rewards. After presenting each of the elements, there will be a follow up discussion on how these elements influence motivation and engagement.

The core activities are the most vital element of GBL. They must provide students appropriate challenges and the ability to successfully complete the activities (Dignan, 2011). According to Dignan (2011), games “provide us with what we crave: a set of escalating challenges, feedback on our progress, and the thrill of victory” (p. 8). The feeling of success motivates students to want to continue to the next challenge sustaining their engagement. Csikszentmihalyi (2008) described the level of appropriate challenge where a balance is maintained between boredom and anxiety creates the state of flow, a state of deep engagement. Furthermore, to stay in the state of flow, each challenge must slightly increase in difficulty keeping with the rate of change of one’s skills. According to Dignan (2011), “flow activities induce a state of mind classified by enjoyment, loss of time perception, and a suspension of self” (p.7). Thus, games with appropriate challenging activities can lead to the state of flow resulting in deep engagement.

Another GBL element is autonomy, which was included in Montessori's method that emphasized self-paced and self-initiated learning, as well as free activity during learning (Montessori, 1964). The Montessori method is grounded on the notion that children are self-directed learners (Dignan, 2011). Providing choice allows students to direct their learning and pursue their interests as well as complete challenges at their appropriate ability and comfort level. As a result, autonomy to make choices motivates students from the empowerment and ownership they have over their learning.

The final key element of GBL is structure, which is the design of the game to ensure successful learning experiences. The structure in a game is what distinguishes a purposeful educational game from natural play: "We speak, it is true, of games in education, but it must be made clear that we understand by this term a free activity, ordered to a definite end; not disorderly noise, which distracts attention" (Montessori, 1964, p. 181). The structure of games needs clear goals, rules, rewards, and feedback to reach learning objectives. These elements maintain productive game play for purposeful learning to take place.

Learning experiences that comprise the GBL elements I have described increase motivation and engagement. The basis for learning through GBL is to hold our attention and create enjoyment in our mind (Dignan, 2011). According to Dignan (2011), "Games are engagement engines. To design a game is to take something – some basic enjoyable and/or satisfying interaction – and carefully apply rules to help players maximize the enjoyment and/or satisfaction they have with the interaction" (p. 3). Furthermore, students are internally motivated with GBL. Like in the card reading example observed by Montessori, students were motivated by learning rather than playing with the toys. The inclusion of rewards has been referred to as an element (Betrus & Botturi, 2010) of GBL which can include points or badges, but the internally

motivating rewards are the successful experiences of mastering challenges and gaining knowledge. In summary, GBL should include challenging activities, autonomy, and structure to meet purposeful learning goals that provide rewarding and engaging experiences. Today there are more opportunities to incorporate these GBL elements in classrooms using technology.

Benefits of GBL

Review of the literature revealed that GBL has positive effects in classrooms with increased engagement and motivation (Hays, 2005; Ke & Abras, 2013; Marino et al., 2014; Sáez-López et al., 2015) and student achievement (Ke & Abras, 2013; Meluso et al., 2012; Spires, Rowe, Mott, & Lester, 2011). However, the findings on student achievement were mixed with some studies finding positive effects on achievement (Ke & Abras, 2013; Meluso et al., 2012; Spires et al., 2011) and others reporting no significant effect from learning through games (Carr, 2012; Marino et al., 2014; Sáez-López et al., 2015). In addition, other findings included collaboration (Ke & Abras, 2013) and self-efficacy (Meluso et al., 2012). This section will further elaborate on these findings of GBL in education beginning with motivation and engagement, followed by student achievement, collaboration, and self-efficacy. Finally, overall conclusions of GBL will be discussed.

Motivation and Engagement. Increased motivation and engagement were reported in multiple studies with none of the studies concluding that GBL decreased or had no effect on motivation and engagement. Ke and Abras (2013) observed students' eyes remained on the screen and their postures seldom changed revealing the games grabbed students' attention. Some students were so immersed in the games they did not voluntarily stop playing even when the game session was over. Conclusions from this study indicated that the use of instant reward and feedback, as well as challenging, open-ended tasks contributed to sustaining engagement. The

importance of experiencing success was also evident from one game that caused frustration and less engagement for some students because it was too difficult. The use of GBL in classrooms, including those with students who have special needs or learning disabilities, revealed to have a positive effect on engagement and motivation (Ke & Abras, 2013; Marino et al., 2014). For example, one student commented, “That [one of the computer games] was my favorite...It was cool to see how genetics actually happened in a plant shop” (Marino et al., 2014, p. 94). Another student was so engaged and motivated that he continued to play the game at home with his father. In a study (Sáez-López et al., 2015) investigating the effects of MinecraftEdu, overall positive attitudes were reported from parents, teachers, and students regarding the use of MinecraftEdu for educational purposes. Moreover, this study and others found the use of GBL to be enjoyable (Ke & Abras, 2013; Marino et al., 2014; Sáez-López et al., 2015). These findings reveal digital games can create enjoyable learning experiences and support students’ engagement and motivation.

Student Achievement. Ke and Abras (2013), Meluso et al. (2012), and Spires et al. (2011) found positive effects on learning achievement, whereas multiple studies found no significant effect with learning through games (Carr, 2012; Marino et al., 2014; Sáez-López et al., 2015). However, Ke and Abras (2013) observed times when the games were not contributing to intended learning objectives. In addition, even though Sáez-López et al. (2015) found no significant effect, the group that used games had a higher mean than the control group. These mixed findings on student achievement make conclusions of effects on learning unclear. It is noteworthy to mention that Sáez-López et al. (2015) found the majority of participants surveyed thought MinecraftEdu enhanced creativity and developed discovery. The development of other

skills, particularly 21st century skills, are worthy of consideration when evaluating the effectiveness of implementing GBL.

Another important consideration for effects on student learning is the instrument used to measure learning. Typically, these instruments are tests that include acquisition of facts rather than assessments of higher order thinking such as critical thinking and other 21st century skills (Meluso et al., 2012). Marino et al. (2014) recognized this especially when the control group received more traditional instruction with review sessions teaching to the test and the experimental group practiced and applied skills through games. With the review sessions teaching to the test, it is likely they were more effective in increasing test performance even though students reported game play allowed them to gain more understanding of concepts (Marino et al., 2014). To adequately evaluate the effects GBL has on student learning, alternative assessments need to be considered that include the evaluation of 21st century skills and how to apply learning in more complex ways.

Collaboration. Some studies reported opportunities for collaboration through GBL in classrooms. One study (Sáez-López et al., 2015) included collaboration through enriching interactions between students and teachers using a virtual learning environment. This platform gave the opportunity for rich discussion of topics and connections about student creations and discovery during game play. Playing games has initiated conversations between students with increased verbal expressions, questions and comments, especially when tasks were more difficult (Ke & Abras, 2013) indicating these collaborative interactions were to receive help with learning content in the game, resulting in students learning from each other (Mikropoulos & Natsis, 2011). Students specifically suggested improving games by adding more collaboration (Marino

et al., 2014) and requesting to sit and play with another student (Ke & Abras, 2013) indicating students find collaboration valuable during game play.

Self-Efficacy. Self-efficacy was another finding discussed in the use of GBL in classrooms. Meluso et al. (2012) found self-efficacy to increase after students played an online computer game for only four days. This study used a self-efficacy survey designed to better understand what areas cause students difficulty learning science. The game is comprised of immersive, three-dimensional learning environments with characters situated within a story world. Students can interact with characters, learn about science content, and apply learning through problem solving. In a review of research, Mikropoulos and Natsis (2011) found many studies reported academic self-efficacy impacts student choice of learning activities and the amount of effort they attribute to learning both in the classroom and while playing educational video games. For example, a study with students gathering data in a virtual game environment revealed students with higher self-efficacy demonstrated better data gathering behaviors initially (Ketelhut, 2007). Self-efficacy was measured from student behavior data gathered as they played the virtual game, which were analyzed using individual growth modeling. However, by the end of the game, self-efficacy no longer correlated with data gathering behaviors suggesting virtual games can serve as a catalyst for change in students' self-efficacy and learning. These studies reveal the potential impact GBL can have on students' self-efficacy.

In conclusion, the literature revealed GBL has potential benefits for students' learning experiences. Specifically, GBL has shown to increase motivation, engagement, and self-efficacy, as well as create an enjoyable experience of learning. Students particularly found collaborative games to be valuable. Findings also indicate a potential to increase learning. As mentioned earlier, alternative assessments need to be considered when evaluating the effects on

student learning. The literature revealed students are more engaged and motivated with challenging, open-ended tasks while playing games. Furthermore, learning depends on the design of the game. Incorporating what has worked in other classrooms to provide better learning experiences should be considered when implementing GBL in classrooms including challenging, open-ended tasks with appropriate structure to allow for intended learning. These elements can be added to classroom instruction through educational games or in non-game contexts.

Gamification

Gamification is a newer concept of GBL that incorporates game elements such as points, levels, and challenges in non-game contexts (Simões et al., 2012). The difference in GBL and gamification is that GBL usually refers to actual games created for educational benefit (Glover, 2013) and is commonly associated with video games (Simões et al., 2012), whereas gamification adds game-like elements to the learning process (Deterding, 2012). Although gamification is considered new, its concept has been used for a long time to engage people from Weight Watcher points to gold stars in elementary school and has the potential to be beneficial throughout education: “Educational gamification is a method that could encourage some of the same sense of pride and achievement in learners of all ages” (Glover, 2013, p. 2000). The purpose of gamification is to take advantage of the game elements that increase student engagement and motivation. A teacher may gamify an activity or instruction by including game elements such as turning learning tasks into challenges or quests that have varied point values where students can choose challenges to complete. Gamification is “most effective as a pedagogical tool where it forms part of a well-planned strategy to encourage research, inspire

creativity, teach basic principles, or hone problem solving skills” (Educause, 2011, p. 1). With effective implementation, gamification can be beneficial in the classroom.

Gamification presents coursework as a challenge rather than a chore which fosters student engagement and increases student retention (Educause, 2011). This approach gives students autonomy to explore content motivating them to participate more deeply and even change their self-concept as learners (Lee & Hammer, 2011) as well as try a wider range of tasks that they might not otherwise do (Glover, 2013). Furthermore, gamification provides a low threat environment where students feel more comfortable to take chances allowing them to make and learn from mistakes (Kingsley & Grabner-Hagen, 2015; Lee & Hammer, 2011). Kingsley and Grabner-Hagen (2015) found gamification in a middle school science classroom that integrated content with 21st century skills facilitated the development of 21st century skills of creativity, critical thinking, collaboration, and communication. The authors concluded that “gamification offers the unique opportunity to combine content area instruction, literacy, and 21st century learning skills in a highly engaging learning environment” (Kingsley & Grabner-Hagen, 2015, p. 51). Additionally, gamification has led to increased student enjoyment (Kingsley & Grabner-Hagen, 2015), academic achievement (de-Marcos, Domínguez, Saenz-de-Navarrete, & Pagés, 2014), interest, motivation, and engagement (Bellotti et al., 2013). With these benefits, gamification has the potential to enhance students’ educational experiences.

However, gamification has its challenges and criticisms. Gamification can feel more complex to students or reveal their difficulties to the rest of the class while trying to understand content (Educause, 2011). It can be challenging for teachers to employ and result in feelings of disappointment when application is not successful. Gamification has been criticized for being distracting and time-wasting, as well as trivializing content. Moreover, extrinsic recognition and

rewards for completing activities can demotivate students and create competition that is not helpful to some students (Glover, 2013). Hanus and Fox (2015) used extrinsic recognition to gamify instruction by giving badges for completed tasks and using a leaderboard to track progress. They found the gamified group of students had lower intrinsic motivation, class satisfaction scores, learner empowerment, and grades, as well as socially compared themselves more. These findings along with the other challenges and criticisms of gamification revealed the importance of the design of gamification learning activities.

In conclusion, the design of how gamification is implemented in classrooms is crucial. In other words, gamification can be done well and done poorly (Deterding, 2012). First, gamification can do very little to make low quality materials and activities engaging or meaningful; therefore, “it is essential that the pedagogy and level of the activity are appropriate before adding extra layers of complexity through gamification” (Glover, 2013, p. 2004). Next, thoughtful consideration of the context and students should be used when deciding which game elements to use and how to use them. When gamification is “employed thoughtfully and effectively, game elements can engage and motivate students, encourage exploration, foster independent effort, and generate unexpected solutions” (Educause, 2011, p. 2). Given the potential to enhance learning experiences, further research is needed to better understand what aspects of gamification are most beneficial to use in educational gamification.

Summary

Foundational ideas of situated learning theory and the literature review informed this study’s examination of PSTs’ learning about mindsets with an online gamification tool. First, the importance of the whole person and the social world within they live was considered, including the context of this rapidly changing world and today’s learners immersed in

technology. The participants in this study are considered 21st century students and most have experienced this technology immersion their whole lives. Many of these 21st century students have the internet at the tip of their fingers where they can get immediate answers to their questions, play online games, listen to any song they want, and contact a friend anytime. Gone are the days of searching for answers in encyclopedias, waiting for your favorite song on the radio or waiting until you get home to call someone. Technology has led to different patterns of communication and interactions between people; thus, it is highly relevant to how we learn, especially for 21st century students who have never known a time without technology.

Furthermore, foundational ideas of situated learning indicate learning should take place with authentic tasks, as well as in social settings with opportunities to extend capabilities and learn with other people, tools and resources (Putnam & Borko, 2000). These concepts align with the learning opportunities that 21st century students want with opportunities to work with peers, use tools of their time, and have a real and relevant education (Prensky, 2010). In addition, they want ownership and to share control in what they learn. Given these points, an online gamification tool was used to teach PSTs about mindsets that incorporated autonomy for PSTs to choose from authentic tasks. These tasks are similar to the work of in-service teachers such as planning learning activities. The online gamification tool incorporated opportunities to work collaboratively and use critical thinking, creativity, and communication skills, all of which have been identified as important skills in the 21st century workforce (Partnership for 21st Century Learning, 2007).

In closing, the greater access to and benefits of technology make online instruction a promising approach for teacher learning. However, it is important to understand what is and is not effective for teacher learning situated in online environments. For these reasons, PSTs'

experiences were examined after using an online gamification tool to understand its influences and what aspects of the tool contributed to their learning of mindsets, which can inform future implementations of online instructional tools.

CHAPTER 3

METHODOLOGY

This study draws on a situated perspective to examine aspects that contributed to PSTs' learning about mathematical mindsets through the use of an online gamification tool. Of interest are PSTs' understandings of mindsets and practices that support growth mindsets in addition to aspects of the learning situation they perceive contributed to their understandings. With this intention, I applied a process of coding methods that drew heavily on suggestions from Saldaña (2013) and Charmaz (2000) to analyze PSTs' experiences using this study's online gamification tool (OGT). This chapter provides descriptions of the study's methods and participants, the online gamification tool, and the procedures I followed for data collection and data analysis.

Coding allows a systematic approach to qualitative analysis where themes develop from data provided by participants (Saldaña, 2013). This inductive approach emphasizes construction of themes from data to represent participants' perceptions (Bluff, 2005). Although findings cannot be generalized to an entire population, the process of coding allows for the context and experiences to be extrapolated to other situations. The purpose of using coding methods is to study how "participants form meanings and actions, and get as close to the experience as possible" (Bhattacharya, 2017, p. 105), as well as uncover values, beliefs, and assumptions of the researcher and participants (Charmaz & Bryant, 2010). A code is a "word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldaña, 2013, p. 3). Through a process of hierarchical coding and constant comparison of data, codes and themes are identified. Initial coding involves coding participants' own words and identifying codes with similar meaning. These codes develop into broader categories or themes for more abstract meaning and to make connections between categories. A final phase called selective coding is the process that links all

categories and sub-categories to the core category, thus facilitating the development of theory (Corbin & Strauss, 2015). In essence, the process of coding aims to analyze data collected from participants to understand their perceptions and conceptualizations of their experiences (Bhattacharya, 2017). Charmaz (2000) advocates for the continuous study of data to develop codes and themes to explain the data. This approach can provide opportunities to gain insight into how PSTs' develop understanding of mathematical mindsets with an online gamification tool.

Given this study's goal to understand PSTs' learning situated in an online environment, coding is an appropriate method to uncover how PSTs learn using the OGT from their perspectives. The research questions involve PSTs' experiences using the OGT and how it influenced their understanding of mathematical mindsets and instructional practices that foster student growth mindsets. The pursuit of themes and patterns should be grounded in data provided by PSTs to better understand their conceptualizations and experiences learning about mathematical mindsets.

Participants

Participants were purposely selected from preservice secondary mathematics teachers who are part of an undergraduate program for mathematics majors to also obtain an education minor. Participants were recruited from PSTs enrolled in two teacher education courses taken prior to their Capstone semester that includes a semester-long student teaching experience. Table 3.1 provides a summary of the participants. For recruitment, I explained the study, as well as distributed and collected consent forms (Appendix A) to potential participants. This study included 10 participants who enrolled for these education courses Spring 2019 and consented to the study. I was the facilitator for this module on mindsets but was not the instructor of the

courses. These courses made sense for the context for this study because they focused on connections between content and pedagogy for effective teaching of mathematics, as well as classroom interactions between teachers and students. Understanding mindsets in mathematics and pedagogy that fosters a growth mindset can influence teaching practices such as the kinds of mathematical tasks and feedback provided to students (Anderson et al., 2018). Therefore, mindsets are highly relevant to effective teaching practices and the interactions between teachers and students. All participants used the online gamification tool to learn about mindsets in mathematics and completed interviews about their experiences using the tool.

Table 3.1. Summary of Participants

Name	Age	Gender	Education Program Status	Undergraduate Major	Future Plan
Maria	20-25	Female	Senior, Student teaching in Fall 2019	Mathematics	Teach high school math
Will	20-25	Male	Senior, Student teaching in Fall 2019	Mathematics	Pursue master's degree or teach high school math
Lily	20-25	Female	Junior, Student teaching in Fall 2019	Mathematics	Teach high school math
Austin	20-25	Male	Senior, Student teaching in Fall 2019	Mathematics	Pursue master's degree or teach high school math
Danielle	20-25	Female	Junior, Student teaching in Fall 2019	Mathematics	Teach high school math
Travis	35-50	Male	Senior, Student teaching in Fall 2019	Mathematics	Teach middle school math in a rural area
Keanna	20-25	Female	Senior, Student teaching in Fall 2019	Mathematics	Own a math tutoring business or teach high school math
Caitlyn	20-25	Female	Junior, Student teaching in Fall 2020	Mathematics	Teach middle school math
Yvette	20-25	Female	Sophomore, Student teaching Fall 2020 or 2021	Mathematics and Latin	Teach high school math and Latin
Brandon	20-25	Male	Junior, Student teaching in Fall 2020 or 2021	Mathematics	Teach high school math

Online Gamification Tool

This qualitative study used an online gamification tool I designed for PSTs to play a game called *Career Challenges* (<https://sites.google.com/vols.utk.edu/gamificationmindsetgame>) to develop their understanding of mathematical mindsets. In this game, PSTs visited people with different careers in the 21st century and completed “challenges” to earn points. The *Career Challenges* game was created using a Google Site with pages for each 21st century career (Appendix B). The game design was guided by the review of literature on situated learning, 21st century learning, and effective implementations of gamification. Understanding the participants are 21st century students pursuing teaching careers, the game incorporated authentic tasks similar to what teachers do while also including technology and 21st century skills as they are also necessary for the teaching profession. The activities were developed using the literature on mindsets and suggestions provided by Loucks-Horsley, Hewson, Love, and Stiles (1999, 2009) highlighted in *Framework for high quality Professional Development* with appropriately challenging activities that demonstrate new ways to teach and learn with a team approach and reflection. The game design will be further detailed in the following paragraphs.

The gamification activities (Appendix B) in the *Career Challenges* game integrate 21st century skills to develop critical thinking, creativity, communication and collaboration skills (the four Cs). For example, the *Professional Computer Hacker* provides activities to develop critical thinking skills, the *Game Designer* provides activities to develop creativity skills, the *Social Media Manager* provides activities to develop communication skills, and collaboration skills are integrated across the three career activities. These 21st century skills along with technological tools are integrated in this game to provide PSTs challenging and engaging learning opportunities. According to Prensky (2010), 21st century learners want to work with peers,

create products using tools of their time, share ideas, and have ownership in their learning, which align with the learning approach recommended by Partnership for 21st Century Learning (2007) with the incorporation of the four Cs and utilization of technological tools.

The *Career Challenges* game was designed to develop understanding of mathematical mindsets. Purposeful educational games have structures that ensure successful learning experiences, which distinguishes them from natural disorderly play (Betrus & Botturi, 2010). Therefore, the game includes a list of requirements and rules (Appendix B) to provide PSTs the information needed to play the game and complete the gamification activities. To reach the 100 points required to complete the game, PSTs were encouraged to select activities based on their interests and learning needs, rather than completing activities in a fixed order determined by me, the facilitator. An overview of the Mathematical Mindset OGT is presented in Figure 3.1 to illustrate the process of completing the game. First, PSTs completed the starting challenge to become familiar with the key topics related to mathematical mindsets: neuroplasticity, growth and fixed mindsets, and teaching practices that foster a growth mindset. In this challenge, they were introduced to these three topics, reviewed resources, and completed a reflection. Next, students had the freedom to visit professionals from different careers and select challenges to complete. These challenges' point values varied based on the expected effort and time required to complete the challenges. Lastly, students completed a final reflection. The gamification activities were designed to provide high quality professional learning with authentic learning tasks that have appropriate challenge level and support. In addition, the activities demonstrate new ways to teach and learn, incorporate collaboration, and provide time for reflection (Loucks-Horsley et al., 1999, 2009).

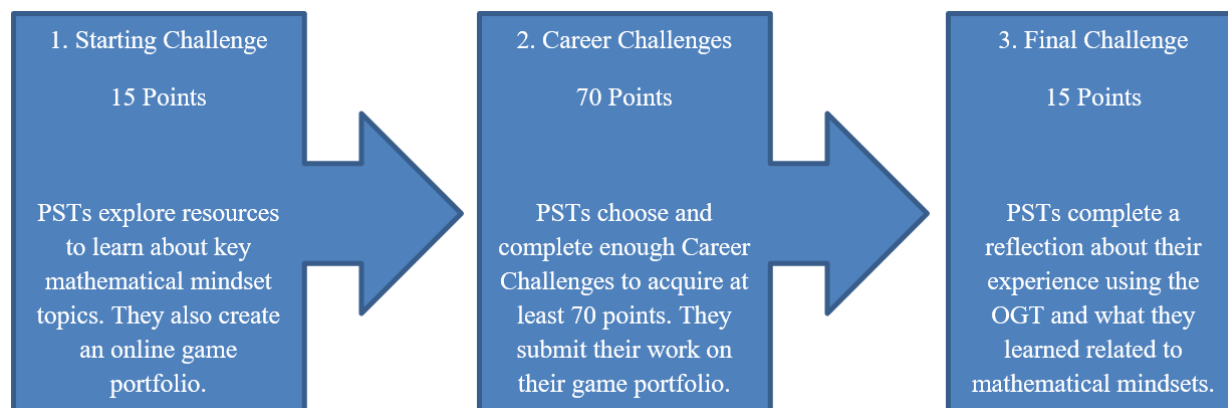


Figure 3.1. Overview of the Mathematical Mindset Online Gamification Tool

The OGT was implemented for a one week time span using a blended learning approach where the learning context involved both face-to-face and online learning. PSTs met in the same classroom that their education course regularly took place and completed activities facilitated using the Mathematical Mindsets OGT. PSTs engaged with the OGT for two class periods and had a full week to complete the game. On the first day, PSTs completed the preassessment and then I introduced them to the OGT. Next, they completed the Starting Challenge and began completing the Career Challenges. On the second day, PSTs had the full class period to work on the Career and Final Challenges. They were instructed to finish the OGT activities before their next class, which gave them a full week to complete the game. While completing activities in class, PSTs had the freedom to move around the room and work with their peers, as many of the OGT Challenges involved collaboration with a partner or small group. Student work involved completing reflections (Appendices C and E) and various activities (Appendices Q, R, S, T, and U) such as solving a math task or creating an online quiz game or video.

Data Collection Procedures

Data was collected to examine PSTs' understanding of mindsets and effective instructional practices as well as their experiences learning about mathematical mindsets with the online gamification tool. To examine PSTs' understandings and experiences, semi-structured

interviews were the primary data source. Data collection also included a pre- and post-assessment of mathematical mindsets and student work from activities completed using the online gamification tool. First, all student work data was collected. Next, interviews were conducted and transcribed. This order allowed student documents to be used and referred to in the interview for intentional inquiry into specific experiences and thoughts revealed in student work documents. This section provides details for each data source starting with all student work including documents from gamification activities and reflections.

Student Work

The activities that were completed during the module on mindsets included a pre-assessment (Appendix C), mathematical mindset inventory (Appendix D), reflections (Appendix E), and gamification activities to learn about mindsets. Merriam and Tisdell (2015) described personal documents being a good source for data about a person's attitudes, beliefs, and views of the world. Collecting reflections and student work from the online gamification tool is an appropriate method to provide insight into PSTs' understandings of mindsets in math and experiences using the online gamification tool. These methods allowed themes to be identified in data provided by the PSTs where they give their thoughts about mindsets and using the online tool. This data was collected using the OGT with Google Forms embedded for PSTs to submit the mindset inventory, reflections, and gamification activities.

Interviews

Semi-structured interviews were conducted to understand PSTs' experiences using the online gamification tool. This type of interview was chosen with the view that participants have a "complex stock of knowledge about the topic under study" (Flick, 2009). Semi-structured interviews allowed me to dig deeper into PSTs' experiences learning about mindsets and to

answer the research questions. Through a semi-structured interview, the participants were able to describe their experiences through the open format while keeping focus on the study's purpose with the interview questions.

Interviews were conducted individually on the university's campus in a private office. The participants were given as much time as they wanted to answer the questions from the interview guide (Appendix F) without interruption. The interview began with me introducing myself and the purpose of the study. Next, background information was asked about the participants followed by opening questions to get a description of the activities each PST completed in the online game. Then key questions were asked to obtain data on PSTs' understandings of mindsets and practices that foster growth mindsets and the aspects of the online tool they perceived as benefiting and limiting to their understanding of mindsets. Student work documents completed during the mindset module were used to provide a reference and help participants understand and answer interview questions. Lastly, closing questions were asked to learn PSTs' thoughts about effective mathematics instruction. My goal was for participants to do the majority of the talking and for me to only ask the interview questions with clarifying and follow up questions to the participants' responses to gain a deeper understanding. Each interview was audio recorded, transcribed, and stored on my private Google account provided by the university. I replaced all student identifiers with pseudonyms that linked individual student's data before conducting data analysis. The key was deleted immediately after replacing student identifiers with pseudonyms.

Data Analysis Procedures

The focus of the data analysis was to understand participants' experiences while using the online gamification tool to learn about mathematical mindsets. Data analysis consisted of a

process of coding cycles to examine the experiences of participants. Charmaz (2006) advocated to first develop theoretical categories and then saturate those categories using diagramming, sorting, and integrating information so analysis is grounded in data collected. This approach uses flexible guidelines; however, Charmaz suggests using certain approaches, which include coding, verifying understanding, documenting researcher's thoughts through memo writing, journaling, and annotating notes. She further detailed how coding can lead to thorough analysis of data through initial coding, focused coding, axial coding, and theoretical coding. These suggestions by Charmaz were used to analyze interview transcripts. In the following paragraphs, the steps taken to analyze data are described.

First, the pre-assessment and mathematical mindset inventory data were analyzed to gain understanding of participants' knowledge and beliefs related to mathematical mindsets before using the OGT. Analysis of these data sources was conducted to provide potential insight to how PSTs' previous knowledge and beliefs about math affected their experiences using the OGT. This understanding helped guide and focus the analysis of student work completed using the OGT and interview data.

The language used in data collected from interview transcripts were analyzed using coding cycles from CGT methods (Charmaz, 2000) to develop codes and themes from data provided by PSTs. My analysis of data was sensitive to words and phrases related to how PSTs talk about students and mathematics and their beliefs about how to support students as they learn mathematics. In addition, my analysis was sensitive to words and phrases related to aspects of the online tool and the learning context that PSTs perceived benefited or limited their understanding of mathematical mindsets. Student work documents were analyzed prior to

interview sessions as part of initial coding. Interview transcript data were analyzed as it was collected and used as the main data source to determine patterns and themes.

Coding Cycles

Coding procedures were chosen based on suggestions from Saldaña (2013) and Charmaz (2006) to develop patterns and themes grounded in data provided by PSTs about their experiences using the Mathematical Mindsets OGT. Multiple cycles of coding were conducted to determine themes similar to the streamlined scheme illustrated in Figure 3.2. Findings developed from this study's analysis are themes that developed from codes and categories determined from the data. However, it is important to note that this study's analysis does not claim to have discovered assertions or theory that is included in Saldaña's (2013) model below. Instead, the focus was on establishing themes to answer the research questions.

During the initial coding cycle, also known as open coding, I coded each PST's interview transcript separately and chronologically. In this first cycle, In Vivo codes and descriptive codes were identified to emphasize participants' actual words or to link comparable ideas from their comments. In Vivo codes "refer to a word or short phrase from the actual language in the qualitative data record" (Saldaña, 2013, p. 142) and is an appropriate method for studies aiming to "prioritize and honor the participant's voice" (Saldaña, 2013, p. 143). In Vivo coding seemed especially aligned with this study's goal of highlighting PSTs' perspectives and experiences. In addition, descriptive codes were used to tag comparable ideas, which is similar to the phenomena of placing "hashtags" in front of topics on social media in order to link and easily search information. Likewise, I tagged similar ideas expressed by PSTs using descriptive codes to more easily organize and compare codes.

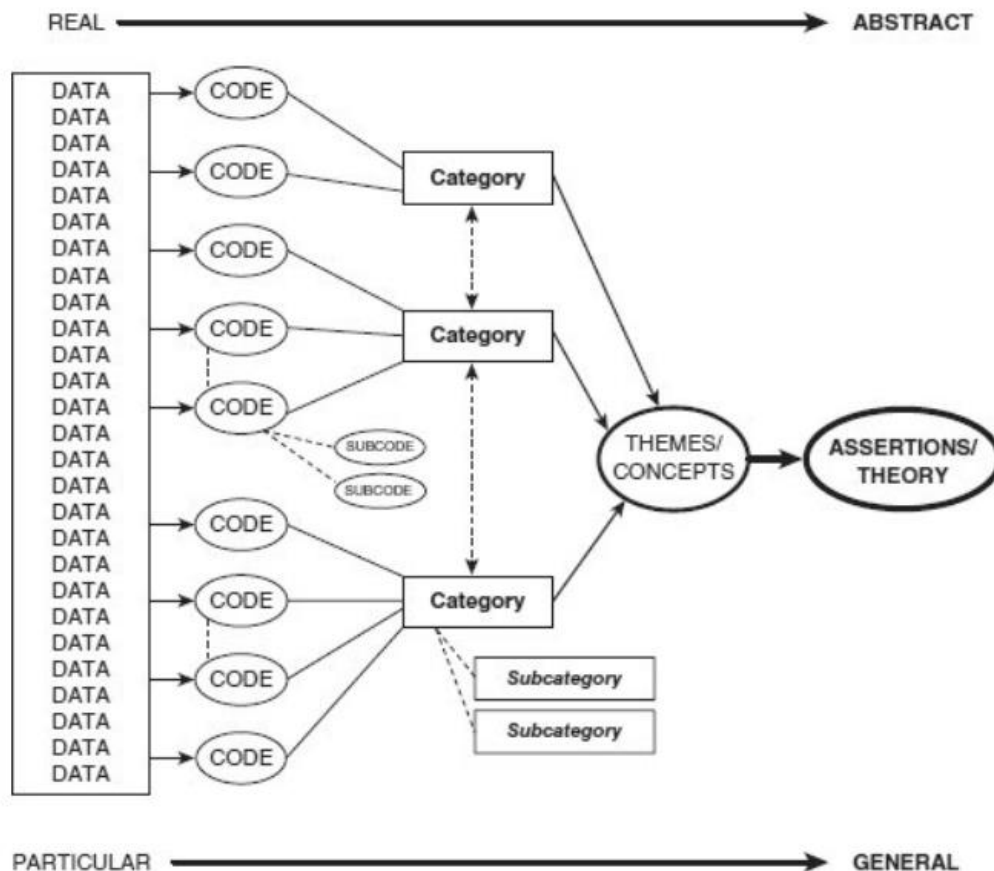


Figure 3.2. Saldaña's (2013) model for streamlining codes for qualitative inquiry

With the intention to increase credibility of my analysis, I cross checked codes for twenty percent of the interview transcript data with two other qualitative researchers for intercoder reliability (Guest, MacQueen, & Namey, 2012). Both researchers were in the third year of their program to obtain a Doctor of Philosophy in Education and had experience conducting research using qualitative methods. One researcher's specialization is in Mathematics Education and the other's is in Literacy Studies. The two researchers were given the same two interview transcripts to code independently. Afterwards, we all three met to compare and discuss our analysis. Our coding was at approximately 95% agreement initially, and after discussing all differences, we had 100% agreement.

During the second cycle of coding, I applied focused coding to determine most frequent and significant codes. Focused coding, derived from Charmaz's (2014) work, was used to search "for the most frequent or significant codes to develop the most salient categories" (Saldaña, 2013, p. 329). This second cycle of coding also included sorting and diagramming to assemble data in different ways and analyze it from multiple perspectives. I created tables for each participants' individual categories and tables to illustrate frequency of categories across participants.

In the final cycle of coding, I narrowed codes and categories using axial coding (Saldaña, 2013) to develop highly refined themes and to focus data in order to answer the study's research questions. Axial coding "aims to link categories with subcategories and asks how they are related" (Charmaz, 2014, p. 148). Grouping similar categories and codes of data allowed discerning of prominent categories and thus, themes were identified to answer each research question. Table 3.2 provides an example of themes identified with supporting quotes for the first research question. See Appendices G-P for all PSTs' data analysis tables that were created to organize their supporting quotes by each research question's themes. These tables can be referenced to view each PSTs' understandings and perceptions of benefiting and limiting aspects. To establish credibility, member checks were used (Creswell & Creswell, 2018) by sending all participants his/her data analysis table of qualitative findings to review. This form of member checking was conducted through email correspondence. Most participants responded confirming accuracy; however, not all participants responded creating an assumption of approval.

Lastly, I attempted to examine how the themes for each research question could be connected. Saldaña (2013) refers to this method as code weaving where individual components are explored to understand how they weave together. In other words, I sought to understand

Table 3.2. Example of Supporting Quotes for Understandings of Mathematical Mindsets

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Providing Challenging Learning Experiences and Tasks	But also, activities. I know activities are really important to instill growth mindsets, like the folding card activity that I did The struggle, the seeing other students struggle and then figuring it out. Because I mean, I think we had like two students in the classroom that day that just kind of tried it and then gave up and walked away. And then when they realized that, uh, me and another student were able to do it, they were like, what? You can do it? I was like, yeah, we just sat here 15 minutes until we figured it out. You know, you just got to sit here and figure it out sometimes. Um, and you just have to have that tenacity to keep going back and like trying to do it again. I think that's an important idea to instill in students through activities like that.
Sending Growth Mindset Messages	I think the video (My Favorite No) honestly was a big aha moment. Like, wow, you know, it's impactful. You can use language as a teacher. I'd hope that when I had a classroom, I'd be doing growth mindset language every day. You know, you can do this, you know, this is not, I have a problem in tutoring every day saying this is a really hard problem, um, but you can do it. I, I try not to start it with this is a really hard problem and just say, you know, you can do this one, instead of saying it's a hard one. And then so little things like that that I'm getting better at and what language to use is something that I need to practice. But that would be my biggest idea I guess, of how to use it in the classroom is just making sure that my language is consistent with a growth mindset
Valuing Mistakes	It was important that she said it was her favorite no, because saying that you know, that this is wrong has a different connotation than I like how this is wrong. But it seemed like the students were more willing to answer or talk about things because they were willing to get it wrong because getting it wrong is okay. And I think sometimes there's a lack of discussion in the math classroom for the reason of, you know, I'm just going to be wrong if I say something. So, I'm just, might not say anything versus I'll be wrong if I say something, but it'll be okay. You know, because it will, we'll grow after that. It won't just be you're wrong, next. So, I liked that aspect of it

“how the puzzle pieces fit together” (Saldaña, 2013, p. 346) to connect how the benefiting aspects perceived by PSTs seemed to influence the understandings they reflected of mathematical mindsets. In addition, I tried to understand connections between the aspects PSTs perceived as limiting and how they influenced PSTs’ understandings. These connections are illustrated in Table 4.3 at the end of chapter four. This final step of analysis allowed a better understanding of how the themes for each of the three research questions were interrelated.

Summary

Multiple phases of coding were used to explore PSTs’ experiences learning about mathematical mindsets with an OGT. Ten secondary mathematics education PSTs agreed to participate in this study. After completion of the module, student work was collected, and 30-minute interviews were conducted with participants individually. Interview transcriptions and student work were analyzed using coding methods drawn from Saldaña (2013) and Charmaz (2014). A summary of data sources analyzed for each research question is provided in Table 3.3. Using this qualitative research approach, this study’s analysis aimed to provide a better understanding of how PSTs learned about mathematical mindsets using an OGT and what aspects they perceived as benefiting and limiting to their understanding. Findings from the analysis are detailed in the next chapter.

Table 3.3. Summary of Data Source and Analysis per Research Question

Research Question	Data Source	Data Analysis
What are PSTs' understanding of mathematical mindsets and practices that foster students' growth mindsets?	Written reflections (Appendix D) <i>Questions pertaining to learning about mindsets, learning mathematics, teaching practices that foster a growth mindset, or ways to support students (Questions 4, 5, 6, and 7)</i> Interview data (Appendix E) <i>Questions pertaining to learning about mindsets, learning mathematics, teaching practices that foster a growth mindset, or ways to support students (Questions 9, 10, 11, and 12). Student work artifacts will be used for reference and guidance.</i>	Analyzed prior to interview sessions as part of initial coding Analyzed as collected
What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	Written reflections (Appendix D) <i>#2 Which challenge in the Career Challenges game did you find the most helpful to your understanding of mindsets?</i> <i>#3 Why was this the most helpful challenge for you?</i> Interview data (Appendix E) <i>Question 7: Did you find any aspects of the mindset especially helpful and please tell about it in as much detail as you can remember?</i> <i>Student work artifacts will be used for reference and guidance.</i>	Analyzed prior to interview sessions as part of initial coding Analyzed as collected
What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?	Interview data (Appendix E) <i>Question 8: Did you find any aspects of the mindset game unhelpful and please tell about it in as much detail as you can remember?</i> <i>Student work artifacts will be used for reference and guidance.</i>	Analyzed as collected

CHAPTER 4

ANALYSIS AND FINDINGS

The purpose of this study was to examine how PSTs' understandings of mindsets are influenced using an OGT. Specifically, this study considered the following research questions: 1) What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets? 2) What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets? 3) What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets? This chapter details the themes for each research question. Three themes were identified for the first research question: providing challenging learning experiences and tasks, sending growth mindset messages, and valuing mistakes. For the second research question on benefiting aspects, themes included experiential learning, social interactions, autonomy and engagement. Finally, for the third research question on limiting aspects, themes included time constraints, clarity of game structure, and development of some critical understandings.

Understandings of Mathematical Mindsets

Before providing details of the themes that answer the first research question regarding PSTs' understandings, it is important to discuss findings from the pre-assessment that guided and focused the analysis to answer this question. PSTs' responses on the pre-assessment indicated more than half of them had already developed some understanding of mindsets. Eight PSTs were able to describe characteristics of growth mindsets and/or fixed mindsets. Words and phrases used to describe a growth mindset were perseverance, hardworking, willingness, practice, believing they can always learn and improve; whereas, phrases used to describe a fixed mindset were "giving up" and "believing you are either smart or dumb." Thus, the majority of the PSTs'

used words such as these indicating they had developed some knowledge of mindsets. In addition, a couple of PSTs used a similar phrase to “you don’t get it yet” that is commonly used by Carol Dweck when she discusses the power of a growth mindset. These comments further indicate using this OGT was not their first experience learning about mindsets. This indication was verified in a few interviews with PSTs when they talked about being introduced to mindsets in a previous class; however, some could not recall the class.

Other understandings revealed in PSTs’ pre-assessment responses were the importance of having a growth mindset to learn mathematics and the prevalence of negative dispositions towards mathematics. Two PSTs made comments related to the first point about the importance of a growth mindset. For example, Brandon noted that a growth mindset toward math “eliminates the idea that math is too hard or not for particular students.” Lily described the importance of having a growth mindset in mathematics in order for students to be willing to learn math skills and be “invested in their mathematics education.” Regarding the second point, understandings of the negative dispositions many have towards mathematics, eight out of 10 PSTs expressed this idea during their interviews. For example, Danielle explained, “there are a lot of people that balk at the thought of math. They’re like, I’m not a math person. I hate math. I’m not good at it.” Travis added that parents also hold negative dispositions toward math: “I find that I have heard many times from, more so from the parents of younger people, I can’t do math. You know, I’ve never been able to do math.” Most PSTs expressed understanding of commonly held negative dispositions toward math. However, this understanding seems to have been previously developed before using the OGT on mathematical mindsets. This previous understanding is reflected in the following quotations.

Will: My friends today, I have one friend specifically who absolutely hated math in school and it's because she believed that she didn't, she couldn't get math. She wasn't a math person. She has the fixed mindset that if you're not good at math, you're not good at math. There's no learning math.

Lily: It's popular these days to really hate math and be like, I hate math so much, math is so hard. I'm so not a math person. I'm a young person. I'm on Twitter and all the time I see tweets of people if you like math, you're ugly.

Lily further explains her observations about dispositions towards math by including the role of the teacher:

When somebody tells me that they really hate math, I always, I go, my immediate thought is, they probably had a bad teacher that did not foster a growth mindset in you whatsoever. That's just unfair. That's robbing you of the whole experience with the whole subject matter that maybe could have led you to a totally different path. And I see things differently knowing about math.

Lily's comments also emphasize the consequences of negative dispositions toward mathematics. Thus, based on their interview comments, the majority of the PSTs appear to be aware of math's negative reputation.

The Mathematical Mindset OGT used in this study provided PSTs opportunities to reflect and connect how these negative beliefs and dispositions affect learning in math classrooms. A number of PSTs identified connections, as evidenced in the following comments:

Brandon: Math is a hard subject for a lot of people and if they don't get it, there's that stereotype, the stereotypical idea that either you get math or you don't get math and I don't believe in that at all.

Lily: I talked about growth mindsets in class before, but it's nice to be reminded about material and, I think this time around learning in the game, having to write those reflections and I did the Twitter thing, I saw a lot of different tweets and I was able to pick out ones that I resonated with the most. I could see myself feeling this way about my classroom, using the same in my classroom and I had a lot more of a practical how I would implement more thoughts that in my head rather than oh, wow growth mindset is really good. I'm going to do that. But this time was more how I'm going to do that.

These quotes and many others reflect that PSTs learned more about how to support student growth mindsets and what that looks like in math classrooms. Across interviews, PSTs described teaching practices that they believed support student growth mindsets. Three themes were identified for the first research question about PSTs' understandings of practices that foster growth mindsets: providing challenging learning experiences and tasks, sending growth mindset messages, and the valuing of mistakes. These themes will be detailed in the following paragraphs.

Providing Challenging Learning Experiences and Tasks

From the 10 PSTs who participated in this study, nine discussed challenging learning experiences and tasks that support student growth mindsets during their interviews. I decided to group experiences and tasks together as one theme because PSTs often referred to the learning experiences that challenging tasks provide to explain how such tasks support student growth mindsets. In this section, I first describe three learning experiences that PSTs understand as important to support student growth mindsets: struggle, perseverance, and success. Next, specific tasks completed by PSTs in the Mathematical Mindset OGT that they describe as

supporting a growth mindset will be presented. Finally, differences among PSTs' understandings will be detailed.

The first and most prevalent experience referred to during interviews with PSTs was the experience of struggle. This experience was brought up in more than half the interviews as an important experience that supports student growth mindsets. The following quotes capture the understanding PSTs conveyed regarding the importance for students to struggle and be challenged:

Lily: Something coming to you right away and struggling through it and then getting the answer, if that's two different people doing that, they both got to the answer. It doesn't mean you can't do it. And struggling means that you're being challenged, and you're being pushed to learn more information. If you're never struggling, then you're not really learning anything new. You're not being appropriately challenged. And so, struggling is important.

Danielle: Present the material in such a way that it challenges all students to appropriate levels. Cause if you're challenging only the low students and everyone else is just floating by, then you're not helping progress the students that are higher achieving. But vice versa, if you are only presenting the material at a challenging level for your higher achieving students, your low achieving students are going to be so lost that they're just going to fall further behind. So, making sure to present the information in such a way that every student is appropriately challenged.

Maria: It's very beneficial for them to learn something they struggle with.

Austin: Something challenging that it's going to stretch their brain and it's going to leave them open for information and leave them wanting answers so they're going to be more engaged.

Within discussing the importance of struggle, a small number of PSTs noted the importance of students seeing each other struggle. The following comments provide an illustration.

Caitlyn: I think it would be interesting. So, I did the Four 4s, and have students do it individually and they may be in groups or as a classroom, share out answers and have people explain how they got it. Also, just have that struggle if we need to. That way students can see how differently the answers are and also just see each other's struggle and that be okay.

Keanna: The struggle, the seeing other students struggle and then figuring it out. Because I think we had two students in the classroom that day that just tried it and then gave up and walked away. And then when they realized that me and another student were able to do it, they were like, what? You can do it? I was like, yeah, we just sat here 15 minutes until we figured it out. You just got to sit here and figure it out sometimes.

These comments reflect an understanding of how struggle and appropriate challenge are essential to learning experiences and tasks. Caitlyn and Keanna indicate they think struggle should be normalized in math classrooms so students can feel comfortable rather than embarrassed when they do not get something right away as Lily described in her comment above. Another example of struggle was discussed by Lily regarding the importance for students to explain their solutions and how that can be a struggling experience. She explained, "Struggle to not just figure out the problem, but prove why it's that way and you're struggling to find the solution and to explain the solution, which can be challenging but important." This comment highlights the importance for

students communicating their understanding, which can be challenging. As can be seen, many of the PSTs' shared comments that emphasized the importance of students experiencing challenge and struggle.

The second experience that PSTs described as fostering student growth mindsets is that of perseverance. PSTs used related terms such as effort and tenacity. Nonetheless, half the PSTs suggested the importance of students' efforts in persevering through challenges:

Maria: That Cut-a-Card game fosters a growth mindset, because of perseverance. The thinking outside the box to solve this problem eventually. Otherwise if you just struggled and then give up quickly, easily, then you just give up the opportunity to learn.

Will: The foldable inside the classroom, students who have that fixed mindset may try something once and then it didn't work, so they shut down or give up. But, with the foldable, having to try it multiple times until you get it, it's just that it teaches you that being wrong is okay. You learn from your mistakes. You try again until you eventually get it.

Keanna: You just have to have that tenacity to keep going back and trying to do it again. I think that's an important idea to instill in students through activities like that.

Lily: It's all about I'm not stuck not knowing this, I'm not a math person so I can't do this. It's more I'm going to put the effort into solving this problem and I might need some help along the way, but I'm going to do it. I want them all to be successful. I obviously want to learn, want them to learn the information, but it's a little bit of a struggle and showing them their own effort can help them get their solution.

Danielle: Cause if they can see their own growth, if they can see I started here and through my own hard work, I'm now here. That's going to show to them and if this is a

consistent thing, they're going to realize, oh, I can keep going. If I put in the work, I'm going to get the results. Rather than a student who's constantly, they feel so overwhelmed or I'm trying, I'm studying and I'm still not getting it.

These comments convey understanding of the need for students to have opportunities to persevere through challenges, so they can grow their abilities and intelligence. In addition, these comments indicate understanding of the relationship between how a challenging task leads to perseverance, which leads to success. The expression of this relationship suggests that these PSTs understand that perseverance is what shapes a struggling and challenging experience into a successful experience; thus, allowing students to see growth as a result of their hard work.

As mentioned above, the third experience referred to by PSTs is success. A few PSTs discussed how success was critical for students to see value in struggle and putting forth effort. PSTs used comments such as “finding out a solution,” “rewarding,” “light bulb moment,” and “a sense of accomplishment.” Some of the quotes already described also convey an understanding of the critical nature of students experiencing success. Lily’s following quotation is an additional example: “But, feel the success and okay, look, I solved this problem and it was hard, but I did it and I still did it and I powered through.” This comment reflects an understanding of how struggle and perseverance are essential to one’s sense of accomplishment or success.

Danielle and Travis extend the idea of success and connect it to how it impacts one’s mindsets:

Danielle: If students aren't able to grasp it at all to where they're like, it's so far over their head, they're going to be, that's going to push them into a fixed mindset because their entire life they're going to never get it. And while productive struggle is helpful, if you never feel that light bulb moment, you're going to be wandering around in the dark for the rest of your life. Also, we need light bulbs along the way to light our path.

Travis: And generally, I'm not a great test taker, but I wasn't failing, I was passing and that's the key word or the key statement actually now in reflection of what I just said. I wasn't failing. I was passing. Passing is succeeding. So, my mind was changing. My mindset, instead of saying "I can't do math," I said to myself, "I obviously can do math."

Danielle and Travis convey understanding that success, or lack thereof, influences one's mindset. Danielle's analogy of light bulbs along a path is a comparison to students experiencing success throughout a challenging learning task. She uses this analogy to emphasize how struggle without success can lead to fixed mindset beliefs; whereas, Travis relates how his past experiences of success contributed to his transition to more growth mindset beliefs. He shared a view of success as being relative to his growth and learning, rather a measure, such as a grade. Both Danielle and Travis connect the impact success can have on someone's mindsets and therefore, view success, defined by solving a problem or learning, as a critical experience to support a growth mindset.

Previously, PSTs referred to tasks they completed in the Mathematical Mindset OGT as they described challenging learning experiences and tasks. They revealed their understandings of experiences that support student growth mindsets as they described these tasks. First, the Cut-a-Card task (Stenmark, Thompson, & Cossey, 1986) shown in Figure 4.1 was referenced the most as a task that supports a growth mindset. Each PST who completed this task mentioned it during his/her interview. The following comments provide some examples of how this task was referenced:

Maria: It's just an interactive, engaging activity to motivate them to learn. And more important too, to foster that growth mindset, which will help them to learn the content better.

Austin: Just activities like this, not necessarily once a day, but the card game, the index card, just showing kids that at the beginning of the day automatically gets them thinking about something. So, and especially something challenging like that, it's going to stretch their brain and it's going to leave them open for information and leave them wanting answers so they're going to be more engaged. So, it doesn't have to be the card thing every day but giving them a problem or something that makes them think will promote a growth mindset.

Keanna: I know activities are really important to instill growth mindsets, like the folding card activity that I did.

Cut-A-Card

Can you figure out how to make a note card do this?



**You cannot cut it apart and then tape it back together.
The note card should still be intact when you are finished.
There are several cards available in case you mess up the first time.**

Figure 4.1. Cut-a-Card Task. Reprinted from Family Math, by Stenmark Thompson and Cossey, 1986.

All three of these comments identify the Cut-a-Card task as an activity that fosters a growth mindset. Engaging in a task that allowed them to struggle, persevere, and succeed seems to have modeled and simulated critical experiences that foster a growth mindset. Moreover, all six PSTs who chose to complete the Cut-a-Card task discussed critical learning experiences and tasks. Based on interview comments, this task appears to have contributed to more than half of the PSTs' understandings of how learning challenges can support student growth mindsets.

Other tasks completed in the Mathematical Mindset OGT that PSTs regarded as supporting a growth mindset were YouCubed tasks (Boaler, 2019b) shown in Figures 4.2 and 4.3. Recall, other than the starting and final challenges, PSTs had the autonomy to choose any tasks in order to acquire 100 points. The point values for tasks varied with the intention for those that required more time and effort to be worth more points. Three PSTs chose to complete one of the YouCubed tasks. All three referred to these tasks during their interviews as they discussed supporting a growth mindset:

Will: You would never think that a random YouCubed challenge could foster this growth mindset, but in reality, it was a big difference.

Caitlyn: I do want to encourage a growth mindset and not allow students to give up, like we said earlier and challenge them in different ways. The YouCubed, I would definitely want to look more at the different activities that they have there and use that specifically with students.

Yvette: There were definitely some activities that I found in there, which I would like to at least introduce in the classroom to kind of help grow their minds a little bit. Like the Four 4s thing that was utterly amazing, and I really enjoyed doing that.

Penny Collection

This activity allows students to explore how numbers are composed, by having them look at different ways of grouping them. There are many different strategies and methods students can use to come up with a solution. Students can use actual pennies, draw diagrams, and use charts to keep track of their findings. As students explore they will notice many different patterns in the numbers they are exploring.



Figure 4.2. Penny Collection YouCubed Task. Reprinted from YouCubed, by J. Boaler, 2019, Retrieved from <https://www.youcubed.org/#>. Reprinted with permission.

Task Instructions

Can you find every number between 1 and 20 using only four 4's and any operation?

or

Can we as a class find every number between 1 and 20 using only four 4's and any operation?

Here's an example $\sqrt{4} + \sqrt{4} + 4/4 =$

Give this challenge to students and write all the numbers from 1 to 20 on the board. Then ask students to come to the board and write a solution any time they have one. The more solutions you get for each number the better.

Figure 4.3. Four 4s YouCubed Task. Reprinted from YouCubed, by J. Boaler, 2019, Retrieved from <https://www.youcubed.org/#>. Reprinted with permission.

These quotes suggest Will, Caitlyn, and Yvette identify the YouCubed tasks as tasks that support a growth mindset. Expanding on this idea, Will described how the Penny Collection YouCubed task fosters a growth mindset:

A lot of students, if they don't get something right away, they give up. It's kind of the fixed mindset way. A challenge like this, that's real world applicable, you may not necessarily need to ever figure this out, but it's still tangible. It's something that you can relate back to. It gives the idea of there has to be a solution out there. So, especially with this problem, you could always tell your students that there is a solution and to I guess persevere until you found out what it is. Even if that's by trial and error, or I think, I don't remember what the number of pennies was, but if it's trial and error up to like 90 times, at least you can eventually get it. And, I think that's just a good way to foster that growth mindset.

Will suggests the tangible nature of this task prompts perseverance. He seems to think because the task involves a physical object, it encourages one to keep trying and not give up. In other words, this task can be solved by experimenting with a number of pennies and using trial and error until one eventually arrives at an answer. One student might need 20 different attempts while another only needs three attempts to see a pattern and figure a more efficient approach to the solution. The important idea, reflected in the comments here, is that a solution can be found whether one needs three or twenty attempts, including students with a range of mathematical experiences, making this a “low floor, high ceiling” task. Will implies the open task and its accessibility increases students’ willingness to put forth effort. Thus, his comments seem to convey that open math tasks foster a growth mindset by allowing students to believe they can

figure them out if they keep trying. Later in his interview, Will extended his ideas to a math task he would soon implement in a classroom:

Having the kids create their own unit rate. So, after that we are going to allow the other students to solve one student's unit rate. But that's going to lead into a discussion of how each of our unit rates that we came up with can be all equally correct because it was based on whatever you thought. So, there's not always one right answer to a math problem. - Not everybody's answer will always be the same and that's okay. - So, that's going to lead to a discussion of why everybody's price per skittle isn't the same. And just to talk about not all the time, people's answers are going to be the same in math.

Will's comments reflect the idea that it is important for math tasks to have multiple solutions.

He further reflects understanding of the importance for students to share different solutions and discuss their ideas and approaches.

Caitlyn and Yvette chose to complete the Four 4s YouCubed task. As previously mentioned, they both perceived this task supports a growth mindset. This perception seems to have been influenced by experiences of struggle and having to think deeply as they solved this task. Caitlyn's detailed account of solving the Four 4s task highlights the struggle she experienced:

I originally just tried to go down the line, starting with one and I thought it was going to go just one, two, three, four, five, all the way down to 20. It didn't happen that way.

Because some of them are a little bit hard at seven and 11. One thing that I was able to do was have some of them patterned. So, 11 and 13 had very similar answers, but instead of adding something I subtract it and while working beside my other partner, I came to realize we had different ways of representing the numbers such as 16. She was like, oh

this is super easy, you can just add four, four times. And I did something extremely complicated, four to the fourth power divided by four times four. Cause that's still the same answer. So, I thought that was really important. That's something important in math. Not every single problem has an exact same pathway to an answer and there's different ways of representing it. So, I thought that was pretty cool.

Caitlyn 's attention to the different representations and solutions reflects an understanding of the benefits of open math tasks. Through her description of the YouCubed task, Caitlyn also conveyed an understanding of the importance of students sharing their ideas and solutions.

Interestingly, Yvette and Caitlyn worked together on the Four 4s YouCubed task; however, they seemed to have developed different understandings of how a task like this supports student growth mindsets. In a previous quote, Yvette characterized this task as one that can expand students' minds, which indicates she thinks tasks like the Four 4s task are beneficial to student learning. She further described the benefits of this task in the following quote:

Yeah, I really liked that one. So I would want to, if not have it as an assignment, maybe as bonus points or just introduce it to my students because it is so much fun and it really gets you to problem solve with so little to go off of, you know? Kind of for the same reason, learning all the things in school is important because even if you don't necessarily use what you've learned in say history in your everyday life, just learning about new concepts will grow your mind. Even if it shrinks back down afterwards, you will have had that experience and it will be so much easier to relearn that and apply whatever it was that you learned to your everyday life.

Yvette's comments express an understanding that certain tasks can "grow your mind" which indicates that she realizes not all tasks support a growth mindset. She seems to think problem solving is particularly important as she mentions it multiple times:

And for stuff like math, it's just a bunch of puzzles. So, you learn problem solving skills.

That's why Sudoku helps you with math, even if it's numbers, but it's not actually math.

It's that mind growing and that logical puzzle solving. That's what actually changes in the mind, you know.

Yvette views logical puzzle solving and problem solving as beneficial to support growth mindsets but distinguishes that as "not actually math." Yvette's comments also speak to characteristics of tasks that can support student growth mindsets. However, her comments do not reflect a connection between math tasks specifically that support student growth mindsets.

As shown above, understandings of challenging learning experiences and tasks were found from nine out of 10 of the PSTs. Although this is one of the most substantial themes identified during data analysis, there are some varying degrees to which these PSTs' expressed understanding of learning experiences and tasks that support student growth mindsets. Two key differences were identified. First, Travis and Yvette provided less insight into their understanding related to this theme. Travis referred to success only once during his interview, and Yvette discussed the Four 4s YouCubed task but did not provide much understanding of how a task like it supports growth mindsets and specifically mathematical mindsets. However, in their interviews, Caitlyn and Will who both also completed a YouCubed task, shared ideas that revealed their understandings of how tasks support student growth mindsets as they discussed ideas related to tasks with multiple solution pathways and the importance of students sharing ideas and solutions.

The second key difference found was between PSTs who completed the Cut-a-Card or YouCubed tasks and PSTs who did not complete one of these tasks. All the PSTs who completed the Cut-a-Card task described some understanding of experiences they thought were important to fostering a growth mindset. On the other hand, the two PSTs who did not complete either the Cut-a-Card task or one of the YouCubed tasks, reflected very little or no understanding of learning experiences and tasks that support a growth mindset in their interviews. For the Cut-a-Card task, six of the ten PSTs decided to complete this task: Maria, Will, Lily, Austin, Danielle, and Keanna. As can be seen from their quotes throughout this section, these PSTs provided multiple comments in their interviews about experiences they believe to be critical in supporting student growth mindsets. The following quote from Maria was typical:

They foster a creative and critical thinking for them by challenging them through the rigorous task and allowing them to struggle and tell them the importance of learning from mistakes. Because you as a teacher, you have to establish that positive learning environment where students know those norms of learning.

Others extended their understanding to ways they plan to support student growth mindsets in the classroom:

Lily: Showing a video, the whole first week, doing an activity like the cut-a-card activity where that's not really tied into any curriculum. You're not, but that kind of thing. And thinking outside of the box and getting students used to that. Then they're used to struggling a little bit. Then when they actually are faced with a math word problem or something, it's okay that you're struggling. Yeah and make sure everyone's appropriately challenged so everyone's feeling that struggle. So, everyone can grow.

Austin: I love these activities. I would do the index card trick or things like it just to have their mind going about something, even if it doesn't pertain to the lesson necessarily just something that helps them think for a second, then they're more open to receive the information.

These comments indicate Lily and Austin think tasks similar to the Cut-a-Card can support student growth mindsets and consequently, positively impact students' future learning of and relationships with math. Therefore, the Cut-a-Card task seems to have been influential in PSTs' understandings of learning experiences that support a growth mindset. PSTs who completed this task mentioned the importance of challenge, struggle, perseverance, and success. Will and Caitlyn also expressed some understanding of math tasks that support student growth mindsets likely because they completed YouCubed tasks that were actual math tasks. However, Yvette also completed a YouCubed task and did not provide as much insight to her understanding of math tasks that support student growth mindsets. Interestingly but not surprisingly, the two PSTs who did not choose either the Cut-a-Card or YouCubed tasks did not describe challenging experiences and learning tasks that support student growth mindsets.

All in all, most of the PSTs have some understanding of how challenging learning experiences and tasks support student growth mindset. However, their levels of understanding vary. It is unclear how to account for this difference. One possibility is that PSTs who already had an understanding of mindsets or interest in challenges chose these tasks. Another possibility is these tasks gave the PSTs a concrete way to talk about the positives of challenges. A third possibility is that the Cut-a-Card and YouCubed tasks impacted PSTs' thinking. As reflected in their interview comments, PSTs experienced struggle, perseverance, and success as they solved

these tasks, which likely contributed to their understanding. These ideas will be further detailed in the Experiential Learning section of this chapter.

Sending Growth Mindset Messages

Teachers can send messages of growth to students through positive feedback that focuses on effort and persistence (Dweck, 2006). Eight of the 10 PSTs in this study discussed how teachers should encourage students to persist and not give up. The following quotes provide some examples of ideas the PSTs expressed regarding teachers sending encouraging messages to students:

Lily: I can see some of the students asking me a lot of questions about it. And I think by questioning back to them, instead of just saying, this is the answer, and this is how you do that, directing them and saying, “I know you can figure it out. You got to work on it.” I think that part of the lesson is the struggle.

Brandon: As a student you might see the Einstein thing. I think, wasn't Einstein, didn't he struggle at some point in school, but now he's one of the most known smart people? So just inspirational things like that and you can learn that you don't need to give up. You just keep trying, keep giving out your full effort and it'll work out for you.

Keanna: I'd hope that when I had a classroom, I'd be doing growth mindset language every day. You can do this. I have a problem in tutoring every day saying this is a really hard problem, but you can do it. I try not to start it with this is a really hard problem and just say, “you can do this one,” instead of saying “it's a hard one.” So little things like that that I'm getting better at and what language to use is something that I need to practice. But that would be my biggest idea I guess, of how to use it in the classroom, is just making sure that my language is consistent with a growth mindset.

Caitlyn: Encouraging students and not just saying that they're wrong, in their answers if they have it represented in different ways than people. Also, even if they are struggling with some of them, still lead them in the right direction so that they're just not defeated by not getting the answer.

Austin: I love these examples, changing stuff from saying I can't do it to I'm on the right track. Just a positive outlook on what you're doing is very beneficial for students and it supports a growth mindset.

Travis: They can say, oh, I can't do that. But like, oh no, you can do math. You've just not met the teacher who can teach it to you yet. That to me is the whole idea behind changing a mindset.

These comments emphasize the value of encouraging students to persist through challenges in order to support them as they experience struggle. In addition, PSTs comments above reflect an understanding of the important role teachers play in communicating their confidence in students. For example, Lily stated she would say the following to students: "I know you can figure it out." According to Dweck (2006) this encouraging message communicates to students that the teacher believes in them and in their ability to learn and thus, sends growth mindset messages. Caitlyn extended ideas of using encouraging messages to helping students learn from mistakes. She thinks teachers should encourage students if their approach is incorrect and guide them in the right direction. Furthermore, she conveys understanding of the benefits for students to use different methods to solve problems and that teachers should encourage them to do so. Similarly, Danielle discussed how teachers can support student growth mindsets as students are experiencing struggle and help redirect feelings of discouragement. She described how "you oftentimes get as a teacher, students who are like, I can't do this" and that as a teacher she would

“break down the problem and see where you're tripping up and let's change that I can't do this to, I don't know how to do this yet and then work towards, I can do this.” Danielle further described the impact teachers’ messages can have on students’ beliefs about their abilities:

Because so often once kids get in their brain that I can't do this, they're right. They can't do it. Cause if you don't think you can do it, then you're not going to be willing to put in the effort to learn how to do it. And so really sitting down with a student and encouraging them and if they see that you still have faith in them, then they're more likely to still have faith in themselves. But so often there's even teachers that will tell students, “It's okay, you're just not good at this.” Then that's going to cement in the kid's brain forever that they're not good at this. So, really just making sure to encourage them and, you can do this, you will get it, you just have to keep trying.

Danielle’s comments accentuate the role of teacher messages in impacting students’ confidence and beliefs about their abilities to learn. She conveys an understanding of how messages such as telling students it’s okay that they are not good at something can likely lead to fixed mindset beliefs about their abilities. On the other hand, encouraging students to put forth effort and help them see their hard work will lead to growth and success can foster growth mindset beliefs.

Two PSTs described a more specific example of sending growth mindset messages where teachers praise process rather than the final product. In other words, instead of praising students on correct answers or good grades, teachers should praise the process and ideas used to solve tasks in order to support student growth mindsets (Dweck, 2006). The following quotes highlight the importance of focusing praise on process and effort:

Will: The process of math rather than the correct answer. I think that gets students because just the little bit of praise of you didn't get the right answer, but you had all of

this correct can make the difference in students shutting down and never wanting to look at math again for the day or the student continuing to do that problem and trying to solve the problem that they're working on.

Lily: I think positive attitudes towards your students is really important because if you are acting negatively for whatever something a student is doing, they're going to think they can't do it. So being encouraging and praising effort over ability, effort over your grade.

These comments connect how praising process encourages students to keep improving and thus, makes a positive difference on students' subsequent learning and growth. In addition to further learning and growth, Lily connects how praising process can benefit students' motivation, success, and dispositions toward math:

Even if somebody isn't, a student is struggling in their grades, if they're working hard, and pointing out, but that's a strength that they have. That I see that you're working hard, then hopefully they can, they're still going to stay motivated to keep working hard and hopefully understand more and more every time they come into your classroom and not see math as a scary thing that they can't do.

Lily highlights how teacher praise that focuses on process and effort can help address the negative dispositions many hold towards mathematics. In short, process praise motivates students because it provides direction for further learning, which sends messages that their intelligence and abilities can grow.

Another noteworthy finding was that two PSTs were able to make connections between previous personal experiences and the impacts growth mindset messages had on these experiences. For instance, two PSTs detailed how past teachers sent fixed or growth mindset messages:

Will: I definitely know that I will foster more of a growth mindset versus the fixed mindset in my own classroom. Just because I can see now how helpful that is. Just looking between my friend and myself. We went to different schools up until seventh grade. So, most of our elementary school math was different teachers obviously, but seeing that where I am now and how I like math versus her absolutely hating math. I think it was a lot to do with how our teachers treated us as students and my teachers were always good about going after you didn't get it fully correct, but here are the things that you did correctly. So, I hope that I can be the same way. Just overall helpful to any student in math and try to get them away from the fact that they can't do math and show them that they actually can do the math.

Travis: You are good at math because you wouldn't be in this class if you weren't good at math. You've already gotten here so you're not bad at math, you can do it. I just wanted to make sure that you are choosing the right path because it's not going to get any easier. And all at once I was encouraged and challenged and that was the key point, that little bit of encouragement of someone saying you wouldn't be here if you couldn't do it, you can do it. That's even in my video, that is my statement.

Connecting to personal experiences seems to have allowed Will and Travis to build a deeper and more concrete understanding of growth mindset messages. Will reflected on how he thinks teachers' messages influenced him and his friend to have very different dispositions towards math. His reflection indicates he understands how impactful teachers' messages can be on students' mindsets and furthermore, how long term these impacts can be. On the other hand, Travis reflected on a specific time when a college professor sent him messages of growth about his math ability, which seems to be one of many experiences that led him to create a video about

his transition from fixed mindset to more growth mindset beliefs. He plans to use this video as a means to send students and their families growth mindsets messages. Lastly Keanna connected growth mindset message ideas to an example she remembered seeing at a local school:

Not just in the classroom, maybe in the whole school. I've seen schools that maybe (Washington) is the example of the school I saw where they had growth mindset on the wall in big letters and then all the different things underneath it that talks about how famous scientists had a growth mindset. When they couldn't figure it out, they kept going and now we have the light bulb. It took so many tries for so many people until somebody finally figured out it was the light bulb. I think that was at (Washington). So even in the whole school, not just in the math classroom. I think it's important for sure.

Keanna was able to identify a school-wide example she had previously seen that sent growth mindset messages to students. Given these points from several PSTs, this study's OGT seems to have created a space for PSTs to reflect on previous experiences and develop understandings of ways teachers can send growth mindset messages.

As can be seen in previous quotes, multiple PSTs described thoughts of how they can use growth mindset messages when they become teachers. Therefore, some PSTs have extended ideas of growth mindsets messages to actual strategies they can use in the classroom. Brandon provides another example of a strategy for sending growth mindset messages to students. He stated, "I would try to put some quotes in my room. I would try to emphasize it on the first day, what things I want to accomplish as a teacher, or not even as a teacher, as a person. How to help them understand certain ideas that they need to understand as people." The Twitter activity seems to have contributed to Brandon's understanding and ideas for using growth mindset messages in the classroom:

I had not seen some of the other quotes, and I thought a lot of the quotes were pretty almost inspirational, and I think that's key to use for not only as a student but also for teachers to use for students. So, I think this, there's a lot of ideas in here that help create an experience for you to learn.

Understanding the importance of messages that students receive from teachers, Brandon has started thinking about how he can send growth mindset messages to his students. This example as well as others indicate PSTs not only developed understanding of the importance of growth mindset messages, but also ways they can send these messages to students.

Another strategy for sending messages of growth to students is by directly teaching them about growth mindsets. This approach was mentioned by four PSTs. One similarity across three of these PSTs was to teach students about growth mindsets as a beginning of the year lesson or activity:

Brandon: Decorate your room with folks like that and to also in the beginning stages, how I mentioned earlier, you connect with your students. I think that's important.

Connect with them and then have your first couple of days. I know a lot of classes in high school and even middle school, the first couple of days aren't really that important. So why don't you make them important and try to ingrain the growth mindset ideas and talk about, use some kind of example of, I don't know what word I'm looking for. I don't know. Just maybe even play this game or something and try to show them why it's important to understand math and understand that you shouldn't give up and all these types of ideas.

Lily: I think I liked the video. I could see not even that specific video, but I could see myself in this future planning a video about growth mindsets or something on the first

day of class, that first day you don't really do anything, so you might as well start building this idea of what a growth mindset is to your students. This is our class. It's going to be like this.

Keanna: If I could give this game to my students, even to show them, teach them what a growth mindset is. Maybe not this game exactly, but I think students would really enjoy something like this where they can see themselves, what a growth mindset looks like. Maybe a first day activity, first day in the classroom, have a discussion about growth mindset and this is the type of mindset we're going to have this year. We're going to get through the year. It's going to be hard for some of you. It might be easier for others and that's okay. We're all going to get through it together. It's a classroom. I think that would be a good first day conversation.

These PSTs have started to think of ways they could teach about growth mindsets, as evidenced in excerpts from interviews. Games like the Mathematical Mindset OGT have potential in this regard. Brandon further described how teaching students about growth mindset can provide a positive learning environment: “starting at the very beginning of the year, similar idea, making sure everyone knows that it's a safe place. You can talk. We're going to learn.” Brandon elaborated on the importance of students learning about growth mindsets:

It's an important idea to bring it to students because if they don't have this growth mindset, they might go away from math because math is a hard subject for a lot of people and if they don't get it, they just there's that stereotype, the stereotypical idea that either get math or you don't get math and I don't believe in that at all. I think that's, it's just we need to try to go away from that. And I think one way to get away from it would be to

teach the growth mindset to students so they won't believe in that idea that you can't understand math for whatever reason.

Like Brandon, Lily and Keanna also described plans of teaching students about mindsets early through a game or video indicating they believe directly teaching students about growth mindset is an effective strategy. Although these three PSTs gave an example of how they could teach about growth mindset, the strategies given were similar or identical to the tasks provided to them in the Mathematical Mindset OGT. Next, I will present how one PST was able create his own tool that he plans to use to send growth mindset messages to students.

Travis was the only PST who chose to create his own video in which he decided to share his mindset transition story. Travis had previously learned about mindsets and was aware that he had experienced a mindset shift himself, specifically towards his beliefs about his own ability to learn math. Therefore, Travis had already developed a significant amount of understanding about mathematical mindsets. This Mathematical Mindset OGT allowed him to apply his understanding and to send growth mindset messages not only to students, but also their families:

I started to think about what one of my grand ideas was, as far as how I can not only help my students when I do have my own classroom, but half of the battle of teaching a younger person, that's also teaching their parents how to help them learn, especially with busy career oriented lives or maybe a fixed mindset. You know, you have to provide tools.

Travis details why he decided to create a video of his story:

I find that I have heard many times from more so from the parents of younger people “I can't do math,” “I've never been able to do math.” Like I mentioned a moment ago, if we've just never met the person who can teach it to you, what better way. I find that

personal story, the human narrative is something that we can all connect to. So, since my video was essentially my story, I shared it with a couple people. I shared it with a couple friends, and they said, “Are you going to put that on YouTube? Other people should see this.” I've heard word that I might've brought a couple people to tears.

Travis' comments indicate that the purpose of him creating a video about his mindset shift is to send growth mindset messages to his future students and their families. In his video, he narrates his life and how he developed fixed mindset beliefs about his math ability at a young age. He explains how overtime he started believing in himself and developed a desire to study mathematics. Through hard work he earned a degree in mathematics, but more importantly a love for the subject. He decided to be a math teacher so he can share this love with others and help them believe they can learn math. Travis' story epitomizes the journey to a mathematical mindset and based on his interview comments, he was inspired to share it with others. This OGT offered Travis a space to share his story by creating a video. Thus, through his video creation and interview comments, Travis demonstrates a significant understanding of the importance of growth mindset messages and how as a teacher he can send them to students and their families.

In summary, eight PSTs expressed understanding of the importance of sending students growth mindset messages. Furthermore, several PSTs discussed ideas of how they would send these messages to students when they become teachers. Four PSTs described plans to directly teach about growth mindsets, which is one way to send growth mindset messages to students. However, it is important to point out a prominent difference regarding PSTs' ideas for teaching students about growth mindset. Brandon, Lily and Keanna discussed using a video about mindsets or a game similar to the Mathematical Mindset OGT. Even though these PSTs expressed ideas about teaching growth mindsets, their ideas are virtually identical to how they

learned about mindsets using the OGT. On the other hand, Travis created his own product, a video telling the story of his mindset shift. That is to say, Travis designed a resource that incorporates his own growth mindset messages. He also planned how he would provide students and their families access to this video using a Google site. Given these points, Travis reflects a significant understanding of how to send students' growth mindsets messages, as evident from his video creation and interview comments regarding how he plans to share it with students.

Valuing Mistakes

Valuing mistakes in order to support student growth mindsets was another understanding expressed by several PSTs. Although this finding was not as predominant as the other two themes in this section, it is worth noting because half of the PSTs mentioned the importance of learning from mistakes. It is also important to note that PSTs' understandings varied with one PST particularly expressing a deeper understanding of valuing mistakes. In this section, I will first present understandings conveyed from four PSTs who revealed some understanding of the importance of learning from mistakes. Next, I discuss how one PST's comments reflected a deeper understanding of utilizing mistakes as learning opportunities.

Three PSTs discussed learning from mistakes as they discussed the tasks they completed in the OGT. For instance, the Cut-a-Card task was described by two PSTs as a task that encourages perseverance as one makes mistakes:

Will: The foldable inside the classroom, students who have that fixed mindset may try something once and then it didn't work, so they shut down or give up. But, with the foldable, having to try it multiple times until you get it, it's just that it teaches you that being wrong is okay. You learn from your mistakes. You try again until you eventually get it.

Maria: I think first the trial and error thing, that process you're teaching them, not just give up as soon as you can't find a solution.

In these comments, Will and Maria connect how learning from mistakes can foster a growth mindset. First, Maria noted the task teaches one to “not just give up” and Will stated it “teaches you that being wrong is okay.” These core ideas of supporting a growth mindset (Boaler, 2016; Dweck, 2006) convey their understanding of the process of learning from mistakes. Maria often referred to this process as “trial and error.” She continued to explain that “it's as soon as you give up, you give up opportunity to learn. So, it's pretty important for them to have that kind of positive thinking about learning.” Based on their comments, Maria and Will appear to think that one's mindset impacts his/her response to mistakes and whether he/she decides to give up or keep trying. Understanding these responses affect one's subsequent learning, Will's and Maria's comments reflect the belief that students should be encouraged to learn from mistakes and see them as opportunities to grow. Their comments also indicate they experienced the process of making and learning from mistakes while solving the Cut-a-Card task. Therefore, they seem to realize that providing challenging tasks is one way for teachers to encourage students to learn from mistakes.

Another task that was connected to learning about the value of mistakes was the Twitter Challenge. Brandon recalled quotes he read as he explored growth mindsets on Twitter. For example, Brandon described the importance for one to view failure as an opportunity to learn and grow:

I never lose, either I win, or I learn. Yeah, I like that quote as well because, when you lose you shouldn't think of it as a negative. You shouldn't think of things negatively. You should try to, if you do great, that's awesome. But if you don't, you should take it as a

learning experience and just get better. I had a teacher who always said, don't get bitter, get better.

The Twitter Challenge involved finding three posts or tweets that are helpful in learning about mindsets. The following excerpt is from Brandon's response to this challenge:

One of my favorites comes from Albert Einstein: "You never fail until you stop trying."

This quote is very powerful in my opinion. If a student, or anybody in general, believes that failure only occurs when you give up, then this is likely to inspire students to give effort and to never give up. Another great quote is from Michael Jordan: "I've failed over and over again in my life. And that is why I succeed." This quote shows that even famous people struggle in life. It is important to view failures as an opportunity to get better.

During Brandon's interview, I asked him why he thought these ideas were important. Brandon responded with the following:

Well, if you give up then you're not motivated. It might be one topic, but in math, typically one topic leads to another topic and leads to another. If you give up at any one point, you're just, you're not going to understand, you're not conceptually understanding.

Brandon's response expresses that he values mistakes and views them as opportunities to learn and grow. Moreover, based on his comments, Brandon seems to think learning from mistakes and not giving up is particularly important in mathematics due to the nature of the subject and how concepts connect and build on one another.

Will provided another insight related to valuing mistakes as he discussed focusing on the process rather than the final correct answer. In previous quotes, Will noted the importance of process praise and for students to learn that it is okay to make mistakes. Will connects these ideas in the following statement:

I think it's not about the correct answer. It's about how you get there. So, the process of getting to the correct answer is what's important. And even if you tell your students that in high school or middle school, elementary school, I don't think it matters, the process and not so much the correct answer.

Based on this statement, Will devalues overly focusing on final answers and instead values the process, which involves making mistakes and learning from them.

Caitlyn also expressed some understanding of the value of mistakes as she described how one of her teachers viewed assignments as opportunities to understand his students' learning needs. According to her description below, this teacher not only used student work to help him understand areas for student growth, he also used them to reflect on his own teaching. Caitlyn described her teacher's outlook on assignments as such:

I heard one of my teachers, I think he said the other day that the homework and stuff, it's just telling him what it is that he has or hasn't taught us well. And just having the homework or any activities show what you do know so that I can help you further understand different concepts. So, not just giving an assignment and just marking it wrong and never go back to it.

Caitlyn's comments imply that she agrees with her teacher's outlook on assignments and that teachers and students should use them for growth. The last sentence in the quotation above brings attention to the benefits of having students inspect their mistakes rather than moving on and never looking at them. Thus, Caitlyn seems to value mistakes and understand the learning benefits they can offer if teachers leverage them as opportunities for student growth. As for teachers' learning, she appears to regard self-reflection as an essential disposition for one to

continually improve their teaching. In short, Caitlyn conveys an understanding of valuing mistakes for student learning and of ways teachers can do this in the classroom.

In comparison to the previous examples, Keanna discussed the value of mistakes in the classroom in much more detail throughout her interview. It appears the My Favorite No video was a major contributor to her ideas about valuing mistakes as she discussed it multiple times. For instance, she explained that “it was important that she said it was her favorite no, because saying that this is wrong has a different connotation than I like how this is wrong.” In the My Favorite No video, a math teacher demonstrates a strategy where she gives her students a math problem and then selects her favorite incorrect answer, such as a commonly made mistake. She then anonymously shares her favorite incorrect answer with the class and uses it as an opportunity for everyone to learn from mistakes. Keanna described how the teaching strategy illustrated in the video can benefit the classroom learning environment:

But it seemed like the students were more willing to answer or talk about things because they were willing to get it wrong because getting it wrong is okay. And I think sometimes there's a lack of discussion in the math classroom for the reason of, I'm just going to be wrong if I say something. So, I'm just, might not say anything versus I'll be wrong if I say something, but it'll be okay because it will. We'll grow after that. It won't just be you're wrong, next. So, I liked that aspect of it.

In this quotation, Keanna reflects her beliefs regarding mistakes and how they are critical opportunities for growing and learning in mathematics. She also believes, based on her comments, that math classrooms should be a place where students feel comfortable in taking risks and making mistakes. However, Keanna is aware this is often not the case and that many students are unwilling to share ideas for fear of being wrong. Furthermore, she connects how fear

of making mistakes can hinder communication and collaboration among students and consequently, have negative impacts on their learning.

Like Will and Maria, Keanna also referred to the Cut-a-Card Challenge as she talked about valuing mistakes. As she described the task, she expressed her ideas about learning from mistakes:

I think that connects to the second activity (Cut-A-Card task) I did too, growing and learning from your mistakes. Almost like process of elimination, but not always in that aspect. It's not always you get this wrong, so don't do that, move to the next thing.

Sometimes you learn something specific within your mistake. Maybe in a sense of like solving two step equations. I multiplied by two first, but my friends subtracted this over first. Which way was easier? It's not necessarily the wrong way, but we can learn from the things that we do to get better and faster or understand more. So, making them, those mistakes, they might not even be mistakes. They're just, errors or things that you can learn from.

Keanna's detailed account of how one might learn from mistakes reflects a significant understanding of valuing mistakes. Her comments indicate she realizes that learning involves a "process of elimination" or trying an idea and seeing what does and does not work. She also appears to realize this process involves making and learning from mistakes, as well as learning better or different methods to a solution. Later in her interview, Keanna discussed a project in her high school Geometry class that she identified as an example of valuing mistakes. Interestingly, she mentioned this teacher and this classroom application early in her interview without relating it to how a teacher can value mistakes:

Keanna: I remember a lot of math classes just being like worksheet, homework, review the homework, worksheet in class, homework on the worksheet. It was very much like that. There was some lecture style. You get the definitions on the board, you kind of talk through a PowerPoint, but then you just do a worksheet sometimes in groups, and then you go home and do the homework on your own and then come back as a class and refresh on the homework. I feel like the geometry class was a little different because there were more project-based instruction in the geometry class. We had more take home projects and group projects that we did together versus the traditional lecture style. But we still had lecture style because there's so many proofs and theorems that you need to know in geometry. So, she would still do that. But then more project-based I think learning.

Me: Can you give me an example or details of just one of the project-based assignments?

Keanna: Yeah. We had this, a binder that we had to create. It was like creating your own geometry book for the semester. It was the final project. Instead of taking an exam at the end of the year, which I had never done a final project instead of a test for a math class. So usually it's an English class, you do a research project or something and then you're done. But this math class, you had to create your own geometry textbook of all the things. You had to pick, I think five or ten topics that you struggled with the most and then that's what you put in your textbook and you had to write a definition, you had to have example problems and then you had to solve those example problems. You had to do that for each of the five to ten topics and then you created this little textbook for yourself.

Towards the end of the interview, Keanna connected how this final project in her Geometry class valued mistakes by allowing students to focus on topics they were struggling to understand:

I could see that especially with the binder activity because that forced you to go back to the topics that you didn't do so well, in the quizzes that you didn't do so good on. She made you pick those topics if you didn't do well and so, it's going back and having to understand in order to do your final project is forcing us to have a growth mindset.

Instead of just forgetting about that topic we didn't know how to do, you can figure it out.

Just spend some time on this project and put it together. So, I guess that's a good example in the math classroom.

Throughout her interview, Keanna's comments reflected a deeper understanding of the valuing of mistakes. First, she described how the strategy used in the My Favorite No video valued mistakes. Second, she identified how one learns from mistakes while solving challenging tasks such as the Cut-a-Card task. Third, she connected how one of her high school teachers valued mistakes through a final project. Keanna's interview comments convey a considerable amount of understanding regarding how mistakes are a critical part of the learning process and how teachers can value mistakes in math classrooms.

In summary, the PSTs who participated in this study had previously developed knowledge of mathematical mindsets, as evidenced in the pre-assessment data. Their experiences using the Mathematical Mindset OGT provided opportunities to build on this prior knowledge and develop understandings of teaching practices that support growth mindsets. Thus, using this OGT made PSTs' understanding of mathematical mindsets more concrete by developing ideas of what fixed and growth mindsets look like in the classroom.

Benefiting Aspects

Data analysis for the second research question investigated aspects that PSTs perceived as benefiting to their understanding of mathematical mindsets as they used the OGT. Notable

themes were discovered during the data analysis process. These themes represent the participants' perceptions of the benefiting aspects as a group with consideration to their similarities and differences. Themes for common benefiting aspects presented in this section are 1) Experiential Learning, 2) Social Interactions, 3) Autonomy, and 4) Engagement.

Experiential Learning

As PSTs described their accounts using the OGT, it was apparent that certain tasks created experiences that are critical in supporting student growth mindsets. Eight PSTs communicated perceptions that they learned through experience as they used the OGT. These PSTs mentioned a few different tasks, but the most notable was the Cut-a-Card task. How this task afforded experiential learning will be presented first, followed by the Video Creation and YouCubed challenges.

Based on interview comments, PSTs particularly regarded the Cut-a-card task as a challenging task that produced experiences of struggle, perseverance, and success. Learning through such actively engaging and meaningful experiences indicates this task afforded PSTs what Dewey (1916) devised as experiential learning. Five out of the six PSTs who completed this task expressed perceptions that they found it beneficial to their understanding. One of the main reasons given was that the task allowed them to struggle in the role of the learner. This can be characterized by the following descriptions:

Lily: I already knew some about mindsets. I think that doing that card activity and experiencing that. That was actually a simulated student doing a math problem and struggling and then finally getting to the answer. That was just a nice reminder of that, it's actually real. We're not just reading all these articles about students struggle and then

they get there and you feel good. It does feel good when you solve a problem and it motivates you to solve the next problem too. So, it's nice to feel that.

Danielle: I personally started, I was let me make a cut or two in here and see how I can fiddle with this. At first when I saw it, I saw the picture wrong. So, I thought it would literally just be two cuts and pulled it out. But then I realized that caused a twist in the paper that wasn't in the actual paper. So it was just for me, it was a lot of just kind of trial and error of looking at it. I can kind of generally see that there's been some cuts in these areas. So then let me see where I can go from here. There's a lot of thrown away note cards because they ended up getting cut in half or cut wrong. But, I enjoyed it, in the sense that it really puts you in the mindset of the student who was doing the activity.

Wrapped up in these comments are moments of struggling, learning from mistakes, persevering, and succeeding. Lily and Danielle both seem to recognize that by completing this task, they were able to feel and sense critical experiences that Dweck (2006) and Boaler (2016) advocate for students to have in order to foster growth mindset beliefs. Their comments indicate that learning about mindsets from a student's perspective allowed them to feel the impacts learning challenges can have on students. As Lily stated, the Cut-a-Card task simulated the kind of experiences that can help students see how a challenge leads to growth.

Other comments further supported the notion that the Cut-a-Card task provided PSTs actively engaging experiences as they learned about mindsets. Another experience discussed was feelings of determination:

Will: I thought it was interesting. Well, to be honest, I thought it was going to be easy, but it wasn't as easy as I thought, but after a while it just became like determination to figure out how to do it. So, you start because of something... it was also looked

interesting. So, you start with something that looks interesting and possibly easy and then you learn that it wasn't easy. But at that point my mindset was that I had to get it done because of determination and curiosity.

Austin: You really had to think about how it was made that way. Because if you look at an index card, it's just normal. But then when you looked at this one, it was cut so strangely, and the fold was weird that you'd have to think about it, or it would just bug you. You'd have to find out the answer until it just bugged you to death.

These comments indicate that struggling through this task induced determination to solve it. The challenge of the task seems to create a process of critical experiences that support a growth mindset starting with curiosity and struggle. Then, according to their comments, Will and Austin became determined and persevered through the challenge, which led to success. This process was indicated by multiple PSTs as they struggled to solve the Cut-a-Card task and eventually succeeded:

Lily: Feel the success and okay, look, I solved this problem and I was, it was hard, but I did it and I still did it and I powered through.

Will: We had a lot of trial and error based problems. Well a lot of trial and error in this problem. Eventually me and a group of students were able to make the correct cuts and folds to make it look like the model. – So, just to quote unquote work on something for a long time, granted the timespan, and then figure it out, It's just a good experience to have.

Austin: But the fact it was taped down to where you couldn't move it or work backwards with it, it was hard to figure out, but eventually, I could see it without having to move the paper physically. I could think it in my mind and move the paper and then I saw the cuts, figured it out.

Feelings of success are evident in the comments above. Lily further detailed how figuring out the Cut-a-Card task led to a sense of accomplishment:

It was exciting. I was like, oh my gosh, that makes so much sense. Not even it makes sense, but it is possible. I can even do it. I'm not even sure if it's real. But I think once I figured it out, it was a little bit of a sense of accomplishment.

In these comments, Lily indicates this task made her not only feel accomplished, but also confident. Her feelings of accomplishment and confidence appear to be a result of overcoming a challenge that involved struggling, persevering and figuring out the task. Thus, based on her comments, Lily felt the impacts these critical experiences have on one's confidence. According to Dweck (2006), such a revelatory experience can support a growth mindset; therefore, this kind of experiential learning is significant in helping educators understand the impacts learning challenges can have on students' beliefs.

In addition to struggle, perseverance, and success, Maria's description of solving the Cut-a-Card task conveyed that she experienced a transition from more fixed to more growth mindset beliefs. The following passage provides this interesting insight into Maria's experiences:

And at first, it's very challenging and I struggle a little bit how to get into that shape and at first, I kind of like, this is impossible. There is no way to cut-a-card to that. After trial and errors and analyze a little bit how this missing part is still standing up or the other side, it's not missing but it's on the top of that card, which it was really complex. But then through trial and error as I say, and then eventually I found a way by flipping over the card.

Thinking this task was impossible indicates Maria momentarily experienced feelings of hopelessness and thoughts of giving up, which reflects a fixed mindset. However, subsequent

comments reflected more growth mindset beliefs as she described how she persisted to figure out the solution to the task. This intriguing account of her thoughts emphasizes the remarkable nature of this task and how it, according to her comments, led her to feel both fixed and growth mindset beliefs. More importantly, the description of her thoughts transitioned from more fixed to growth. This noteworthy finding reveals the possibility of providing such a transition through a fifteen minute task.

Travis also expressed thoughts that transitions from fixed to more growth mindset beliefs. However, he described the Video Creation Challenge as the source that provided this transition:

I took it as a challenge because I instantly knew what I wanted to do. I made my mind up on what I wanted to do. I had very little time to do it, but I had made a commitment to do it and it required me again to fix my mind, I guess to change my mind because there was a point there where I was like, I can't do this. I had to go through the experience again just to even complete it. And when I was done, I found success and I'm very happy about that.

Evident from his comments, Travis is aware that he experienced a transition of mindset beliefs from the Video Creation Challenge. In the end, he felt success and reflected in his comments the perception that creating a video was beneficial for his growth and learning. As has been noted, Maria and Travis described a transition of thoughts that reflected more of a fixed mindset to thoughts that reflected more of a growth mindset. This transition is a significant finding when considering a single task can provide such reversed feelings. Furthermore, these feelings are important for teachers to understand to better support student growth mindsets.

A final finding for the experiential learning theme relates to what Dewey (1916) describes as the two components that comprise experiential learning, the active doing phase and

the passive, deep thinking phase. Two PSTs described these phases as they discussed OGT challenges they completed. For example, Danielle's interpretation of the Cut-a-Card task speaks to these two phases:

Tried the Kahoot to go along with it because that one was more almost a meta sense of let me make the questions about mindsets, which really required me to go back and look back at those videos and the PowerPoint that you posted and whatnot to really understand the information so that way I can regurgitate it as a question and then come up with answers as well to the question. Whereas, with the first activity (Cut-a-Card task) was more let me put these mindsets into action and to think a little more about what's actually covered in material of growth mindset.

Danielle's comments indicate that she perceived the Cut-a-Card task allowed her to actively engage and think deeply about her learning. Providing another example, Caitlyn expressed a similar perception as she discussed the Four 4s YouCubed task:

So, we were learning about it while doing it as well. And so, I liked that. Definitely something that was kind of in my mind but, hadn't really thought about growth mindsets as much. But spending more time on it and it gave me more time to reflect on it and thinking about using it in the classroom.

Caitlyn explained that she was “doing” while learning about mathematical mindsets indicating this task allowed her to actively engage. She further supports this point in the following quote: “So, we were learning about it while doing it as well. And so, I liked that.” As for the passive phase, she mentioned that the task allowed her to reflect and think about what she had learned. As indicated from Danielle's and Caitlyn's comments related to active engagement, reflection

and thinking, they reveal that certain tasks, namely the Cut-a-Card and Four 4s tasks, appear to comprise the two phases of experiential learning.

In conclusion, experiential learning was conveyed by most PSTs as a benefiting aspect to their understanding of mindsets. The Cut-a-Card task was the most frequently referenced source for creating experiences that support growth mindsets. A small number of PSTs were more general in describing their overall experience using the OGT as Keanna was in the following quote:

I think the beginning activity of everybody doing the same thing was also helpful because that gave me information that I needed to get to understand growth mindsets and then my activities I chose helped me experience them more.

Nonetheless, eight PSTs communicated perceptions that they learned through experience using the OGT, making this a substantial theme for benefiting aspects.

Social Interactions

Using an online tool within a physical classroom of peers unsurprisingly created different social interactions that influenced PSTs learning of mathematical mindsets. Seven PSTs mentioned in some way how interactions with other people influenced their learning experiences while using the Mathematical Mindset OGT. The degree in which social interaction arose in their interviews varied greatly from impacts on their choice of tasks to how collaboration contributed to their understandings. These variations of social interactions will be detailed in the following paragraphs.

Four PSTs' described how their peers influenced which tasks they chose to complete. The following quotes indicate that their location within the room and who they were sitting near played a factor in their learning:

Danielle: Cause [Will] and I were sitting next to each other. Did you want to work with a partner, we should be together, and he was like sure. And that one was he said, let's do the Cut-a-Card. Okay. It was his idea.

Maria: A lot of us around that table did that together.

Keanna: I did the paper activity. I did that one because I saw somebody trying to figure it out and I wanted to figure it out. We played off each other to figure it out. But I did that one because it attracted me the most at the time.

Austin: The person sitting next to me also did the same challenge. After looking at her project, I noticed that all these people had different ideas about growth mindset. They were all very similar, but they all had a different experience with it, or they had a different perspective on it. So, I wanted to see how people were thinking differently as well. So, there were a couple of quotes in a couple of visuals that I thought were very appealing that answered some of the questions that I had about it or they gave good examples of what a growth mindset looked like.

The above comments directly state or imply that these four PSTs' choice of tasks was influenced by their peers. While on the surface this might seem like a small way to influence their learning, it is important to consider how different their experiences would have been without this peer influence on their choice of tasks. Some PSTs would likely have chosen different tasks which would have changed their entire experience and thus, the understandings they developed about mindsets. This finding also sheds light to how even when an online platform is the primary resource for facilitating a module, the people in the physical setting play a major role.

Two other PSTs offered more detail on how working with peers had a positive impact on their learning experiences. First, Caitlyn noted how she and Yvette worked together as they

solved the Four 4s YouCubed task: “We worked side-by-side and would compare and maybe if we were really struggling on one, we would help each other out.” Caitlyn explained how they wanted to complete solutions for task independently because they each wanted to be able to figure it out: “I remember when we were sitting there, sometimes we would figure out one before the others. Oh, you got that one. Wait. Let me see if I can figure it out first.” Caitlyn and Yvette’s interactions while working side-by-side seemed to have motivated them to figure out solutions on their own first. In Caitlyn’s interview, she indicated she was aware of the influence of the social interactions with Yvette. However, Yvette did not provide insight on any influence Caitlyn or any other peers had on her learning experiences as she used the Mathematical Mindset OGT.

Lily also conveyed the perception that she found working with others as a benefiting aspect of the OGT. She provided a thorough explanation of how working with a group of peers contributed to her understanding:

There was a group of us that were doing it at the same time and I think that if it had just been me the whole time trying to look at it and figure it out, I might not have. It would have taken me a lot longer A, and B I wouldn't have, I might not even have gotten there. I might've given up. But I've found it helpful to talk about my ideas and other people were there to hear what I was saying, oh wait no let's do it this way and stuff. But I could see what other people were doing too and that was just helpful to have other people doing it too. But I'd already looked at it and was like, huh? How is it like that?

As can be seen from her comments, Lily found communicating and collaborating with others helped her struggling experience shape into a successful experience. Thus, her comments

indicate she perceives learning with others can help one grow from where they are, as well as accomplish more than they could individually. She elaborates on this idea in the following:

I just think sometimes you can't, you might not get there on your own. If you're not talking about, I find it really helpful at least in my experience, to talk about it. Even if I am super confused, at least I'm bouncing off my ideas and my ideas are being heard from someone else and it gives us a starting point to work together to get there. And it's a lot more of this is a challenge and we are going to get there rather than, I'm sitting here with it on my desk with one lamp on struggling over this problem and it's going, it's lonely and dark and sad. Whereas, in a group, it's to me seems less pressure, I guess.

Her comments emphasize how working together creates a more positive and less stressful environment while solving a challenging task. Furthermore, as indicated in her comments, Lily found working with others benefited her learning because the group was able to accomplish more by contributing their ideas, building on those ideas, and figuring out a solution together.

As previously noted, the people in the physical setting played a major role in how learning was situated in this study. Many PSTs chose to work with their peers or were influenced by them in some way. Another example is how Travis expressed a desire to be involved:

To participate in other people's work. I learn from other people. So, when my fellow student asked if I would take the quiz, I just thought, why not? I'm a team player, so I just wanted to be involved.

Travis' comments reflect his valuing of learning and working with others. He also pointed out how the overall gamification approach encouraged social interactions:

The challenges were, there were challenges that were extremely accessible. The fact that you can also since you're working towards a point base, work with other students. That was really great, participating in other people's quizzes and games that they were creating.

His comments give attention to the structure of the game and how it provided a more collaborative approach rather than a competitive one that many associate with gamification. The OGT was structured such that each PST had to acquire 100 points. As he noted, he perceives the overall point requirement permitted a noncompetitive gamification approach that did not seem to hinder collaboration. This view is further supported when Travis' stated that he wanted "to help one of my fellow students along" so he chose to complete one of their Kahoot quizzes. It's worth noting that he did not need any more points after completing the video challenge to meet the requirements of the OGT, so it seems Travis decided to complete the Kahoot quiz merely to be involved and help a classmate. All things considered, social interactions within the physical context of the classroom appear to have substantially influenced PSTs' learning experiences while using the OGT.

On the other hand, two PSTs indicated they found the ability to learn from people outside the classroom as a benefiting aspect of the OGT. Austin found using Twitter to explore information about growth mindset allowed him to gain different ideas and perspectives from information shared or tweeted by others. His following quote provides this perception:

The Twitter one was very helpful because you could see everybody's different perspectives. So, if I was thinking growth mindsets is just blank, then maybe I wasn't capturing the full effect of a growth mindset. But having these different inputs, I now have all these definitions to work with to get a good visual of what a growth mindset is.

And I have all these new tools that I've found, the visuals and the quotes and stuff like that to implement it into the classroom.

Based on these comments, Austin perceives that through Twitter he can learn and grow from interactions with others, which adds a different element of social interactions. Unlike most PSTs who mentioned social interactions from peers in their class, Austin found social interactions with others through an online tool as beneficial to his learning.

Another example of learning from someone outside the classroom was described by Keanna. Recall, she watched the My Favorite No video that provides an example of a teacher valuing mistakes in a math classroom. In her following comment, she reveals that the social interactions within the OGT tasks played a factor in how she decided which tasks to choose:

The ones that I can see the teachers or students doing work were the ones that I like to pick. My Favorite No was a teacher in the classroom and then even the paper folding was, I saw another student doing it and I wanted to work with them. And then [Yvette's] Kahoot I chose as a time thing. But I was gravitated to the ones that had more interaction between me and somebody else or me and another person in the video or something.

Interestingly, Keanna seems to consider working with peers in the classroom and learning from a teacher in a video both as ways for her to interact with others. As can be seen in her comments, she believed learning from someone else through a video benefited her understanding because it allowed her to see a classroom example of a teacher supporting a growth mindset:

I picked the Favorite No, because it was actually a teacher representing what a growth mindset looks like in the classroom. And I wanted to see what that was first to help me understand what it was a little more.

In the following quote, she further detailed this perception and notes that she had not previously seen what a growth mindset looks like in the classroom:

I liked it because it was actually a teacher doing mindsets in the classroom and I didn't really know what that looked like besides in the [education program] classes that I've taken because in our classes they tell us about growth mindset and all that stuff. But I never really seen it in my actual math classes.

As evidenced by these comments, Keanna seems to perceive using this OGT was her first time learning about how to support a growth mindset in the classroom. In addition, her comments offer some insight to how watching a video and using other technological tools can provide a form of asynchronous social learning opportunity. Although Keanna did not directly interact with this in-service teacher, she seems to consider watching and learning from the teacher's ideas and teaching strategies illustrated in the video as a form of interaction. Thus, as evidenced in their comments, a couple of PSTs perceived the technology aspects of the OGT provided opportunities to learn from others outside of the physical classroom.

In short, most PSTs found social interactions with their peers as a benefiting aspect of this OGT. Several PSTs specifically described how peers influenced which tasks they chose to complete. Some even chose a task because they wanted to work with a peer. Two PSTs indicated they chose a task because seeing another peer doing the it sparked their curiosity. Furthermore, a couple of PSTs provided details in how collaborating with peers benefited and contributed to their understanding. Ultimately, even though technology played a major role in facilitating the module on mindsets, the people in the physical classroom seem to have had a greater influence than social interactions online. However, two PSTs did find the ability to learn from people

outside the classroom beneficial to their learning, which was afforded through the technological tools included in the OGT.

Autonomy

Most of the PSTs found the game element of autonomy as a benefiting aspect to their learning about mathematical mindsets. More specifically, nine out of the ten PSTs communicated that they liked having the autonomy to make choices in which tasks they completed. Other ideas expressed related to the benefits of autonomy included having a variety of tasks to choose from and the personalization of learning as PSTs were able to choose tasks based upon their interests. Furthermore, it became clear in the data analysis that technology played a major role in how autonomy was provided in this OGT. These ideas are further detailed in this section.

Recall that the OGT was designed to allow PSTs autonomy to choose which tasks to complete. Other than the starting and final challenges, PSTs had a great amount of freedom and control of how they learned about mathematical mindsets. Many PSTs directly stated in their interviews that they liked having choice. In the following quotes, PSTs related how choice affected their motivation or engagement:

Lily: I liked that I had choice because I could pick the activities that I wanted to do and I chose to solve the problem of why the card was that way, not forced to do it. So that's also, I'm more motivated to do it and to experience that growth mindset activity of this is hard and then, oh look, I did it. Whereas, I wasn't forced to, which I think is an important part of having a growth mindset, is that even if it is a required assignment and stuff, there needs to be motivation to get to the end of the road. I think the choice helped me to be motivated.

Austin: Letting me be able to choose what I wanted to do, engaged me more so I was more susceptible to receiving the information that was given to me in these projects.

Maria: It helps me a lot when I have my own choice to use what information I learned and how I got to express my learning to the audience. So, I think it's really important for teachers to think about what different ways of information you can present to students.

Also, what kind of expressions you allow students to use.

These comments provide insight to how autonomy affected PSTs' motivation and engagement, which is another benefiting aspect that will be detailed more in the next section. Having a say in how and what they learned seems to have greatly contributed to these PSTs' engagement and motivation. Based on their comments, Lily and Austin perceived having choice benefited their learning experiences because they were able to choose tasks that interested them. In Lily's comment above she described how she was not forced to learn in one certain way. Similarly, some discussed how choice makes it feel like a game:

Lily: I think keep a lot of options and choices. I found that makes it seem more of a game to me to have a lot of choices. I really liked, that was my favorite one.

Maria: Gamification is definitely, I think it's a very beneficial tool in future education or nowadays education in the classes where students, they can learn from enjoyment, not just simply learning in a bored way. They don't want to learn because a lot of secondary education, they are forced and I don't want to say forced, but it's required. It's not what they choose to pursue.

Maria extended the idea of gamification to how it increases student engagement and motivation:

Most students have that mindset think, oh I go to school just because I have to. It's not, I choose to. So, implementing this kind of game method of teaching will engage them and motivate them to learn and maybe also they will find some interest in that process.

Maria's comments emphasize how choice and the game-like approach is more engaging for students because it does not feel like a task they are forced to do. In addition, she seems to think having student choice can help students develop more interest in what they are learning. As evidenced in the above quotes, multiple PSTs' expressions conveyed that they believe having choice has positive impacts on engagement and motivation.

In addition to having choice, several PSTs mentioned the multiple options of tasks. For instance, Austin said, "The game itself split up well to give you multiple options to do stuff. So, one thing was, if you didn't understand a growth mindset through one option, you had multiple options that work for it." In another instance, Will noted, "The amount of ways that you can present material is substantial, especially with these, with this topic, there was so many options of activities to do to familiarize ourselves with growth versus the fixed mindset." In these comments, Austin and Will indicate they found the number of options benefiting to their learning: Moreover, some PSTs discussed the variety in the kinds of tasks included in the OGT:

Austin: Along with having the optionality, I like the variety, what was asked of us to do because the Twitter one you're looking up stuff and the card one you were working with something physical. So doing different things, you could have had a lot of options to do things, but they were all Twitter based or they were all physical based. But having a variety of different outlets to go find a growth mindset out of was interesting and helpful.

Travis: It was very diversified in the tasks. Not everyone is like me and tries to jump for the biggest thing on there. And that's good. Some people need small bites, some people need big bites.

The ideas voiced in these comments connect to how multiple PSTs found it helpful in choosing tasks they found interesting. By having a variety of ways to learn about mindsets, it seems more PSTs were able to find tasks that interested them. A few PSTs mentioned the game structure or how the way the game was organized was helpful as they chose tasks to complete:

Caitlyn: I liked how within the growth mindset game and having encouraging, something being challenging, or things represented in different ways. You were able to work through that, within it. So, we had the critical thinking or the game designer, social media and so, people were able to work in areas that they wanted to and able to learn about growth mindset.

Travis: You had three different sorts of mindsets within that game, so it was a little easier for someone to say, "You know, I'm a creator."

Maria: I think you said three different categories, computer hacker, social media, - and game design. Yeah. That definitely offers student choice and they are still learning.

In these comments, PSTs are describing the different categories that organized the tasks within the OGT. Yvette also mentioned these categories:

Yvette: Something that I did like about it and you should definitely keep was you had different genres of you had the computer hacker, you had the social media manager, you know you had, as far as I can tell, those are almost different, what are they called?

Learning techniques or whatever.

Me: Learning styles?

Yvette: That's it. They're almost different learning styles. Not totally, but somewhat. I do like the amount of options.

The above comments highlight how people learn differently and by providing options, one can choose tasks that are best for his/her learning needs and preferences. It appears, based on their interview comments, these PSTs liked how the tasks were organized by 21st century professions and found the layout of the OGT helpful as they searched through the options of tasks. However, not all PSTs agreed with this aspect of the OGT. Two PSTs' expressions indicated they thought the organization of the OGT was somewhat confusing. This differing perception will be detailed in the Limiting Aspects section of this chapter. Nevertheless, most PSTs indicated in their interviews that having multiple options and a variety of tasks was a beneficial aspect of the Mathematical Mindset OGT. As Will stated, PSTs were not limited to learn about mindsets in one way:

The fact that you had so many different options, you weren't limited to one task or whatever. You could literally go into whatever profession that you chose, and it didn't matter what profession you chose, it didn't matter what activity you chose, you were still learning about the concepts of growth versus fixed mindset.

Likewise, Caitlyn thought it was helpful to have "different representations of things and also there not just being one way of learning about growth mindsets and discussing it." These quotes highlight how PSTs had multiple pathways to develop understanding about mindsets. With this autonomy, they had more freedom to choose how and what they learned.

As previously noted, having choice allowed PSTs to complete tasks that interested them. However, the main goal of this OGT was for PSTs to learn new information about mindsets through challenging tasks. With this intention, the directions in the OGT included growth

mindset messages (highlighted in Figure 4.4) aiming to encourage PST to choose tasks that would be appropriately challenging for them. A few PSTs noted that they chose tasks that involved something they wanted to learn about related to mindsets:

Austin: That was a question I had was, you have a student that may be saying something like that. What's something you could say back to them that supports them?

Keanna: I picked the Favorite No, because it was actually a teacher representing what a growth mindset looks like in the classroom and I wanted to see what that was first to help me understand what it was a little more.

Yvette: I knew what Kahoot was, so I was already drawn to that and the whole neuroplasticity thing really interests me. So, because that was directly related to it, I was drawn to that.

The ability to choose tasks seems to have benefited PSTs' understanding by allowing them to

Let's Play! I am Captain Layton, your traveling guide. Welcome to my game where you get to travel to see different careers and complete challenges.

You will visit different 21st century careers and complete challenges to get points. These challenges will help you learn about mindsets and how teachers can foster a growth mindset. You have multiple paths to collect your points. Choose challenges you will enjoy and that will HELP YOU LEARN about mindsets! Have fun and safe travels!

Game Rules:

1. You must collect at least 100 points by class on Friday, March 29th.
2. For each career challenge you complete, include the following on your game portfolio:
 - Title of challenge
 - Amount of points the challenge is worth
 - All collaborators (if any)
 - Your submission for the challenge (link, text, image, etc.)
3. Everyone starts and ends in Your Classroom.

Part of this game is figuring out how to solve the challenges on your own or with others playing the game. If you get stuck or struggle to complete a challenge, that is not a bad thing! That means you are learning!!! Persevere through the challenge. You can use your peers and any resources available to you to complete the challenges.

Figure 4.2. Mathematical Mindset OGT directions with growth mindsets messages

choose tasks based on their learning needs and wants. In effect, the OGT seems to have provided PSTs a personalized learning experience. This idea was communicated by Danielle:

I liked that we were given the information about it beforehand and then given a bunch of options. So, I liked the variety in terms of, well there's one that I was thinking about doing where you reacted to the video where there was one where you could make a video. So that's somebody who's more creative. I'm not a super creative person and I don't like to film myself and so the one where you film a video of yourself seems, I'd be tortured, please don't make me do that. But I'm sure other people are oh my God, that sounds so much fun. So, I really did enjoy that you could personalize it.

Danielle liked being able to choose challenges that would provide her different experiences, as evidenced in her comments. She further explained this point as she noted, “I thought it would be good to have for myself, two different things.” She chose to complete the Kahoot because she thought it would be fun to talk about the material; whereas, she thinks the Cut-a-Card task involved implementing the material. This reasoning is shown when Danielle stated, “I thought it'd be fun to do something to where I was actually talking about the material rather than just implementing material.” As reflected in her comments, she perceived that these two challenges provided her different learning experiences.

Maria provided another insight to how this OGT offered a personalized learning experience. She discussed the importance in having not only different options of presenting information to learners, but also different options for them to express their understanding:

Provide different instruction for students. So, you putting a lot of resources, different resources, either a video to help the students who are visual learners, who learn better by

listening and stuff like that. Also, you put articles, maybe a lot of people are fast readers. They can learn much better with the context, with the words written on the paper so, differentiate instruction. How you provide me different materials, material in different ways to help students learn subject and now that's the output, this is input different ways of input. But what kind of output you allow student to deliver to you? The presentation, expression, what kind of expression? They can use a picture, draw a picture to indicate their understanding or they can write in words. Just provide as many ways of delivering their understanding.

Based on her comments, Maria interprets the ways instruction is delivered to learners as inputs and the ways students deliver and express their understanding as outputs. Furthermore, she appears to perceive the OGT included options for both inputs and outputs as indicated when she described the tasks she completed. Maria believed the Cut-a-Card and Kahoot Quiz challenges provided her different ways to express her understanding. For the Kahoot Quiz, she noted it allowed her to be an inventor because “You can invent the question. You create the question for others to learn from you.” In the following quote, she distinguished the two challenges:

That's taking that shift from that Cut-a-Card game from where you re-invent, recreated what others already recreate. You are learning something from somebody already established, but whereas the Kahoot game you learn some information and apply information to create something new.

This quote indicates Maria perceives the Cut-a-Card challenge as solving something someone else created. On the other hand, she perceives the Kahoot game as allowing her to create and “actually do something that's my own work.” She further described this perception:

It definitely is shifting from learning the knowledge of the growth mindset and fixed message into creating my own works. You'll see my own words and you'll see my own examples. It's really helped. Helpful, more memorable too in the future.

Her comments reflect a sense of ownership in creating her own example questions for the Kahoot quiz, which she felt helped her learn and would help her retain what she learned. Thus, this ownership is another way Maria found autonomy as a benefiting aspect of the Mathematical Mindset OGT.

Another idea regarding autonomy involves PSTs' freedom to explore resources. In the Starting Challenge, they were provided multiple resources to learn about mindsets including links to articles, presentations, and videos in which they could freely click on and review. In other words, they were not limited to read a set of materials in a predetermined order. Two PSTs mentioned this autonomy that was provided in the Starting Challenge. For instance, Lily stated, "There was still a little bit of choice. The Padlet, I think there are a few things you could choose. You didn't have to watch every single thing or read every single article." In another instance, Keanna described how the freedom of exploring resources in the Starting Challenge kept her engaged:

The mindset resources. I didn't want to move on to what we were doing because I spent so much time on the mindset resources, just looking at all of those and I guess it's cause they were all right there for me to move around and open one and then close it. I think that was a really good starting off point because I saw all the peer reviewed articles and things about mindsets that there are. It's a big field and it's important and I could see that from those articles or videos in that section. I think that part was really helpful.

Her comments speak to the interactive aspect of the OGT and how it allowed learners to freely click on and access resources they wanted to explore, which evidently engaged Keanna. As previously noted, the resources within the OGT were provided using various technological tools. Thus, technology is another element involved in the autonomy PSTs experienced using the OGT.

Affordances of technology. Technology played a major role in designing this OGT with learner choice and a variety of tasks. Therefore, it is important to consider how technology afforded PSTs more autonomy as they learned about mathematical mindsets. PSTs mentioned multiple benefits of technology in their interviews including accessibility, immediate feedback, social learning, and visuals. As for supporting learner autonomy, the following paragraphs focus on how technology afforded autonomy to PSTs as they learned about mindsets.

Perhaps the most impactful affordance of technology was PSTs' accessibility to a variety of resources. Google apps and Padlet were online tools used for sharing resources with PSTs for them to explore. With this approach, PSTs could freely move around the website and review resources independently. These online tools also afforded autonomy by allowing PSTs to access the OGT anytime and from anywhere. Additionally, they could choose which resources they wanted to use to learn about mindsets. A few PSTs mentioned the articles and/or presentations, however most seemed to find the videos more appealing. Will provided an explanation of why his generation prefers videos:

The YouTube videos embedded within are super important and helpful I think because, the older I guess our generation gets and the upcoming generation, the less they want to read. So, if they can have somebody explain it to them in a YouTube video, it's going to be really helpful.

Yvette, Brandon, Travis, Lily, Danielle, and Keanna also mentioned using videos indicating they were the most frequently used resources in the OGT. Yet, it's important to realize that PSTs could use any or all the resources they wanted. In addition, the entire OGT could be accessed outside of the classroom. Keanna noted, "If I'm allowed to keep the link then I'll probably keep going back and looking at those resources." As shown in interview comments, the online tools embedded in the OGT allowed PSTs accessibility and autonomy to explore mindset resources of their choice.

Another notable outcome related to autonomy and technology is that this OGT afforded the possibility for PSTs to be creative and go beyond expectations. The tasks included in the OGT are open tasks that have multiple pathways in solving or completing them allowing various degrees of creativity in responses. However, some of the tasks required PSTs to create a product such as an activity or video. These kinds of tasks are open to virtually endless possibilities. With this open format, Travis incorporated the application of online tools he learned about as he became Google certified, which is a requirement of his teacher preparation program:

We're going through Google educator certification and then I thought, well since mindsets is actually so important to me, maybe I should just make a whole other page on my website about the neuroscience of education. So, I ended up posting the videos. The first thing, it's a very simple website at this point.

Travis figured out how he could use YouTube and Google sites to communicate growth mindset messages to his future students and their parents. As previously detailed, Travis created a video of his own mindset journey. In the following quote, he explains how using this OGT helped him determine his plan for sharing his video:

The reason why I said that it was a Google website, right? Because again, that's where I got the idea of creating my Google website. I was like, I think that was a site. I wonder if I could put some stuff because you made a website for us to go to and do this thing. What if I made a website for students to go to and do this thing? And I did have an application for it at the moment.

As can be seen from his comments, Travis went beyond what was expected for the Video Creation Challenge and created a website to make his video accessible to students and parents. Therefore, it appears the OGT modeled a classroom application of online tools he learned about while becoming Google certified. A small number of other PSTs expressed ideas related to the use of technology similar to this study's OGT. For example, Maria said, "Especially for students nowadays, technology is a big thing. Almost everyone knows how to play games." This comment indicates Maria is thinking about the use of technology to facilitate learning games. In another example Brandon described using technology to teach students about mindsets:

Kids know how to use technology now. So, I think it's a good thing to try to incorporate this idea through technology because they know how to use it and they like using it. So, why not try to incorporate something important.

However, for Travis, it appears the OGT provided him a significant amount of autonomy to be creative, which motivated him to create a video and a website to share the story of his mindsets shift with others.

In conclusion, autonomy was perceived as a benefiting aspect by most PSTs. Nine PSTs indicated this perception as they discussed having choice while learning about mathematical mindsets. It's important to note that the choices provided throughout this game were possible

due to the affordances of the technological tools that compose this game. Therefore, the affordances of technology support the perceived benefiting aspect of autonomy.

Engagement

As has been noted, multiple PSTs deemed that having autonomy to choose tasks contributed to their engagement. They expressed perceptions in their interview comments that having choice allowed them to personalize their learning experience and complete tasks based on their interests. In addition, a few PSTs discussed the use of games to make learning more enjoyable. For these reasons, engagement was identified as another benefiting aspect perceived by PSTs.

All the PSTs that participated in this study expressed in their interview comments that the Mathematical Mindset OGT engaged them in some way. Learner engagement is commonly described as a multidimensional construct comprising the following three components: cognitive, behavioral, and emotional engagements (Christenson, 2012; Connell & Wellborn, 1991; Groccia, 2018; Kong, Wong, & Lam, 2003). According to Groccia (2018), these components engage learners at three levels through what they are thinking (cognitive), doing (behavioral), and feeling (emotional). Examples for these levels of engagement are presented in Connell's (1990) comprehensive model of student engagement as shown in Table 4.1. PSTs expressed emotional engagement through words such as interest, like, fun, curious, love, and enjoy. Therefore, emotional engagement will be the focus for this theme. However, indications of cognitive and behavior engagement are connected to other themes and will be discussed before presenting emotional engagement.

Table 4.1. Cognitive, Behavioral, and Emotional Engagement (Connell, 1990)

<u>Cognitive</u> • Flexible vs. Rigid Problem Solving • Active vs. Passive Coping with Failure • Independent vs. Dependent Work Styles • Independent vs. Dependent Judgement • Preference for Hard Work vs. Preference for Easy work											
<u>Behavioral</u> • Class Participation vs. Uninvolvement • On-task vs. Off-task Behavior • Extra-curricular Academically Oriented vs. Extra-curricular Non-academically Oriented • Career Plans • Classes Skipped • Tardiness											
<u>Emotional</u> <table> <tr> <td>• Anger</td><td>• Interest</td><td>• Nervousness</td></tr> <tr> <td>• Happiness</td><td>• Sadness</td><td>• Curiosity</td></tr> <tr> <td>• Boredom</td><td>• Discouragement</td><td>• Excitement</td></tr> </table>			• Anger	• Interest	• Nervousness	• Happiness	• Sadness	• Curiosity	• Boredom	• Discouragement	• Excitement
• Anger	• Interest	• Nervousness									
• Happiness	• Sadness	• Curiosity									
• Boredom	• Discouragement	• Excitement									

Cognitive and behavioral engagement are tangled in other themes previously mentioned. First, cognitive engagement was expressed when PSTs described experiences of struggle, perseverance, and thinking deeply, which is detailed in the experiential learning section. Thus, some PSTs comments indicate their cognitive engagement as they used the OGT, especially while solving the Cut-a-Card task. Second, Danielle and Caitlyn described the two phases of experiential learning, active engagement and reflection, as they discussed using the OGT. These phases of experiential learning connect to engagement in two ways. First, according to Skinner

and Belmont (1993), active engagement encompasses both behavioral and emotional. Second, reflecting and thinking deeply about learning signifies cognitive engagement. In addition, Travis revealed his perception that this OGT behaviorally engaged PSTs:

It was laid out very nicely. There were a couple of fun little things like go make yourself an Avatar and make your game portfolio. Those are modern nuances to our online presence that's fun. It's fun to do and anybody can, even someone in my age group can be like, "Oh well, I've never done that before. I wonder how I would do that." So, it was fun, and it got me involved instantly. So, the layout in general I think was very beneficial as to actually get your participant involved.

In his comments, Travis described how he thought the Mathematical Mindset OGT offered instant involvement implying that one would be interacting and participating quickly as they use the OGT. Furthermore, the social interactions detailed previously further indicates that PSTs were behaviorally engaged while using this OGT. As can be seen, cognitive and behavioral engagement were conveyed during interviews with PSTs and are subsumed in other themes previously detailed. The rest of this section will present how emotional engagement that was expressed in interviews with PSTs.

Emotional engagement involves how one feels as he/she engages in learning activities which can lead to positive or negative reactions toward his/her learning experiences (Martin & Torres, 2016). Factors related to emotional engagement include self-efficacy, expectations, perceived control, autonomy (Ainley, 1993; Skinner & Belmont, 1993), boredom, happiness, and sadness (Christenson, 2012). All the PSTs expressed experiencing positive emotions at some point while using the OGT. The following quotes represent typical comments that capture PSTs' emotional engagement:

Danielle: So, I really did enjoy that you could personalize it.

Yvette: I really enjoyed that one because it was so puzzle-like. And I really enjoy puzzles.

Travis: It was playful, and when I say playful, there was no any sort of point where you go, ugh this is discouraging. Everybody else I saw interact was happy to do so. They enjoyed what they did.

Brandon: And I liked that one specifically the most because I found one tweet, it had a bulletin board and it had a quote from a bunch of famous people like Albert Einstein or Michael Jordan, a famous athlete or a president or something like that. People that you know, and they like. All the quotes were a growth mindset type of quote. So, it was really interesting to read some of those.

Keanna: I didn't want to move on to what we were doing because I spent so much time on the mindset resources.

Austin: I thought when I began the project, I had a path in mind, but then I completely changed as I was doing it. So, the card one caught my attention after I saw it and wondered what was going on. So, I wanted to figure that one out first because it's very interesting.

Maria: I really like that Cut-a-Card activity in the game, online game thing. It was very, to see a different way, different perspective to approach a problem. I think it's interesting.

These quotes consist of example emotions such as enjoyment and interest that indicate PSTs found using the OGT as an emotionally engaging experience (Connell, 1990).

Some PSTs referred to specific tasks as they conveyed the benefiting aspect of engagement. Yet again, the Cut-a-Card task was most frequently mentioned as inducing

engagement. The following quotes provide some insight to why this task was found to be especially engaging:

Austin: Just the unnatural appearance of the index card as it was being cut and I thought, that's a cool trick to show your friends too because it blew my mind. Because all my friends, they're like, "Oh [Austin], your math, that's cool or whatever" and they think it's lame, but then you show them something like this and I'm like, "What? That was done with math somehow?" and you're like, "Yeah.' I guess so." It's just an interesting party game I guess.

Maria: First, it's really more visually learning. I think I learn better by seeing picture or stuff. So that's why a picture is worth a thousand words. When I saw that picture, I thought, that's fun and it's a hands-on experience and that's why I chose it.

Lily: Looking at the picture, I had absolutely no idea how that worked and so, I wanted to know how the card was like that. I think is why I picked that because I wanted to know how. (Lily)

Based on these comments, the visual aspect of the Cut-a-Card challenge seems to have contributed to PSTs' attention and interest while solving this task. The task's goal was to make an index card look like the example card that was folded and taped to a piece of paper. The example card was displayed on a table at the front of the classroom and a picture of it was on the OGT (as shown previously in Figure 4.1). The visuals seem to have grabbed PSTs attention initially and then the challenge of the task further engaged PSTs as they developed determination to solve it. This notion was reflected by Will as he described the Cut-a-Card task: "You start with something that looks interesting and possibly easy and then you learn that it wasn't easy. But at that point my mindset was that I had to get it done because of determination and curiosity." In

Austin's quote above, he raised the idea regarding how a task like this might help people with negative feelings toward math find the subject more interesting. His comments insinuate that the visual aspect of this task evokes engagement through curiosity and enjoyment and thus, can help people view math more positively. Overall, several PSTs indicated that they found the Cut-a-Card task engaging as expressed through emotions of interest, curiosity and enjoyment.

Another task that PSTs appeared to find emotionally engaging was creating an online quiz. In this challenge, PSTs chose to create Kahoot quizzes about mindsets. The following quotes reveal PSTs' engagement from this task:

Caitlyn: One of them was the Kahoot game and that was fun trying to put questions that weren't super easy, but allowed students to think a little bit harder about what growth mindset actually is and the difference between the fixed mindset.

Maria: I really enjoyed that on Kahoot creating question thing. It took me a long time because I really think deep and provide some scenarios. I put a lot of scenarios.

Yvette: Because I knew what Kahoot was, so I was already drawn to that.

These comments contain words describing PSTs positive emotions, which indicates they enjoyed this task. Yvette's comments bring attention to another interesting point in how she was drawn to the task because she was familiar with Kahoot. This reasoning implies she had previous positive experiences using Kahoot quizzes and therefore, was inclined to create one of her own. Her comments suggest that her familiarity with and positive experiences using Kahoot influenced her to use this tool to create an online quiz about neuroplasticity, a concept she found interesting. Likewise, two other PSTs' indicated during their interview that they also chose tasks based on familiarity:

Brandon: When I saw the Twitter one, I was like, oh that can't be hard. Let me just go to Twitter right quick because I love Twitter. I'm a big Twitter user. And then I guess that was another reason I picked it, because I connect with Twitter, because I understand Twitter. I use it all the time.

Travis: As far as the creator challenge, the video, when you first introduced the game to us, I immediately saw that out of every single thing that was an option. That was the one I wanted to do. I've made movies throughout my life. I'm a creator. I've been a professional artist for a large part of my life.

According to their comments, Brandon and Travis chose tasks based on their familiarity with what the task entailed. Therefore, their interview comments provide further support that familiarity and past experiences contributed to several PSTs' engagement while learning with the OGT. To demonstrate, their familiarity and positive experiences using similar tools helped PSTs choose tasks they found interesting and engaging. For example, Brandon had previously enjoyed using Twitter, a tool commonly used for people to communicate information and ideas. Having enjoyed using the social media tool previously, as noted in his comments, helped him choose the Twitter challenge, which he expressed was engaging to him. Moreover, learning about growth mindsets using Twitter allowed Brandon to see how this tool can be used for productive, educational purposes. As for Travis, he specifically stated he has created videos before, which influenced his immediate attraction and interest in the Video Creation challenge. All things considered, it appears several PSTs drew from past experiences to choose tasks they thought would be enjoyable and interesting; therefore, familiarity contributed to their engagement while learning about mindsets.

All things considered, the majority of PSTs' interviews convey the impression that emotional engagement played a major role in their choice of tasks. In other words, most PSTs appear to have sought tasks that they thought would be enjoyable and interesting. Therefore, it seems their goal was to be emotionally engaged. This notion is further supported by Danielle's comments as she discussed choosing challenges based on what she wanted to do rather than the amount of points the task was worth:

Honestly, cause that's just how the math worked out. Because I wanted to do those two because I did the Cut-a-Card and that was already 30 (points) and then I wanted to do something using the material and not just applying it. So, the Kahoot sounded like the one I wanted to do and the math just happened to add up and if the Kahoot had been just enough to put me at a 100, I still would have done it. It just happened to go over.

She expounded on what challenges she thought would and would not be fun:

It (Twitter challenge) just doesn't fit with my personality and what I like to do with things and again, the paper one was one where I could do it, but these other ones sound more fun while still covering and learning the same basic things.

As she noted, Danielle did not complete certain challenges because she did not think she would enjoy them as much as the challenges she chose to complete. As can be seen, Danielle chose challenges she believed would be fun and thus, emotionally engaging.

As evidenced in their interview comments, all ten PSTs who participated in this study found this OGT to be engaging in some way, especially emotionally engaging. PSTs mentioned their interest, curiosity and enjoyment as they used the Mathematical Mindset OGT. In addition, PSTs' described experiences of active engagement, thinking deeply and social interactions,

which are indications of cognitive and behavioral engagement. Ultimately, all the PSTs conveyed perceptions of engaging experiences as they used the OGT.

Limiting Aspects

For the final research question, interview transcripts were analyzed to understand the aspects that PSTs perceived limited their learning experiences while using the Mathematical Mindset OGT. Their perceptions of limiting aspects were more varied and consequently, themes were less apparent. Yet, through multiple cycles of analysis, connections among their perceptions surfaced and themes were identified. The following three themes represent the aspects PSTs' perceived as limiting to their understanding of mathematical mindsets: 1) Time Constraints, 2) Clarity of Game Structure, and 3) Development of Some Critical Understandings. Similarities and differences among PSTs perceptions within these three themes are presented in this section.

Time Constraints

The most evident limiting aspect perceived was time constraints, which was conveyed by six PSTs. Naturally, according to their comments, PSTs considered the amount of time tasks would take when deciding which challenges to complete. As they described these considerations, it was apparent certain tasks were chosen less or not at all because PSTs perceived they would take too long. Additionally, a small number of PSTs expressed wishes to have more time to use the OGT. These insights will be further detailed in the following paragraphs.

Perceptions regarding time constraints were seemingly influential in affecting PSTs choice of challenges or tasks to complete. The most frequently mentioned task that dissuaded PSTs was creating a video. Multiple PSTs commented on not choosing challenges that required

creating a video. For instance, Will initially expressed a desire to create a video and then changed his mind. He provided an explanation of his decision:

Me: I remember you saying at first, “I really would like to make a video.”

Will: Yeah, I thought about a video and then due to a lot going on that week, I didn't think I would have time to put in the effort that I would like to put into a video.

Me: Okay

Will: So, I just switched to stuff that I could do during class rather than outside of class material.

Will's comments indicated he was deterred from creating a video because he perceived it would take too much time for the amount of effort he would want to put into this task. This thought reveals Will was interested in creating a video and furthermore, cared about the quality of the video. However, this seemingly positive thought in the end dissuaded him from completing this challenge because it would take too much time. Likewise, Austin detailed how he thought creating a video would be fun, but would take too much time:

One of them was making a video or something and I thought that would take too long in my busy schedule. I couldn't do that one because I didn't have time to do it. It sounded fun though, but having to go through the process of designing a video, making a video and then editing it, uploading it, all that stuff just seemed a little bit too much. But it was worth a lot of points.

Austin perceived the process of creating a video as complex with multiple steps that would take too much time, as evidenced in his interview comments. Additionally, he stated it was worth a lot of points, so he seemed to think the point value was appropriate. Despite believing the Video

Creation Challenge would be fun, his comments indicate that his perceived time constraint drove his decision in not completing this challenge.

Conversely, Yvette did not believe the point value for creating a video was appropriate for the time and effort it required. The challenge she referred to involved creating a video, but it was a different challenge than the one referred to by Will and Austin. Yvette was referring to the YouCubed Challenge that required solving a YouCubed task and reflecting on how the task supports a growth mindset. She started this challenge and completed the YouCubed task in class. However, she thought this challenge also required her to create a video explaining how she solved the task and therefore, she did not complete the entire challenge. Yvette misunderstood the directions in that the video was an optional part of this challenge to obtain extra points. This misunderstanding led her to explain why she did not choose to create a video:

Yvette: 10 points for an entire video given how little time we have as students. That seems like a really small amount and I know this isn't a super serious thing. I don't think this was for a grade. I can't remember. But it wasn't a super terrible thing. That's what only 10 points for a video. But if this were more, what's the word I'm looking for? Weighty, I guess.

Me: In your grade or class?

Yvette: It had more to do with the grade and that was one of only a few options or whatever, then that would be okay, that's really not cool. That's like here, write this five page paper for a two percent boost to a quiz in this giant class. Do you think I got time for that?

In these comments, Yvette expressed that her perceptions were apparently influenced by the OGT tasks not weighing into her grade. These thoughts seem to have potentially influenced the

time and effort she thought she should put into completing challenges for this game. In addition to her focus on grades, Yvette was focused on the reward or amount of points the challenges were worth. She did not perceive some of the point values were appropriate considering the amount of time it would take to complete the challenge as she directly stated, “I think a some of the points where a bit skewed.” At this point, I felt that Yvette might have misunderstood the type of video this challenge required, so I tried to clarify the intentions for creating a video for this challenge. Our next interactions were as follows:

Me: I definitely get what you’re saying and my thoughts were you do that activity, and then quickly record yourself on a phone or on a quick video saying this is how I did the activity. Record your explanation, how you solved it. If you were to give an amount of points, what would you think that would be worth?

Yvette: That sounds really simple, it sounds simple in practice, but then when I'm actually visualizing, how would I do that. Then I would have to, I would either have to hold it and do it as I do it. Sorry, film as I perform each of the problems, which could get really awkward or I would have to film it and just try to explain it without visually representing it. So then if I wanted to do both, explain it and do it, then I would have to prop it up on something and, I overthink things a lot to be fair.

Me: But it just wasn’t worth it?

Yvette: Yeah. I don’t know. Just 10 points plus there's how would we upload that? So, then we'd have to go to the trouble of rendering it on YouTube and uploading it to there.

Me: Okay

Yvette: And then having to link that and everything.

Yvette clearly found, as evidenced in these comments, the process of creating a video complex and time consuming and therefore, difficult for her to complete. Her detailed description of steps for creating a video provided a better understanding of why she perceived this time constraint. In addition to videos, time constraint perceptions were conveyed for other tasks. For example, tasks that involved critiquing another peer's work were not chosen because PSTs felt constrained by time, so they chose not to complete them:

Brandon: Yeah, unless you were doing it that day we had met initially, but I don't think anyone had time because I think most people did one thing and they might've ran out of time to do anything else because we were short on time I think.

Danielle: I think some of those would have been more helpful in a bigger class because with only nine people, it was hard to tell if anybody was going to do any of those.

These quotes indicate these challenges were perceived to be difficult to complete in the time frame given. Having to wait to see if a peer completed one of the challenges within a small class deterred PSTs from choosing these challenges. However, this was not the case for Kahoot quizzes. Some PSTs chose to complete a peer's Kahoot quiz likely because they were familiar with this tool and could more easily access their peers' Kahoot quizzes. PSTs' perceptions of accessibility will be further discussed later in the next section. Other more general examples of perceived time constraints were expressed by Brandon and Keanna:

Brandon: Some of them I didn't quite understand what to do and some of them I was wondering how long it might take.

Keanna: There was an activity that asked for a two page paper and I didn't pick that because I thought it would take too long. But if I was given more time, I don't think that it would pose an issue at all. It would be a great activity to write a paper about mindsets.

But I just didn't choose that one because I thought it would take too long. But I thought all of the activities were really enriching. If I had time to do them, I would definitely do all of them. I couldn't find any of them that I would be like, oh, I don't think this would show me what a growth mindset is. It was just picking the ones that would fit into the time period that I had that day, was really the idea.

These comments highlight the influence time had on these PSTs' decisions. To detail, Keanna first chose to complete the Cut-a-Card and My Favorite No challenges, which she indicated was based on wanting to interact with peers and learn a classroom application of teaching practices that support a growth mindset. She then chose to play Yvette's Kahoot quiz "as a time thing" and because it was worth the exact points she needed to obtain:

I needed 10 more points and I knew that I could do a quiz to get the 10 more points. And there weren't, I don't know there were any other ones that had a small amount of points for an activity. So, it was more finishing up.

As she noted, Keanna considered the time and point value as she selected the last challenge. Later in her interview, she expressed that she would like to further use the OGT: "Having more time to look at it. So, if I'm allowed to keep the link then I'll probably keep going back and looking at those resources." This comment indicates Keanna would like to learn more about mindsets. However, she chose her last challenge based on time and amount of points rather than on what she wanted to learn.

Overall, it is evident time constraints were influential on many PSTs' choice of challenges. A small number of PSTs suggested it would be beneficial to provide more time to learn about mathematical mindsets. First, Yvette suggested giving a "slightly bigger time frame

to do it.” Second, Danielle took this idea a step further and described using a long-term approach to teach about mindsets:

I think it'd be interesting to make this more a long term thing to meet with freshmen and do something like this their very first class as a teacher and periodically check in and do sort of mindset type things throughout rather than just one weeklong thing and then you know we're done.

Danielle's comments suggest she thinks it would be more effective to learn about mathematical mindsets consistently throughout a teacher preparation program, rather than one isolated weeklong module. This approach or at least implementing the OGT for a longer period could potentially alleviate the perceived time constraints and help PSTs make more choices based on their learning interests and needs.

Clarity of Game Structure

Six PSTs' interview comments expressed confusion at times while using the OGT. Analysis of these comments shed light on the OGT's games structure elements lacking in clarity. These elements include the game's goals, instructions, and feedback. Some of these PSTs found the OGT's game structure in general to be lacking in clarity while others found specific challenges to be confusing. Additionally, another limiting aspect related to the OGT's structure involves one's ability to access it and the resources within it. These games structure elements will be presented in this section.

Three PSTs mentioned confusion related to the overall goals of the game. First, Will and Austin discussed how the theme of the game was misleading and confusing:

Will: I think when students see computer hacker or stuff like that, we figured that maybe it would be more oriented towards that profession, I guess you could say. So, computer

hacker and coding, so maybe a game or something on coding or just things that go more with the profession that you choose, I thought would be more beneficial, I guess.

Austin: The subcategories that you chose, I forget what it was a game developer or social media outlet. I didn't necessarily understand why you chose those titles. Maybe if you had every option in one list or something instead of splitting them up into three different categories. Because it wasn't hard to look for stuff to do but having to go through each tab and looking through all of them and then picking one and then having to go back to it or some. Navigating through the page might be a little bit simpler if you had a list of all the activities on one page.

It appears the organization and theme of the game caused confusion on what the overall goal was for the Mathematical Mindset OGT. As Austin noted, he thinks it would be easier to navigate the game if all the challenges were together rather than divided among multiple pages. Lily also experienced confusion initially:

I think at first, I was confused how it worked, but then once I actually started doing it, I got what I was trying to do. I just need to pick a number of activities that will get me these points. But initially I was confused, but once it actually was doing it, that was kind of went away.

This initial confusion as Lily began the game brings attention to the need for clearer goals and instructions. Lily constructively provided suggestions to make the start of the game smoother:

A map, so to speak, of this is the starting, because we had to do the starting and then we got up in the classroom and so, I was confused about what happened in between. What that would look like and then once I realized, oh, I just need to get those points to get to

100 and I already have these points here. I'm going to have to do these, so I already have those. But I think I wanted...I was confused about the bigger picture.

Lily's recommendation for adding a map or a figure to visually represent the game process relates to the overall goals and instructions of the game and making them clearer. As she described, she had difficulty getting started because she did not know what she needed to do to complete the game. She noted another point of confusion: "I guess there was no way where I could see the points I was going to get accumulating I think, I don't know if you could do that in the future." In this comment, she suggests adding the ability for one to track his/her progress, which is a form of feedback. Feedback is an element of game structure and seems to be another weak aspect of this OGT. Although no other PST indicated feedback as a limiting aspect, Will was the only PST that described receiving feedback. He noted the immediate feedback one receives when playing a Kahoot quiz: "If you didn't know the answer, it gave it to you right away. If you did know the answer, you felt rewarded because you got points for knowing the answer." Thus, in addition to clearer goals and instruction, this OGT needs to provide more feedback and the ability for one to track his/her progress.

A couple of PSTs mentioned confusion from specific challenges. First, Brandon did not complete the Cut-a-Card Challenge because he was confused by the instructions: "Think it was this one, Cut-a-Card. I don't think I knew what it wanted." He suggested making the instructions clearer:

Maybe just the instructions on it be a little more, or even instead of being more specific maybe sometimes I think instructions can be a little too complex. Maybe shorten them and quick bullet points because I think a lot of people will understand short and easy steps.

Brandon clearly found the instructions for the Cut-a-card Challenge to be confusing, as evidenced from his suggestions for improving them. Another challenge noted as having confusing instructions was the YouCubed Challenge. For this challenge, Yvette completed the Four 4s YouCubed task with Caitlyn and expressed that she enjoyed completing this task. Yet, as described previously, she decided to not submit it as one of her challenges because she misunderstood the directions: “I would have done the Four 4s, except that involved making a video and being in college, that was a bit much.” We both realized she misunderstood the directions for this challenge, as shown in our following interaction:

Yvette: I really enjoyed that one because it was so puzzle-like and I really enjoy puzzles. But like I said, it needed you to do a video.

Me: I appreciate you saying that too because the video was actually if you wanted extra points. So, you could do the activity for the 40, and then for an extra 10 points, record yourself explaining it.

Yvette: So, what was the activity itself?

Me: Just doing the Four 4s activity, which you click on there to get it and then just tell me how you think it would promote a growth mindset.

Yvette: Oh my gosh, I totally read that wrong then.

Yvette mentioned this confusion throughout her interview:

For the Four 4s, there were some things where it was a little confusing as to what the actual thing was and that very well could have been my fault because I either read too slow or I scan and I don't catch everything so.

She recommended making it more obvious when a challenge had an optional part for extra points: “Perhaps you could put bonus options in a different color or a different font or something

to visually separate it other than just 10 bonus points.” Although Yvette ended up doing another challenge and did not submit a response to the YouCubed challenge, she viewed her experience completing the Four 4s task positively:

Oh yeah, I did the thing. Because I read the thing wrong, I thought we would have to do the video and whatnot, but yeah, when I found it in class, I did it for fun and it was awesome.

Yvette’s misunderstanding brings attention to how unclear directions in an OGT like the one used in this study can greatly impact participants’ learning experiences. To demonstrate, Yvette did not finish the YouCubed challenge because she thought she had to create a video which she perceived would take too much time. Therefore, she did not complete the reflection questions for this challenge and missed the opportunity to think about how such a task supports a growth mindset. This missed opportunity likely limited the understanding she developed of learning experiences and tasks that support growth mindsets.

Lastly, another confusing aspect of the OGT involved difficulty accessing online tools. Two PSTs indicated this confusion but in different ways. First, Travis explained how accessing the OGT was difficult after the first day and suggested using the university’s learning management system (LMS) to share a link to the OGT.

I’m not the only person out of the group who couldn’t find the link a second time.

Sometimes emails disappear. Because the emails disappear sometimes, maybe the only real suggestion is some way to make that site link a little more accessible.

The LMS was used to share the link with the other class and those PSTs did not express this difficulty. Therefore, Travis’ suggestion would likely eliminate this issue of accessibility. In

addition to accessing the website for the OGT, Brandon described how accessing each other's student work made it difficult to do challenges that involved critiquing a peer's response.

One thing about this one about connecting, because I guess some people had trouble trying to connect. We have a group meet in our class and some people are like can you help me do this and some people are like, oh I'm already done or some people didn't even respond and so, maybe if there's, I don't know how to apply it to where people can definitely go do it because it's only 10 points. It's real quick, real easy. So, if there's a better way to make it to where people can do that specific one because I know a lot of people definitely want to do this, a quick easy 10 points that I can get for the game.

Recall, a couple of PSTs noted they did not attempt challenges that involved critiquing a peer's work because they had to wait for their peer to finish their part. A second reason for not completing these challenges appears to be confusion accessing their peer's work. As a result, difficulty accessing each other's work is a limitation of the OGT because PSTs missed an opportunity to learn from each other through the process of critiquing and receiving feedback.

In summary, the lack of clarity of some game structure elements used in the Mathematical Mindset OGT was perceived by six PSTs. Their perceptions and confusions impacted their learning experiences causing some of them to not choose challenges they were interested in completing. Therefore, lack of clarity likely impacted the understandings PSTs developed.

Development of Some Critical Understandings

The final and conceivably the most significant theme for limiting aspects is that half of the PSTs' expressed indications that they did not develop some critical understandings of

mathematical mindsets. The most evident example of this perception is Keanna's and Maria's desire to learn more about math tasks that support student growth mindsets. Keanna stated:

I know activities are really important to instill growth mindsets, like the folding card activity that I did. So, I guess I need a little bit more knowledge and research on my half to know what kind of activities are good in the classroom.

It can be inferred that Keanna is talking about math tasks since she plans to teach math. Later in her interview, Keanna expressed understanding of important experiences to support growth mindsets as she described the Cut-a-Card task. I asked her how she thought that could look in a math class, she responded, "This is where I need more help understanding." In this comment Keanna took ownership in needing to learn more about math tasks. However, developing understanding of mathematical mindset tasks was one of the objectives for this OGT. A couple of the challenges focused on characteristics of math tasks that support growth mindsets, but Keanna did not choose to complete one of those challenges. For this reason, it appears she did not develop this understanding. Then again, she was able to connect how a math project from high school was an example of valuing mistakes; therefore, she had developed some understanding of a task specific to math that supported a growth mindset. Although this may be true, Keanna perceived that she needed more help with developing this understanding. Maria also suggested for the OGT to have more opportunities to "involve their thinking even mathematically." Given these points made by Keanna and Maria, they appear to have developed limited understanding of mathematical mindset tasks, tasks that support a growth mindset in mathematics (Boaler, 2016). Therefore, this OGT appears to not have developed an in-depth understanding of mathematical mindset tasks.

Another indication of the OGT not developing some critical understandings was communicated by Caitlyn and Yvette as they both expressed believing they had not learned much new information from using the OGT. When I asked Caitlyn if she had learned anything she had not previously learned about mindsets, she responded “Not that I can remember off the top of my head.” Caitlyn said she had already heard about growth mindsets before in one of her education courses, but she couldn’t “specifically remember which one” and when asked if she remembered what they did, she responded: “Not exactly, but I just remember talking about encouraging the growth mindset in the classroom.” She also said, “I’m trying to remember when I did learn it, what did we do to really introduce it” and “it was probably more hands-on and not on the computer and I can’t remember exactly what we did.” These comments provide little insight into Caitlyn’s previous experiences learning about mindsets, but they do reveal she perceives to have developed little new understanding in this study. She also views the OGT to not be hands-on, implying she does not think it involves active participation. This is a considerable difference in what she expressed earlier in her interview regarding wanting to use the Four 4s task with students to have them share answers and see each other struggle. She also noted she would like to learn more about YouCubed tasks: “YouCubed, I would definitely want to look at the different activities that they have there and use that specifically with students.” Her previous comments indicated she did develop understandings from this OGT, particularly the importance of providing challenging learning experiences and tasks. Yet, her ending interview statements were contradictory as she could not recall any newly developed understanding regarding mindsets.

In addition, Yvette conveyed a similar perception about not developing new understanding. However, this perception aligned more with the little insight she provided about

her understandings during her interview. Yvette clearly provided the least insight into her understandings of mathematical mindset and the most insight into her perceptions of limiting aspects of the OGT. Thus, her comments offer an important opportunity to understand why she had such a different experience compared to the other PSTs. For one thing, she described the OGT as a good refresher:

I feel if this were the first time I was learning about growth mindset, I probably would have had more pivotal moments. But because I had learned about it before, this is more a nice refresher than an eye opening super... feeling experience. Revelatory. That's what I was looking for.

Yvette noted she felt the OGT provided a review of mindsets and therefore, it is important to consider what challenges she chose to complete. Recall, Yvette completed the Four 4s YouCubed task but did not complete the reflection part of the challenge. She also created a Kahoot quiz because she was interested in neuroplasticity. In the following comment, she expressed that she did not learn much from this challenge:

It's funny because when I was explaining to my mom what neuroplasticity was, she was totally against it. I don't know if she's fixed mindset or not. I really don't. But it was eye opening seeing wow, some people totally don't agree with this or they don't see it that way. So, I don't know. I wouldn't say I learned anything totally mind blowing from this if only because I already knew some of the stuff in it. But I do like what I did learn from it if only to know okay, I'm not the only person that sees it this way, the whole neuroplasticity thing.

Her comments convey she did not perceive creating a Kahoot quiz developed much new understanding of mindsets. Moreover, she does not express having developed understanding of mindsets specific to math.

A less obvious but key perception expressed from two PSTs involves the need to have a better variety of resources. This point brings awareness to how the variety of resources impacts the understandings that PSTs can potentially develop. In the following quotes, Danielle and Maria communicated their thoughts regarding the OGT needing a better variety of resources:

Danielle: I think the one thing it's repetitive, especially the information at the beginning because there's three videos and then the two articles were one thing and then beyond that, there's that whole list of other options and a lot of them at that point are just repeating the same information.

Maria: I think probably that website you can gradually add more stuff for people to explore and learn.

They extended these thoughts to specific examples of resources provided on the OGT that they found unhelpful. For instance, Danielle specifically stated her negative view of one article being “very discombobulated.” She elaborated this view in the following statement:

They started talking about mindsets a little bit and then went off to do this study about gender and then there's another study and then again there's two sentences again about mindsets and it just felt very – And, I know, talking to other people in class, they had fairly similar takes on it though.

Danielle’s comments indicate she did not find the article helpful and that improving the variety of resources is needed to provide more information about mindsets and thus, develop more

understanding. In another instance, Maria voiced the need for a variety of resources to create better questions for the Online Quiz challenge:

Maybe the Kahoot game can be frustrating at first because you have to create many questions and you feel growth mindsets is only one big idea of this. It's hard to come up with many questions, but after thinking more deeply, you looking, searching more specific information about that, it's easier to come up with more questions. So, more you know, the more questions you can come up with.

Although Maria felt some frustration, it's important to point out that she perceived creating a Kahoot made her think deeply and learn more information about mindsets to create questions. Even still, she indicates a better variety of resources would have helped her learn more: "Maybe you can encourage them or share more kinds of resources for them to read about in order to help them come up with better questions to ask." In brief, Danielle and Maria appear to have found the resources provided in the Starting Challenge were somewhat limiting to their understanding and recommended including other resources with different information about mathematical mindsets.

A final suggestion voiced by Danielle was that she would have liked to do more challenges implying she wanted to learn more about mathematical mindsets. She thought the two challenges she completed were not enough and recommended making so "you have to do three things and not just two." She suggested adjusting the point values to require the completion of more tasks:

Make them all worth less points, I guess. Or some of the big ticket ones worth less point because in terms of, I don't know, it almost felt like I did the two things and then I was done and, I don't know, when you're talking about gaining 100 points, in my head I

thought that was going to be a bigger thing than it actually ended up being. Because especially after [Will] did my Kahoot which is another ten points, so that one assignment was already I think 60 of hundred points.

Danielle's recommendation insinuates she wanted to learn more about mindsets and did not think the point values for challenges were weighted appropriately for her to complete enough activities. This is a significant difference from how many PSTs perceived time constraints with not enough time to complete tasks.

All in all, five PSTs indicated that the understandings they developed from using the OGT was limited. In particular, most PSTs did not indicate they developed understanding of mathematical tasks and two actually indicated they would like to have learned more about math specific tasks. Two PSTs' expressions indicated they did not gain much, if any, new understanding from using this OGT. Furthermore, it was indicated that a better variety of resources and the completion of more tasks would be more beneficial. PSTs comments that provided their perceptions of limiting aspects are significant for future improvement and development of this and other OGTs. These implications will be discussed in the next chapter.

Summary

The purpose of this study was to examine PSTs' understandings of mathematical mindsets. In addition, a major focus of this study was to explore how PSTs' developed understandings using the OGT; therefore, their perceptions of benefiting and limiting aspects were explored. Table 4.2 presents the final themes identified for each participant. This summary provides a recap of the major themes for each research question. After summarizing the major themes, I present how PSTs' understandings connect to their perceived benefiting and limiting aspects.

Table 4.2. Themes Identified for Individual Participants

	Maria	Will	Lily	Austin	Danielle	Travis	Keanna	Caitlyn	Yvette	Brandon
Providing Challenging Learning Experiences and Tasks	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Sending Growth Mindset Messages		✓	✓	✓	✓	✓	✓	✓		✓
Valuing Mistakes	✓	✓					✓	✓		✓
Experiential Learning	✓	✓	✓	✓	✓	✓	✓	✓		
Social Interactions	✓		✓	✓	✓	✓	✓	✓		
Autonomy	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Engagement	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Time Constraints		✓		✓	✓		✓		✓	✓
Clarity of Game Structure		✓	✓	✓		✓			✓	✓
Dev. of Some Critical Understandings	✓				✓		✓	✓	✓	

Understandings of Mathematical Mindsets

The PSTs who participated in this study indicated in their preassessment responses that they had already developed some understandings of mathematical mindsets. In these responses, eight PSTs noted characteristics of growth and fixed mindsets and two PSTs expressed understanding of the negative dispositions many people hold toward mathematics. Furthermore, during their interviews, eight PSTs discussed negative dispositions towards math in such a way that it appeared they had become aware of these dispositions from previous life experiences. Based on the analysis of their interview comments, PSTs were able to build on this knowledge while using the OGT to develop understandings of actual practices teachers can use in the classroom to support student growth mindsets. These understandings include the following themes: Providing Challenging Learning Experiences and Tasks, Sending Growth Mindset Messages, and Valuing Mistakes. The findings for these themes are summarized below:

- Nine of the ten PSTs' interview comments reflected an understanding of important experiences and characteristics of tasks that support student growth mindsets. However, this understanding varied and appeared to be related to the challenges PSTs chose to complete. Most notably, the Cut-a-Card Challenge seemed to provide an opportunity for PSTs describe their understandings regarding challenging learning experiences and tasks. It is unclear whether this difference is due to PSTs prior understandings and/or interests that influenced them to choose these tasks and/or if completing these tasks impacted PSTs' understanding.
- For growth mindset messages, eight PSTs indicated understanding of ways to send students growth mindset messages, namely, encouraging messages, process praise, and directly teaching about growth mindsets.

- Finally, understanding the value of mistakes was conveyed by half the PSTs. Four PSTs indicated some understanding, whereas one PST reflected a more in-depth understanding of valuing mistakes. In her interview, Keanna explained the importance of learning from mistakes and practices teachers can use in the classroom to value mistakes. She was the only PST that completed the My Favorite No challenge, which she referenced multiple times, indicating this challenge was influential in developing her understanding of valuing mistakes.

Given these points, the understandings PSTs developed about mindsets appeared to depend on the challenges they chose to complete. Moreover, PSTs' expressions indicated the challenges had different benefiting and limiting aspects, which will be reviewed next.

Benefiting Aspects

Prominent themes were identified for the aspects that participants perceived as benefiting to their understandings. These benefiting aspects include Experiential Learning, Social Interactions, Autonomy, and Engagement. A review of these aspects is provided below:

- Experiential learning was indicated as a benefiting aspect from eight of the ten PSTs. These PSTs conveyed in their interviews that they learned through experiences that support growth mindsets as they used the OGT. In particular, they expressed experiencing struggle, perseverance, determination, and success. Five PSTs related these experiences to the Cut-a-Card task.
- Seven PSTs' interview comments suggested they perceived the social interactions experienced while learning about mindsets benefited their learning. Most mentioned social interactions with their peers that were in the physical classroom; however, two PSTs mentioned interactions with people outside the classroom.

- Autonomy was another benefiting aspect perceived by nine PSTs. They expressed having choice from a variety of tasks as particularly beneficial in allowing them to complete tasks they found interesting. Another factor of this theme was the major role technology played in affording autonomy.
- Finally, engagement was a benefiting aspect revealed by all ten PSTs. More specifically, all participants expressed emotional engagement with feelings of enjoyment, interest, and curiosity. As evidenced in the Experiential Learning and Social Interactions themes, cognitive and behavioral engagement were also indicated as PSTs described deep thinking, active engagement, involvement, and social interactions.

These benefiting aspects provide insight to how PSTs developed understandings as they learned about mathematical mindsets using the OGT. Before I connect how these benefiting aspects influenced PST's understandings, I summarize the aspects that PSTs perceived as limiting to their understandings of mathematical mindsets.

Limiting Aspects

The limiting aspects perceived by PSTs were more varied. Nevertheless, PSTs offered multiple aspects they perceived limited their understanding, as well as suggestions for improving the OGT. These limiting aspects include Time Constraints, Clarity of Game Structure, and Development of Some Critical Understandings. Highlights of these aspects follow:

- Six PSTs discussed time constraints in such a way that it appeared they perceived it limited their understanding. These perceptions were mostly conveyed through explanations of why PSTs did and did not choose to complete certain challenges. Most notably, PSTs discussed tasks that involved creating videos or critiquing another peer's work as dissuasive.

- Six PSTs' indicated they found the lack of clarity in the OGT's game structure as a limiting aspect, which included the game's goals, instructions, and feedback as well as the accessibility of the OGT.
- Five PSTs' communicated perceptions of the OGT not developing some critical understandings of mathematical mindsets. Seemingly, the most specific example is the lack of understanding developed about math tasks that support a growth mindset.

As had been presented, some PSTs' understandings of mathematical mindsets were limited as they did not develop some critical understandings that others developed using this OGT. To demonstrate, recall that three themes were identified for PSTs' understandings of mathematical mindsets: providing challenging learning tasks and experiences, sending growth mindset messages, and valuing mistakes. Although, the OGT seems to have provided opportunities for PSTs to develop these ideas, only three PSTs indicated some understanding of each of these three themes. A somewhat obvious reason for PSTs not developing some critical understandings is they did not choose challenges that would develop this understanding. In other words, the understandings PSTs developed likely depended on the challenges they chose to complete. The connections between PSTs' understandings and the benefiting and limiting aspects of the challenges will be discussed next.

Connecting PSTs' Understandings to Benefiting and Limiting Aspects

It became apparent that PSTs' understandings and the aspects they perceived benefited and limited their understandings appeared to be connected. These connections can help determine the activities or sources that provided opportunities for the benefiting and limiting aspects to become clearer and thus, provide contexts for PSTs to make their understandings of mathematical mindsets concrete through examples derived from the challenges. In the following

paragraphs, I first present connections between PSTs' understandings, perceived benefiting aspects and their sources. Next, PSTs' understandings, perceived limiting aspects and their sources will be discussed.

In Table 4.3, the connections between PSTs' understandings about mathematical mindsets, the OGT challenges referenced in PSTs' descriptions of their understandings, and the benefiting aspects of the challenges are presented. Each major OGT challenge is listed in descending order by the frequency in which PSTs chose to complete them. The first and most evident connection identified is how the Cut-a-Card challenge provided PSTs the benefit of experiential learning and consequently, they were able to offer examples from the Cut-a-Card challenge to explain challenging learning experiences and tasks. This task also involved engagement and social interactions, but experiential learning was often indicated as PSTs described their understandings of challenging learning experiences and tasks. The next major connection identified was between the Twitter Challenge and understandings of growth mindsets messages. Several PSTs indicated this challenge helped them learn encouraging messages to send to students. Additionally, PSTs indicated this challenge was engaging and provided autonomy to choose posts they found meaningful. Also, Brandon perceived he was able to learn from others using Twitter; thus, this challenge involves a form of online social interaction and learning. The final connection was between the My Favorite No challenge and developing understanding of valuing mistakes. Keanna was the only PST to complete this challenge and she reflected a noticeably deeper understanding of valuing mistakes. Other connections that were less evident can be seen in Figure 4.3 between developed understandings, the various challenges, and benefiting aspects. These connections offer a better understanding of how PSTs developed the critical understandings of providing challenging learning experiences and tasks, sending

growth mindset messages, and valuing mistakes. They also provide insight to possibly why some PSTs did not develop some of these understandings as it seems to have depended on what challenges they chose to complete.

Table 4.3. Connections Between PSTs' Understandings and Benefiting Aspects

PSTs' Understandings About Mathematical Mindsets	Challenges Referred to in PSTs' Descriptions	Benefiting Aspects of the Challenges
Providing challenging learning experiences and tasks	Cut-a-Card task	Experiential learning Engagement Social interactions
	YouCubed task	Experiential learning Engagement Social interactions
Sending growth mindset messages	Twitter search of growth mindsets	Engagement Social Interactions Autonomy
	Video Creation	Engagement Autonomy
Valuing Mistakes	Video Creation	Engagement Autonomy
	Twitter search of growth mindsets	Engagement Social Interactions Autonomy
	My Favorite No video	Engagement
Review: definitions, details	Creating an online quiz game/Kahoot game	Engagement Autonomy

Connections among PSTs' understandings, their perceived limiting aspects and the sources of these aspects were less apparent. Perhaps, these connections were less apparent because the limiting aspects deterred some PSTs from completing certain OGT challenges. To demonstrate, one connection that was identified is how perceived time constraints deterred PSTs from completing specific OGT challenges. Such challenges include those that involved creating a video, critiquing another peer's work, and writing a two-page paper. In addition, the lack of clarity in game structure perceived by some kept them from choosing certain tasks. To explain, Yvette noted she did not complete the YouCubed challenge and Brandon noted he did not complete the Cut-a-Card challenge due to confusion of what these challenges were asking them to do. Consequently, these PSTs did not complete challenges that others found benefiting to their understanding of mindsets. Therefore, the perceived limiting aspects of time constraints and clarity of game structure caused some PSTs to not complete certain challenges, which possibly limited their development of some critical understandings.

Another noteworthy connection concerning limiting aspects is that creating a Kahoot quiz does not appear to have developed any of the critical understandings identified as the three themes for this study's first research question. Caitlyn and Yvette, who both created a Kahoot quiz, referred to their experience using the Mathematical Mindset OGT as a review or "refresher" of information that they had already learned. Keanna described solving another peer's Kahoot quiz provided her the "little details and definitions." Likewise, Danielle thought creating a Kahoot quiz helped her review resources about mindsets and required her "to go back and look back at those videos and the PowerPoint." Still, PSTs did not identify creating or playing a Kahoot quiz as a source for developing critical understandings of mathematical mindsets.

Two other key points concerning limiting aspects involve math tasks and autonomy. For the first point regarding math tasks, not many PSTs provided insight to understanding of tasks that support mathematical mindsets, a growth mindset towards mathematics (Boaler, 2016). From the OGT challenges completed, only the YouCubed Challenge provides an example of a mathematical mindset task. Other OGT challenges focused on math norms and teaching practices for math classrooms, but none of the PSTs chose these challenges. As for the second point, autonomy appears to be wrapped up in PSTs' understandings and perceived limiting and benefiting aspects. PSTs perceived autonomy as a benefiting aspect; however, it also appears to have limited some PSTs understandings of mathematical mindsets. To explain, if PSTs did not choose tasks that were appropriately challenging and developed new knowledge, then autonomy limited the understandings they developed from using the OGT.

In closing, analysis of interview data applied procedures of open-coding to identify patterns across participants' experiences using an OGT. These patterns provide insight to how PSTs developed understanding using the Mathematical Mindset OGT and what aspects they perceived as benefiting and limiting. After identifying themes of their understandings and perceived benefiting and limiting aspects, connections among these themes provided a better understanding of how the OGT influenced PSTs' understandings and experiences. The implications and recommendations based on these themes and connections are presented in the next chapter.

CHAPTER 5

DISCUSSION AND IMPLICATIONS

Mathematical mindsets play a critical role in whether people pursue STEM disciplines. Recently, the U.S. Bureau of Labor Statistics forecasted that jobs in STEM fields will increase by 8.8% between 2018 and 2028 while overall employment is expected to increase by 5.2% (Bureau of Labor Statistics, 2019). In addition to the increase in STEM jobs, the median annual wage for STEM occupations is more than double the median annual wage for non-STEM occupations. Since math is a key component of all STEM content areas (Rittmayer & Beier, 2009) and people's fixed beliefs towards math transfers to other math-related subjects (Boaler, 2019a), it is pertinent for educators to consider ways to foster student growth mindsets in mathematics. The purpose of this study was to examine how PSTs' understandings of mathematical mindsets and teaching practices that foster growth mindsets are influenced using an online gamification tool (OGT). The 10 participating PSTs provided insights to their experiences using this specific OGT and what aspects of the tool benefited and limited their learning. Broadening these insights can inform researchers and teacher educators of approaches to develop understandings of mathematical mindsets and ways to implement OGTs. In this chapter, I detail this study's relevance to mathematics education, its practical and theoretical implications, and my growth and learning from conducting this research.

Relevance to Mathematics Education

Studies concentrating on teaching practices that support student growth mindsets are relevant to mathematics education as they have the potential to help address the prevalent negative dispositions many people hold towards mathematics (Boaler, 2019a; Boaler & Selling, 2017). This study's data analysis found that the Mathematical Mindsets OGT helped PSTs

describe teaching practices that support student growth mindsets. PSTs described the following teaching practices: 1) providing challenging learning experiences and tasks, 2) sending growth mindset messages, and 3) valuing mistakes. Teaching practices have been found to impact students' mindsets (Haimovitz & Dweck, 2017), including their beliefs about their abilities in mathematics (Anderson et al., 2018). Therefore, these findings are pertinent to mathematics education.

Moreover, a substantial amount of research offers indication that teaching practices used in mathematics classrooms have significant impacts on students' understandings of and relationships with mathematics (Boaler, 2019a; Boaler & Greeno, 2000; Cobb, Gresalfi, & Hodge, 2009; Horn, 2008). These practices teach students how to engage with mathematics. For example, Cobb et al. (2009) found students who engaged with mathematics by obtaining correct answers and using prescribed methods developed negative feelings such as frustration towards math. On the other hand, students who engaged with mathematics by asking questions, justifying their ideas, and critiquing others' ideas conveyed perceptions that they had a more active role in learning mathematics. Such experiences allow students to develop more positive beliefs towards mathematics as well as towards their abilities to actively engage with mathematics (Boaler, 2015; Boaler & Greeno, 2000; Cobb et al., 2009). Furthermore, students' experiences and beliefs related to learning mathematics can have great impacts on their futures, as Boaler and Selling (2017) found when they studied the long-term effects of different teaching practices. They compared a group of students who experienced a more traditional approach to learning mathematics to a group of students who experienced a more problem-based approach. The traditional approach was lecture-based; whereas, the problem-based approach included more active engagement from students with open math tasks and freedom to explore their ideas.

Consequently, students who experienced the problem-based approach demonstrated increased mathematical understanding and higher achievement on tests. They also developed beliefs that they could learn and do mathematics. Furthermore, these actively engaging experiences had long-term impacts on their beliefs towards mathematics and on their employment and social status (Boaler & Selling, 2017). As young adults eight years later, the students who learned mathematics with a problem-based approach reflected growth mindsets towards mathematics. They described beliefs that they could tackle any problem, were prepared to persevere through struggles, and viewed “mathematics as knowledge that they could adapt and use” (p. 97). The explanation offered by Boaler and Selling (2017) for these positive long-term impacts is “that their different school experiences gave the Phoenix Park students a better start in life and afforded them the opportunity to move upward in the social scale.” As can be seen, the teaching practices used in math classrooms can greatly impact students’ beliefs about their ability to learn math and their future interactions with math into adulthood, which is particularly important at this time with the growing opportunities in STEM fields of study and professions. Therefore, it is an important responsibility of mathematics teacher educators to develop preservice and inservice teachers’ understandings of teaching practices that support student growth mindsets and more positive dispositions towards mathematics.

The current study used a situated learning perspective (Lave & Wenger, 2001; Putnam & Borko, 2000) to consider how and in what ways PSTs engaged with an OGT as they learned about mathematical mindsets. These considerations are relevant in mathematics education to better understand effective approaches to develop educators’ knowledge of teaching practices that support growth mindsets. This knowledge includes ways to actively engage students while learning mathematics. Although there is a considerable amount of research providing evidence

that students need to actively engage in their learning, these learning environments are rare in mathematics classrooms (Jacobs et al., 2006; Litke, 2015). It is critical for mathematics education research to examine effective approaches to develop educators' understandings of best teaching practices that actively engage students and support growth mindsets beliefs towards math. Implications from this study's examination of an OGT used to develop these understandings will be detailed next.

Practical Implications

This study's findings provide practical implications for two areas of teacher education. First, findings for PSTs' understandings of mathematical mindsets and teaching practices that support growth mindsets are significant for mathematics teacher education programs seeking to promote effective strategies in fostering students' growth mindsets. Second, this study contributes understanding of effective online instruction in teacher education programs by providing awareness of aspects that PSTs perceived as benefiting and limiting to their understanding as they used the OGT. The themes found for PSTs' understandings of mathematical mindsets and their perceived benefiting and limiting aspects will be revisited in this section to discuss the implications offered by this study.

Understandings of Mathematical Mindsets

As noted in the previous chapter, PSTs indicated understandings of how teachers can support student growth mindsets in math classrooms. The themes for PSTs' understandings include the following: 1) providing challenging learning experiences and tasks, 2) sending growth mindset messages, and 3) valuing mistakes. Implications for these themes will be provided in the following paragraphs.

Providing challenging learning experiences and tasks. The majority of PSTs that participated in this study, based on their interview comments, reflected an understanding of challenging learning experiences and tasks. Specifically, they mentioned struggle, perseverance, and success as important experiences for students to develop beliefs that through hard work their abilities in math can grow. In PSTs descriptions of critical experiences that they believed support a growth mindset, the OGT challenge most referenced was the Cut-a-Card Challenge. This challenge appeared to provide PSTs the opportunity to experience struggle, perseverance, and success, thus providing PSTs the opportunity of learning through experience. In addition, two PSTs indicated this task allowed them to actively engage and think deeply about their learning, which are important components of experiential learning (Dewey, 1916). Likewise, YouCubed tasks were also described as creating experiences of struggle, perseverance, and success. This study's findings bring attention to how these challenging tasks appear to have essentially simulated experiences that support growth mindsets. These challenges seem to have provided a context for PSTs to make their understandings of mathematical mindsets more concrete through examples of challenging learning experiences and tasks.

Researchers in mathematics education have established the importance for teachers to be able to select appropriately challenging mathematical tasks (Boaler, 2016; M. S. Smith & Stein, 1998; Stein, Grover, & Henningsen, 1996). Tasks with a high level of cognitive demand are significant for students to think, reason, and problem solve (Smith & Stein, 1998; Stein et al., 1996) and result in increased student learning (Stein & Lane, 1996). Such tasks would involve experiences of struggle, perseverance, and success and consequently, increase the potential for students to develop growth mindsets towards mathematics (Boaler, 2016). Given these points, PSTs should be given opportunities to develop understandings of mathematical tasks that support

student growth mindsets. Findings from this study highlight how having PSTs engage in challenging tasks themselves appears to help make their understanding of challenging learning experiences and tasks more concrete. Therefore, mathematics teacher educators should provide opportunities for PSTs to engage with challenging math tasks to model and simulate experiences that are critical to supporting student growth mindsets.

Sending growth mindset messages. Most of the PSTs expressed an understanding that teachers can send growth mindset messages to students through encouraging messages, process praise, and directly teaching about growth mindsets. PSTs indicated the Twitter challenge contributed to this understanding. They described how the Twitter challenge provided examples of messages, visuals to display in classrooms, and ways to respond to students to encourage them to keep trying. The Twitter challenge gave PSTs the autonomy to explore and select posts they found meaningful, which multiple PSTs indicated they found beneficial to their understanding. Travis demonstrated a deeper understanding of how to send growth mindset messages by creating a video about his personal mindsets shift, which he plans to share with his future students and their parents. He was able to use his ideas and understandings of growth mindset messages and create a product to use in the classroom. The open format of the OGT provided him a space to take his learning to this level and create a meaningful product of his own.

Both the Twitter and Video Creation challenges seem to have two common components that contributed to PSTs' understanding of ways to send growth mindset messages. Both challenges involved concrete classroom applications of growth mindset messages and gave PSTs autonomy to have choice and ownership in how they developed this understanding. Both components should be considered by mathematics teacher educators for developing understanding of ways to send growth mindset messages, as well as developing other concepts

related to mathematical mindsets. Concrete examples are important for PSTs to understand what mathematical mindsets look like and how to support them in classrooms. Providing autonomy can motivate learners to go beyond the requirements of a task and allows them to explore resources based on their interests and learning needs. Additionally, Twitter can be used as an educational tool for PSTs to explore and learn from ideas and information shared by other educators (Carpenter & Morrison, 2018). Thus, teacher educators should consider using concrete examples of teaching practices, providing PSTs choice in their learning, and incorporating online tools such as Twitter when appropriate.

Valuing mistakes. Valuing mistakes was a final theme for PSTs' understandings of mathematical mindsets, which half the PSTs communicated an understanding of during interviews. How PSTs learned about the value of mistakes varied with two PSTs referring to the Cut-a-Card challenge, one referring to examples provided on Twitter, and one mentioning the importance for students to correct their mistakes. These references provide some insight to how mathematics education programs can develop understanding of the valuing of mistakes through challenging tasks and online tools such as Twitter. However, the most useful implication is provided from how Keanna reflected a deeper understanding of valuing mistakes. She was the only PST who chose the My Favorite No video challenge, which demonstrated a teaching strategy that encourages students to learn from mistakes. Keanna found this visual classroom application beneficial because it illustrated how a teacher can value mistakes in the math classroom. Thus, this challenge made her understanding more concrete through an example of valuing mistakes. These insights reinforce the implications proposed for sending growth mindsets messages in the previous paragraph. Teacher educators should provide concrete examples of ways teachers can support student growth mindsets in math classrooms.

Additionally, videos can be an effective approach to provide concrete examples to PSTs for analysis and reflection (Christ, Arya, & Chiu, 2017; Star & Strickland, 2008) and should be considered by teacher educators to improve PSTs' learning of teaching practices.

Using Online Gamification Tools

This study also provides practical implications for using gamification and online instructional tools in teacher education programs. The review of literature revealed a need to better understand what aspects of gamification are most beneficial to use in education. This study's findings contribute to the literature by providing understanding of aspects that PSTs perceived as benefiting and limiting to their understanding as they used the Mathematical Mindset OGT. As detailed in chapter four, the themes for benefiting aspects were experiential learning, social interactions, autonomy, and engagement. The themes for limiting aspects were time constraints, clarity of game structure, and development of some critical understandings. This section presents two implications that connect these benefiting and limiting aspects. First, online gamification tools can and should offer learners experiential learning. Second, a balance of autonomy and game structure is needed to ensure learning objectives are met. These implications will be discussed in the following paragraphs.

Experiential learning. Over time, access and integration of technology has increased in educational settings. However, typical uses of technology are not supporting meaningful teaching practices such as student-centered instruction that gives students an active role in their learning (Ertmer, Ottenbreit-Leftwich, & Tondeur, 2016). Similarly, gamification has been branded as just the repackaging of traditional teaching strategies (Wiggins, 2016). Recall Dewey (1916) posited that people learn through actively engaging and meaningful learning experiences. Findings from this study provide implications for how to utilize online learning

tools to promote these experiences. The OGT used in this study provided multiple opportunities for PSTs to actively engage in their learning. First, the challenging tasks, particularly the Cut-a-Card task, appear to have afforded PSTs experiential learning where they actively engaged as they solved the task. PSTs indicated they learned from experience as they engaged with these challenging tasks that required them to generate observation and ideas as well as reflect and think deeply about their learning. Secondly, this OGT offered opportunities for social interactions among the PSTs. For example, PSTs communicated and collaborated with each other as they solved the tasks. These actions indicate they were actively engaged in their learning. Lastly, PSTs were able to build on previous understandings and connect to past experiences as they engaged with this OGT. Travis's video of his personal mindset transition is an example of connecting to past experiences to form a more meaningful understanding of mindsets and ways to support student growth mindsets. These findings suggest online instructional tools can offer actively engaging and meaningful learning experiences through high quality tasks.

The importance of high quality and meaningful tasks is a vital element of gamification (Dignan, 2011). This study's findings add to the literature that almost certainly the most important aspect of implementing gamification is to have high quality core tasks. Findings from this study indicate the Cut-a-Card task, YouCubed tasks, Twitter, My Favorite No video, and Video Creation challenges as beneficial to PSTs understandings of ways to support mathematical mindsets. PSTs expressed positive views and increased engagement as a result of these tasks. In contrast, creating a Kahoot quiz seemed to develop low level understanding (e.g. definitions). Furthermore, it did not seem to provide an actively engaging and meaningful learning experience and thus, was not as beneficial to PSTs' understandings. Given these points, online instructional

tools, including OGTs, need high quality tasks to provide actively engaging and meaningful learning experiences.

Balance of autonomy and game structure. Examining connections across themes during data analysis highlighted the need for a balance of autonomy and game structure when implementing gamification in education. Autonomy was a prominent theme for PSTs' perceived benefiting aspects with choice being the most frequent example mentioned during interviews. They found choice allowed them to complete tasks that were interesting and enjoyable; thus, having choice seemed to positively affect their engagement. Another example of autonomy mentioned was having ownership in their learning. Feelings of ownership were expressed as they discussed creating products such as a video or Kahoot quiz. This OGT also allowed autonomy within challenges, so PSTs had more freedom in how they completed them. To explain, Travis had freedom in the content of his video, which allowed him to create a product meaningful to him and that went beyond the minimum requirements of the task. Thus, the way autonomy was included in this Mathematical Mindset OGT appears to have had multiple benefits to PSTs' learning experiences.

However, the high level of autonomy seems to have also limited PSTs' understandings. As described in chapter four, the understandings PSTs developed about mathematical mindsets depended on the challenges they completed. Therefore, autonomy is connected to the limiting aspect regarding PSTs not developing some critical understandings as they used the OGT. Other aspects that relate to this conclusion include the perceived time constraints, as well as some PSTs seemed to choose activities based on familiarity. The perceived time constraints impacted PSTs' choice and therefore, this aspect should be considered by educators when designing gamification tools. Familiarity seems to have positively contributed to some PSTs engagement by choosing

challenges that involved tools they enjoyed using (e.g. Twitter). However, it is possible this also hindered the development of new understandings. For example, two PSTs chose to create a Kahoot quiz because they had used it before, but then conveyed the perception of not learning new information from this OGT. Had they chosen a different challenge that involved something they had not learned previously, they likely would have developed new understandings. The instructions in the OGT encouraged PSTs to choose a challenge that would help them learn, but in the end their learning depended on what challenges they chose. These insights support the necessity for structure when using games in education (Montessori, 1964). With this in mind, a balance of autonomy and game structure is necessary when using gamification in educational settings for learners to experience the benefits of autonomy and to ensure learning goals are achieved.

Another limiting aspect of the Mathematical Mindset OGT was the lack of game structure clarity. Addressing this limiting aspect may provide a solution to the balance of autonomy and game structure. To demonstrate, the design of a gamification tool should start with the learning purposes or the game goals. Then the tool should be created to meet those goals. For this OGT, the goals were for PSTs to learn about mathematical mindsets and teaching practices that support growth mindsets. The OGT career challenges focused on teaching practices that included using challenging tasks, sending growth mindset messages, and valuing mistakes. While PSTs described understandings of some of these practices, most did not describe understandings of all three, which seems to be a result of unclear game goals and the open structure of the OGT. Although this OGT has challenges that involve each of these critical understandings, they were mixed together, and PSTs were not required to choose a task for each critical understanding. Perhaps a better approach would be organizing tasks by the critical

understanding it would develop. This study's tasks would be divided into the following three groups: 1) examples of challenging learning experiences and tasks, 2) examples of sending growth mindset messages, and 3) examples of valuing mistakes. Then PSTs should be required to choose a challenge from each of the three groups. This approach would likely provide a better balance of autonomy and game structure. Moreover, it provides clearer game goals as PSTs would have a better understanding of the big picture of the game and the purpose of each task they complete.

Ultimately, with so many educational programs moving to online environments, it is essential for educators to consider what are optimal aspects for online instruction. This study provides a small window based on my experience implementing an online gamification tool to develop PSTs' understandings of mathematical mindsets. As previously detailed, having challenging and high quality tasks are almost certainly the most important aspect of designing online instructional tools. In addition, providing learner autonomy was also found to be a major benefiting aspect. Learner autonomy connects to the great amount of accessibility that is afforded in online environments. Access to a great amount of information and technological tools allows learners the freedom to explore and discover as they learn about new concepts. These benefiting aspects apply to all online learning environments including those that involve learning independently such as self-paced training modules like Google's Certified Educator trainings. This type of online environment allows learners to progress through modules at their own pace, complete challenging tasks, and have access to a vast amount of information and tools. However, a goal of this study's implementation of an online gamification tool was to encourage collaborative learning. The blended learning approach allowed for a great amount of face-to-face collaboration; thus, perhaps this approach is ideal to build a sense of community while also

leveraging the benefiting aspects of online tools. Conversely, I found online collaboration to be challenging as most PSTs did not interact with one another using the online tools. All things considered, online environments afford many benefiting aspects for education; however, we need to examine better approaches that promote collaboration and build a sense of community.

Theoretical Implications and Recommendations

In addition to practical implications, this study's findings offer theoretical implications related to the situated learning theory. Implications for theory are provided in the following paragraphs, followed by recommendations for future research.

Theoretical Implications

This study's theoretical framing used a situated learning perspective that posits learning is tied to the context in which it takes place (Brown et al., 1989; P. Cobb & Bowers, 1999; Lave & Wenger, 2001; Putnam & Borko, 2000; Saivyer & Greeno, 2009). More specific ideas that guided this study include that cognition is situated in physical and social contexts and distributed across people and resources (Lave & Wenger, 2001; Putnam & Borko, 2000). As asserted in the series forward of Lave's and Wenger's (2001) *Situated Learning: Legitimate Peripheral Participation*, it is essential to analyze the influences on learning in online contexts with the dramatic transformations of ways people communicate and acquire knowledge due to advancements and access of technologies. The current study took place in a blended learning context that combined online and face-to-face learning aspects and activities (Boelens, Voet, & De Wever, 2018). Considerations for theoretical implications of learning situated in a blended learning context are presented in this section. First, influences of the online context are discussed followed by influences of the physical context with attention to the role social interactions play in each context.

The online context for this study involves how learning took place using the Mathematical Mindset OGT. This tool served as a platform to deliver information and activities related to mathematical mindsets and it comprised multiple other online tools to do so. Various resources embedded in this OGT influenced PSTs' learning experiences. First, videos were frequently mentioned as beneficial for PSTs' learning. It seems the visual aspect was particularly helpful as PSTs mentioned being able to see how the brain works in one of the introductory videos and being able to see a classroom application in the My Favorite No video. Second, the online platform provided PSTs a high level of autonomy and personalization of their learning with the freedom to explore resources and choose challenges to complete. PSTs often mentioned videos, but some also stated that the articles and presentations were helpful. Having a variety of resources was perceived as beneficial and some PSTs even suggested to have more resources with more variety of information. Thus, having multiple resources to explore seems to have positively influenced PSTs' learning experiences. Moreover, having an endless access to resources in this online context was influential as some decided to use Google search for answers and one PST created a video and website with tools beyond what was included in the OGT challenges. The OGT is also accessible from anywhere and at any time. One PST specifically mentioned that she would like to continue to learn from it in the future. Lastly, Twitter and other social media tools afford social interactions with people beyond those in the physical location. Austin recognized this affordance of Twitter when he described his ability to learn from others' perspectives using this tool. Such tools allow social interactions where people can share information and ideas with each other. As has been noted, influential aspects of the online context for this study include videos, autonomy, accessibility, and social interactions.

For the physical context, PSTs engaged with the OGT in a classroom with their peers. Two influences of this context are physical materials and social interactions with peers. One task, the Cut-a-Card task, had physical materials that several PSTs expressed were visually intriguing to them. This initial interest resulted in some completing this task. Additionally, a few PSTs noted that they saw one of their peers start this task, causing them to want to do the task too. Multiple PSTs mentioned how seeing their peers engage with a specific challenge influenced them to choose the same challenge because they wanted to work with them, or it sparked their interest. Notably, the physical nature of the Cut-a-Card task influenced peers to work together. One PST explained how collaborating and communicating with peers helped accomplish more than they could have on their own, which supports the idea that cognition is distributed across people and resources (Putnam & Borko, 2000). As can be seen, social interactions were especially influential in the physical context where PSTs used the OGT.

These insights provide important implications for blended learning contexts. The online tools afford access to a multitude of resources that learners have the freedom to explore. Furthermore, the online context creates possibilities to collaborate with people beyond the physical context through online tools such as Twitter. However, learning through social interactions in this study's online context was not a prominent finding. The OGT had other possible modes for social learning such as the challenge that involved critiquing another peer's work, but PSTs' perceived limiting aspects dissuaded them from choosing these challenges. On the other hand, social interactions seemed to be more influential in the physical context, especially in choosing tasks to complete and working together on challenging tasks. Perhaps one explanation for the lack of social interactions in the online context is a result from the more prevalent social interactions in the physical context. More research is needed to understand

influences of social interactions in online contexts and how the physical context impacts these interactions in a blended learning context. Perhaps, a blended learning approach is ideal to have advantageous influences of both the online and physical contexts.

Recommendations for Future Research

The purpose of this study was to provide better understanding of how PSTs knowledge of mathematical mindsets was influenced using an OGT. Findings provide awareness of aspects that PSTs perceived benefiting and limiting as they learned about mathematical mindsets. However, this study highlights further research that is needed to gain a better understanding of how PSTs learn about mathematical mindsets in a blended learning context using a gamification approach. Three recommendations are discussed below to address limitations of this study, as well as provide direction for future research. In brief, the recommendations include further examination of gamification aspects, studies that take place over a longer period of time, and influences of gamification on dispositions and mindsets towards mathematics.

Data analysis revealed this OGT has some limitations including the balance of autonomy and game structure and the social interactions in the online context. Further research should attend to these aspects as well as others to better understand more effective implementations of gamification. As detailed earlier, one approach that should be examined is structuring an OGT so that PSTs must choose a challenge to develop all critical understandings. One suggestion to gain a better understanding of effective gamification approaches in online environments is to use a design-based research methodology. This methodology is appropriate to investigate best designs for online learning tools or technology-enhanced learning environments to “advance design, research, and practices concurrently” (Wang & Hannafin, 2005, p. 5). Another limitation of this OGT’s design was the few instances PSTs interacted with each other online. Possible

solutions to this limitation can be tested using a design-based approach. The OGT used in this study can be modified to increase online social interactions and implemented again to test its results.

Another possible solution to the lack of social interactions is to implement an OGT like the one used in this study over a longer period. Time constraints were the most evident limiting aspect perceived by PSTs. It was mentioned that time was the reason PSTs did not choose challenges that involved critiquing another peer's work. Thus, a longer implementation would address this limiting aspect and allow enough time for PSTs to complete these kinds of tasks. Furthermore, a longer implementation could develop deeper understandings of critical concepts of mathematical mindsets. One PST recommended teaching about mindsets throughout a teacher education program instead of just one isolated module. Creating an OGT that can be accessed anytime with tasks to complete overtime throughout a teacher education program is a possibility. This approach could better support PSTs as they try to use growth mindset teaching practices in clinical placements. Opportunities to apply their learning would likely develop deeper understandings. In addition to a longer implementation, the long-term impacts on PSTs' understandings should be investigated. This study found some of the tasks provided experiential learning, which is closely related to what Putnam and Borko (2000) refer to as authentic tasks. They posit that learning situated within tasks similar to what practitioners do enables the transfer of knowledge outside of the context in which it was learned. It would be valuable to examine if PSTs transfer their understandings of mathematical mindsets as they complete a clinical experience or even more so, when they are classroom teachers.

A final recommendation for future research is to investigate impacts of gamification on students' dispositions towards mathematics and mathematical mindsets. There is a lack of

research in this area. Considering the multiple benefits found from gamification, it is worth investigating if it can positively impact students' feelings and beliefs towards mathematics. Some PSTs discussed using games in math classrooms to help students find math less stressful and more enjoyable. This idea makes sense given how gamification has been found to increase engagement and motivation (Hays, 2005; Ke & Abras, 2013; Marino et al., 2014; Sáez-López et al., 2015), collaboration (Ke & Abras, 2013), and self-efficacy (Meluso et al., 2012) in K-12 settings. Furthermore, more studies in gamification need to take place in teacher education. A recent review of literature (Subhash & Cudney, 2018) on gamification in higher education found similar benefits of engagement (Giannetto, Chao, & Fontana, 2013; Pechenkina, Laurence, Oates, Eldridge, & Hunter, 2017), motivation (Day-Black, Merrill, Konzelman, Williams, & Hart, 2015), enjoyment (Llorens-Largo et al., 2016), student performance (Hamzeh, Theokaris, Rouhana, & Abbas, 2017; Pechenkina et al., 2017), higher effort (Daubenfeld & Zenker, 2015), and attitude (Yildirim, 2017). However, none of the studies used in this review of literature were conducted in teacher education settings. For this reason, research is needed to gain better understanding of effective implementations of gamification in K-12 mathematics classrooms and in teacher education programs.

My Growth and Learning

Reflecting on the past two years and all the experiences this dissertation has provided lets me realize my growth and learning through this process is invaluable. Like Travis, my mindset has transitioned. I have believed some common misconceptions about mathematics and used language such as "I am a math person." Additionally, I thought I would never be a "good writer." My transition began before I started this doctoral journey; however, this dissertation helped me better understand my beliefs about learning and further transitioned my mindset. As I

write the final section of my dissertation, I cannot help but feel emotional that I have persevered through this challenging yet rewarding endeavor that has let me see my ability to grow and learn. More importantly, I understand that everyone can learn and grow.

Before I discuss my own growth and learning from this dissertation process, it is important to describe my prior experiences to provide some background. I grew up in a rural area and in my formal schooling I quickly started believing “I was good at math.” I remember being the first student in my class to memorize all the multiplication facts and get all twelve scoops of ice cream on a bulletin board. I was one of a few students chosen to go to a middle school math contest because I scored the highest on the qualifying assessment. Such experiences made me feel that math was “my thing”. On the other hand, reading and writing has long been a struggle for me. For example, I could not keep up with some of my classmates in the Accelerated Reader (AR) program no matter how hard I tried. I read as much as I could and even tried reading books at higher grade levels to get more AR points, which led to a great amount of frustration. Consequently, it took many years for me to develop a love for reading. I also realized I was usually one of the last people in my class to finish a reading assignment. I saw my lack of speed as a reflection of my low ability to read. I believed being good at something meant it was easy for you and you could do it quickly. Thus, I developed beliefs that “I was a math person” and not very good at reading and writing. However, when math started getting difficult for me, I started to feel less confident with it. I took the advanced level mathematics courses my rural school district offered, but I still came to the University of Tennessee my first year with not near the math background others had. I quickly changed my decision to major in mathematics at UTK, which I think was profoundly impacted by my fear that it would be too

difficult for me. Despite these fixed beliefs, I still loved the subject and decided I wanted to teach middle school math.

I entered the doctorate program after six years of teaching middle school mathematics. My experiences teaching allowed me to see firsthand the prevalent negative dispositions and lack of confidence many students have in learning mathematics. I often heard students say, “I will never be good at math” and “I hate math.” This was not only communicated from students, but also their parents, revealing to me how deeply embedded these feelings are in our society. However, I saw the impact I had on students when I used teaching practices that allowed them to understand math and find it meaningful. My experiences teaching and growing up in a rural area where I witnessed the lack of opportunities in STEM has influenced my doctoral journey and directed me to my current research interests.

Opportunities to teach mathematics education and educational technology courses as well as supervising preservice teachers has led to my desire to become a teacher educator. Working with PSTs made me feel beyond grateful to be a part of their development into classroom teachers. In my first year of the doctoral program, I conducted my first study that examined PSTs’ understanding of math tasks that have a high cognitive demand. It was eye-opening to see the amount of knowledge gained by examining their understandings so closely and methodically. The following year I carried out my first interview with a PST about her experiences using more open, problem-based math tasks. This interview was extremely impactful as I gained knowledge of her experience that I could not have gained through a survey or test. Surprising myself, I enjoyed conducting the interview and analyzing her responses. Moreover, I developed a great amount of appreciation for qualitative research. Now that I have finished the data analysis for my dissertation study, I further understand the value of qualitative research to understand

participants' experiences and conceptualizations. Although both quantitative and qualitative research is valuable, I find myself leaning to the qualitative side, which I did not foresee.

As for mathematical mindsets, I credit my husband with sparking this interest when he bought me Boaler's *Mathematical Mindsets: Unleashing Students' Potential Through Creative Math, Inspiring Messages and Innovative Teaching* during my first year of the doctoral program. This book resonated so deeply with me. It helped me understand and connect why certain practices I used in the classroom helped students learn and enjoy math and others did not. So many of my ideas and experiences teaching middle school math made more sense after reading this book. I used every opportunity I could in the doctoral program to learn more about mindsets. In my first course with Dr. Hodge, I did a literature review on mathematical mindsets, which allowed me to read more works on mindsets including Carol Dweck's *Mindset: The New Psychology of Success*. I was inspired and knew this was a major research interest of mine. Another major research interest developed from an instructional technology course that introduced me to gamification. My previous interest in educational technology led me to connect how I could create online gamification tools to teach concepts in a more engaging way. With the help of my advisor, I was able to find a study that intersected my interests of mathematical mindsets, gamification, and educational technology.

The thought of a dissertation terrified me as I entered the doctoral program. This fear lightened as I became more familiar with research and saw my writing skills improve. The support from my family, advisor, and friends helped me through this challenging process, which I look back and am grateful for all the experiences. I learned how to create an online gamification tool to teach about mathematical mindsets. After defending my proposal and gaining IRB approval, I implemented this OGT with secondary mathematics teachers. I created

data collection tools, implemented the tools, conducted and transcribed interviews, analyzed data using qualitative methods, and communicated findings and implications. This dissertation project has truly allowed me to learn through critical experiences that support a growth mindset. Like in my early years, I still struggle with writing and read slower than many people, but I have a very different perspective of struggle now. The dissertation journey has been filled with struggles, perseverance, and successes. Repeatedly, I have seen that I can learn, grow, and write. Boaler (2019a) stated in the forward of *Limitless Mind: Learn, Lead, and Live Without Barriers* that “the act of learning itself fundamentally changes who we are” and “what we go on to achieve.” My learning from this dissertation has changed me to look at difficult tasks and obstacles in life as challenges that I can grow from and overcome. My different perspective allows me to realize experiences that are difficult and uncomfortable are the ones that help us grow.

My future goals involve helping mathematics classrooms develop positive dispositions towards mathematics where students believe in themselves and think they can learn and do mathematics at high levels. I am excited and beyond grateful to have the opportunity to be a part of the VolsTeach for Appalachia project to help STEM classrooms in East Tennessee have high-quality teachers. In this project and my future work, I hope to help more classrooms support student growth mindsets, especially in mathematics where many lack confidence. Students should not be limited by damaging beliefs about their abilities, but rather should experience the liberating feeling that they can grow and learn anything. I will end with a thought from one PST who articulated well the power of helping students have growth mindsets:

Keanna: The reason that I want to be a teacher, in my philosophy of education in general, is that we need to raise our posterity to be better than we are. And I think part of that is

teaching a growth mindset because maybe we might not have it and might not think that we can succeed now. But we need to instill in the next generation for growth, um, for just the world. I know that sounds like a really big mission that I have. But even if I can do it on a small scale and affect a certain number of students to think that they can achieve something great, then maybe they're the person that discovers the next great thing. I'm not saying that I'm going to be directly responsible for that. Maybe not even me, but another teacher. If we all instill growth mindsets, then maybe everybody will start thinking that they can do great things.

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APPENDICES

Appendix A

Developing Pre-Service Teachers' Understanding of Mathematical Mindsets: Influences of an Online Gamification Tool

Informed Consent Form

You are being invited to participate in a research study being conducted by Rebecca Layton. You are being invited because you have participated in the MEDU 433 Classroom Interactions course. Participation in this research study is voluntary, and you should only agree to take part if you completely understand the study and want to volunteer. This form contains information that will help you decide if you want to take part in this research study or not. Please take the time to read it carefully, and if there is anything you don't understand, please ask questions.

Purpose

The purpose of this study is to understand the effectiveness of an online gamification tool used for pre-service teachers to learn about mindsets. I plan to publish articles and make presentations at conferences to share the results of this research.

Participation

If you choose to participate, I will analyze the lesson plans you created during your time in MEDU 433 Classroom Interactions and materials you completed during the mindsets module that includes all assignments and activities completed using the online gamification tool. These are all things that are part of your regular activities in MEDU 433 and therefore will not require any additional time. In addition, you will participate in an interview. The interview will take place on campus at Greve Hall and will require approximately 30 minutes to complete. The interview will be audio recorded and stored on my password protected Google account. The audio recordings will only be shared with research personnel.

Benefit

You will not receive any direct benefit from your participation in the research project, but we hope to learn things that will benefit teachers and teacher educators in the future.

Risks

This research is considered to be no more than minimal risk, which means there is no more expected risk to you than what you might experience during a typical day. There is the risk of possible loss of confidentiality, as someone could find out you were in the study or see your study information, but I believe that risk is unlikely because of the procedures we will use to protect your information.

Confidentiality

If you agree to participate in the research, I will assign you a pseudonym and use that instead of your name on all of the materials before I begin analyzing them for the research study. The code key and the consent forms will be stored separately from these materials to prevent your name from being linked to them, and only research personnel will have access to the code key and consent forms with your name.

These materials will be stored in a secure location on the UT campus or the researcher's password protected Google account. No information which could identify you will be shared in publications and presentations about this study. If I wish to include your name, recordings, or other information that could identify you in publications or presentations, I will ask for separate written permission for this.

Future Research

Your research information may be used for future research studies or shared with other researchers for use in future studies without obtaining additional informed consent from you. If this happens, all of your identifiable information will be removed before any future use or sharing with other researchers.

Contact Information

If you have any questions about this research, please contact me, Rebecca Layton, at rdoty1@vols.utk.edu or (865) 255-6825 or my advisor, Dr. Lynn Hodge, at lhodge4@utk.edu or (865) 974-8778. If you have any questions about your rights as a research participant, please contact the Institutional Review Board (IRB) of the University of Tennessee, Knoxville, at utkirb@utk.edu or 865-974-7697. You may also contact the IRB with any problems, complaints or concerns you have about a research study.

Voluntary Participation

It is completely up to you to decide to be in this research study. Even if you decide to be part of the study now, you may change your mind at any time and stop participating by informing the researcher you would like to discontinue your participation. You will not lose any services, benefits, or rights you would normally have if you choose not to volunteer, or if you change your mind and stop participating later. If you do not wish to participate in the research, it is not necessary to do anything, as I cannot use your materials without your consent.

Consent

I have read the above information. I have received a copy of this form. I understand that my participation in this research study includes allowing Rebecca Layton to use my lesson plans created during MEDU 433 Classroom Interactions, my materials that I completed during the mindsets module that includes all my assignments and activities completed using the online gamification tool, and the audio recording from my interview for research purposes. I agree to participate in this study.

Participant's Name (printed) _____

Participant's Signature _____ Date _____

Appendix B

Online Gamification Tool

Career Challenges

Welcome to Career Challenges!

Let's Play! I am Captain Layton, your traveling guide. Welcome to my game where you get to travel to see different careers and complete challenges.

You will visit different 21st century careers and complete challenges to get points. These challenges will help you learn about mindsets and how teachers can foster a growth mindset. You have multiple paths to collect your points. Choose challenges you will enjoy and **HELP YOU LEARN** about mindsets! Have fun and safe travels!

Game Rules:

1. You must collect 100 points by the end of the module.
2. For each career challenge you choose to do, include the following on your game portfolio:
 - Title of challenge
 - Amount of points the challenge is worth
 - All collaborators (if any)
 - Your submission for the challenge (link, text, image, etc.)
3. Everyone starts and ends in [Your Classroom](#).

Part of this game is figuring out how to solve the challenges on your own. If you get stuck or struggle to complete a challenge, that is not a bad thing! That means you are learning!!! Persevere through the challenge. You can use your peers and any resources available to you to complete the challenges.

Let's Play

Click the image to travel to that career.



[Your Classroom](#)



[Computer Hacker](#)



[Social Media Manager](#)



[Game Designer](#)

Your Classroom





Computer Hackers- the Critical Thinkers

Welcome to Computer Hackers!

Professional computer hackers seek to crack defenses and find weaknesses in a computer system. Google hires hackers to evaluate weaknesses in their system and create defenses against potential hacking. A computer hacker's ability to think critically and problem solve is essential as they find problems and figure out solutions.

Critical Thinking Challenges

Critical Thinker Challenge 1- 50 points

For this challenge you will create an online quiz game with questions about concepts related to mindsets. You could create a Kahoot, Quizziz, or another online quiz game. Below are the expectations for creating your online quiz/game:

- 8-10 questions with **four** answer options to each question
- at least 20 seconds per question (more if you think more time is needed)
- All questions pertain to mindsets (Brain Science, Fixed vs. Growth Mindsets, and/or Growth Mindset Teaching Practices)
- If requested by Captain Layton, you can support the answers to your questions from the mindset resources provided in this game or from some other reliable resource you used.
- Optional: Try to upload an image/picture for some questions (associated with the topic). Visuals help mathematical understanding by strengthening connections between areas of the brain.

Suggested submission type: link

For an additional 10 points, have another person(s) complete your online quiz/game. Make sure to take a screen shot of their final score to submit. Each person who plays your online quiz/game also receives 10 points!

Suggested submission type: image

Let's Play

Click the image to travel to that career.



Your Classroom



Computer Hacker



Critical Thinker Challenge 2- 40 points

This is for challengers wanting to apply their critical thinking skills to challenging tasks that build a growth mindset. Find and complete one of the [Youcubed tasks](#) that you think builds a growth mindset for the grade level you would like to teach. Make sure to be thorough in showing all work and explain how the task builds a growth mindset. For an extra 10 points, record yourself explaining how you solved the task so that another classmate would understand how to solve it.

Suggested submission type: image of work, video link or inserted on Google Slide.

Here are a few examples:

[The Four 4's](#)



Social Media Manager



Game Designer



Critical Thinker Challenge 3- 10 points

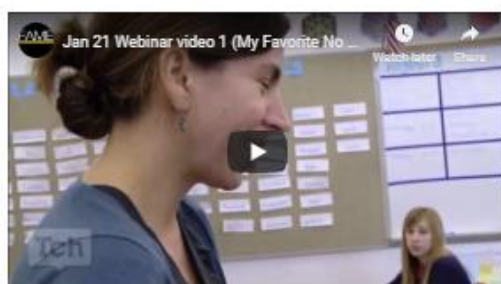
For this challenge, analyze and critique the explanations and work from another person who completed Critical Thinking Challenge 2. Write constructive feedback that you would give that person and submit it to Captain Layton. Make sure to critique how they solved the task, as well as how they explained the task builds a growth mindset. You can do this challenge a maximum of 3 times.

Suggested submission type: text

Critical Thinker Challenge 4- 30 points

Watch the 3-minute [YouTube video: My Favorite No](#) (see below or click linked text). Write a response to the following questions: "Do you think this teaching practice builds a growth mindset? Why or why not?" Type your response on a Google Doc, provide thorough details in your explanation, and make sure you refer to examples in the video. (Minimum 150 word reflection)

Suggested submission type: text



Social Media Manager



Social Media Managers-the Communicators

Welcome to Social Media Managers!

We represent companies on social media, which means we post new content, share material, and respond to comments from customers and others. It is important to have good communication skills as we carry out our job duties.

Communication Challenges

Communicator Challenge 1- 60 Points

Research one of the teaching approaches below and write a 2-3 page paper (double-spaced) on how this teaching approach can foster a growth mindset. Make sure to cite any sources where you get information for your paper/presentation (must use at least 2 sources).

Problem-based learning (or project-based learning)

Inquiry-based learning

Game-based learning

Suggested submission type: text

Communicator Challenge 2- 40 Points

Search #growthmindset on Twitter. Identify 3 posts you find helpful in learning about mindsets and/or ways to build a growth mindset in classrooms. On a Google Doc do the following:

- Include an image of each post. You can take a screenshot of each post and paste them onto a Google Doc.
- Describe what you learned from each post and why you found them helpful.
- Write a minimum of 250 words (total for all three posts).

Tip: You can adjust the size of the image and wrap text around it by clicking on the image.

- Click on one of the blue dots and drag to adjust size.
- Click wrap under the image to make the text wrap around the image.
- You can move the image by clicking it and dragging or using the arrows on the keyboard.

Suggested submission type: Google doc link (if portfolio is on Google Slide), text and images on Google Doc

Let's Play

Click the image to travel to that career.



Your Classroom



Computer Hacker



Social Media Manager



Game Designer

Communicator Challenge 3- 30 Points

Using a 1-take video, respond to one of the questions below (A 1-take video is a simple video recording of yourself explaining something). Watch the videos below to learn about 1-Take videos. Make sure to identify the question you are answering at the beginning of your video.

[Resources for mindsets](#) (these resources can help you answer the questions)

1. Why is fostering a growth mindset important when teaching STEM?
2. How can a teacher foster a growth mindset about learning mathematics?

You can also do this challenge in a small group (2 or 3 people) and create a [paperslide video](#) (a paperslide video is a video recording of paper with information that are slid across a table as one explains the information- see video below).

You can create the video and share it however you want. One option is to upload it to YouTube and embed the video in a Google Slide or share the link. You can also try using Art in Canvas and make a public link for your video.

Suggested submission type: video link, inserted video on Google Slide



1-Take Videos



Paperslide Videos

Game Designer



Video Game Designers- the Creators

Welcome to Video Game Designers!

As we create video games, we design characters, challenge levels, puzzles, art and animation. It is important for game designers to be innovative with new ideas as they create games. Game designers use creativity and innovation as they create new video games.

Creativity Challenges

Creator Challenge 1- 70 Points

Create a 3-5 minute video about mindsets! You can create a paper slide video or another kind of video about a concept(s) related to mindsets. This can be an instructional video explaining mindsets that describes one of the main topics (Brain Science, Fixed vs. Growth Mindsets, and Growth Mindset Teaching Practices), you can choose one of the options below or you can use another idea (run your idea by Captain Layton first). This challenge can be done independently or with a small group (2 or 3 people). You can earn 10 extra points by creating a 5 question online quiz or assignment that aligns with your video.

[See some different video ideas here.](#)

Option 1: Create a paperslide video explaining the norms in a mathematics classroom that build a growth mindset.

Option 2: Create a Google slide presentation of the brain science research that supports growth mindsets. Create a screencast of your presentation with you explaining the information on your slides.

Option 3: Create a skit acting out the ways people with a growth mindset respond to challenges compared to people with a fixed mindset. You can be acting in the skit or create a paperslide video with drawings.

Suggested submission type: video link, inserted video in Google Slide

Creator Challenge 2- 40 Points

Create an activity using at least one math norm or teaching practice that builds a growth mindset. Explain how this activity incorporated this math norm/teaching practice and builds a growth mindset. You can complete this challenge with a partner or independently.

[Click here for math norms](#)

[Click here for teaching practices](#)

Suggested submission type: varies depending on activity (links, images, etc.)

Let's Play

Click the image to travel to that career.



Your Classroom



Computer Hacker



Social Media Manager



Creator Challenge 3- 30 Points

1. Complete the "Cut-A-Card" challenge below. You can also look at the note card example provided by Captain Layton. (First, try this challenge independently and then you can work with a partner)

2. Respond to the following questions:

- Compare how you think someone with a fixed mindset versus a growth mindset would respond to the "Cut-A-Card" task?
- How does this task foster a growth mindset? The following article may be helpful (it details 5 teaching practices that foster a growth mindset):
 - [Unlocking Children's Math Potential: 5 Research Results to Transform Math Learning](#)

This challenge can be done with a partner.



Suggested submission type: image of your card (optional), text

Creator Challenge 4- 10 Points

Complete another person's assignment from Creator's Challenge 2. Make sure to be thorough in completing the assignment by showing all work. Write a short reflection about how you do or do not think the assignment fosters a growth mindset and make sure to explain your reasoning.

Suggested submission type: varies depending on activity (links, images, etc.), text for reflection



Game Designer

Appendix C

Pre-Assessment

Career Challenges Starting Reflection

Thank you for your time completing this reflection. Please provide detailed responses to the following questions to the best of your ability.

1. Last name

2. First name

3. Why is it important for students to develop growth mathematical mindsets?

4. What do you think it takes to learn mathematics well?

5. How would you respond to a student that struggles to understand a concept you are teaching in your classroom?

6. Describe important instructional practices to use when teaching mathematics.

Powered by



Appendix D

Mathematical Mindset Inventory

Please answer the extent to which you agree or disagree with each statement.

	<i>Strongly disagree</i>	<i>Disagree</i>	<i>Somewhat disagree</i>	<i>Somewhat agree</i>	<i>Agree</i>	<i>Strongly Agree</i>
1. I like math. 2. Mathematics involves mostly facts and procedures that have to be learned. 3. I am quick to understand math. 4. I enjoy being challenged in math. 5. In math, answers are either right or wrong. 6. Math is boring. 7. People who really understand math will get an answer quickly. 8. Math is confusing to me. 9. In math, it is important to think hard about ideas. 10. I look forward to my mathematics lessons. 11. In math, it is important to remember lots of methods. 12. I can tell if my answers in math make sense. 13. When I get a bad grade in math, I think that I am not very smart in math. 14. I believe that I can do well in math. 15. When confronted with a problem, I give up easily. 16. When I make a mistake in math, I feel bad. 17. People can learn more math, but they can't really change their basic math intelligence. 18. Math is creative. 19. It is important in math to be fast. 20. There are limits to how much people can improve their basic math ability. 21. If I put in enough effort I can succeed in mathematics. 22. Sometimes math makes me feel afraid. 23. You have a certain amount of math intelligence, and you can't really do much to change it. 24. Math is a subject with lots of connections between ideas. 25. It is really helpful to talk about math with others. 26. There is usually only one way to solve a math problem. 27. I like to solve complex problems.						

Appendix E

Career Challenges Final Reflection

Please read each question below carefully and provide detailed responses.

1. What is your name (last, first)?

2. Which challenge in the Career Challenges game did you find the most helpful to your understanding of mindsets? *Mark only one oval.*

☐

Critical Thinker Challenge 1

☐

Critical Thinker Challenge 2

☐

Critical Thinker Challenge 3

☐

Critical Thinker Challenge 4

☐

Communicator Challenge 1

☐

Communicator Challenge 2

☐

Communicator Challenge 3

☐

Creator Challenge 1

☐

Creator Challenge 2

☐

Creator Challenge 3

☐

Creator Challenge 4

3. Why was this the most helpful challenge for you?

4. Why is it important for students to develop growth mathematical mindsets?

5. What do you think it takes to learn mathematics well?

6. How would you respond to a student that struggles to understand a concept you are teaching in your classroom?

7. Describe important instructional practices to use when teaching mathematics.

Appendix F

Developing Pre-Service Teachers' Understanding of Mathematical Mindsets: Influences of an Online Gamification Tool

Semi-Structured Interview Guide

Introduction:

- Introduce yourself: I am a doctoral student from the Theory and Practice in Teacher Education department. I am conducting a study about using an online gamification tool to teach pre-service teachers about mindsets in mathematics.
- The purpose of this study is to examine how the use of an online gamification tool influences PSTs' understanding of mindsets in mathematics. This study can help mathematics teacher education programs seeking to promote effective strategies in teaching of mathematics.
- Pre-service teachers' responses to interview questions and your coursework assignments and activities from the mindset module collected for this study will be used to examine their understanding of mindsets in mathematics.
- Names on all student responses will be replaced with a pseudonym permanently. Unidentifiable responses will be kept on a secured computer account protected by a password to ensure confidentiality. The results reported will not include any specific information about individuals. Audio recording of interviews will be stored on a password protected computer owned by the researcher.

Background of Interviewee

1. First, please tell me about your studies and where you are in the VolsTeach program.
2. What are your future teaching plans or goals?
3. Tell me about your experience learning math in high school?
 - a. Can you give me an example of this experience while learning math?
 - b. What was a typical math lesson like when you were in high school?

Opening Questions

4. Which activities did you complete during the mindset game?
5. Describe what you did for each activity and please tell about it in as much detail as you can remember?
 - a. Did you work with a partner on any of these activities?

Key Questions

6. Walk me through how you chose activities to complete in the Mindset game.
 - a. Tell me more about why you chose the activities you completed.
7. Did you find any aspects of the mindset game especially helpful and please tell about it in as much detail as you can remember?

- a. Tell me more about how this aspect/activity/assignment/etc. influenced your understanding of mathematical mindsets. How did it help you understand mathematical mindsets by participating in this activity?
- 8. Did you find any aspects of the mindset game unhelpful and please tell about it in as much detail as you can remember?
 - a. Tell me more about how this aspect/activity/assignment/etc. was unhelpful in learning about mathematical mindsets.
- 9. Walk me through critical moments in learning about mathematical mindsets using the online gamification tool.
 - a. Tell me more about how this aspect/activity/assignment/etc. influenced your understanding of mathematical mindsets.
 - b. How did it help you understand mathematical mindsets by participating in this activity?
- 10. Can you describe how you implemented teaching practices that foster a growth mindset in your last lesson plan?
 - a. Tell me more about why you decided to include this teaching practice(s) in your lesson plan.
 - b. How does this teaching practice foster a growth mindset?
- 11. Please give me an example of a learning experience while using the mindset game that stands out to you and helped you construct a math activity that fosters a growth mindset. This math activity could be for either your final lesson plan or while completing one of the activities/challenges in the mindset game that involved creating an activity or assignment.

Closing Questions

- 12. What do you think is important for teachers to include in their instruction of mathematics for their students to be successful?
 - a. Why do you think this is important?
 - b. How would this help students?
 - c. How do you plan to foster a growth mindset in your classroom?
 - d. Did the mindset game help you understand what teachers should include in their instruction?
 - How?
 - Why or why not?
- 13. What are your hopes for your teaching of mathematics in the future?
 - a. Why do you think this is important? How would this help students? Is this different from your experience? How?

Appendix G

Maria's Data Analysis Table

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Providing Challenging Learning Experiences and Tasks	I like to be struggle. Yeah. I like this being like struggling, like finding the solution. That process is um, very like learning a lot of stuff from that and also at the end if you find out a solution it will be rewarding system. You want to challenge yourself without somebody telling you.- This is just a way to challenge yourself I guess. It's like very beneficial for them to learn something they struggle with It's just an interactive, engaging, um, activity to kind of motivate them to learn. And the more important too, to foster that growth mindset, which will help them to learn the content better That cut-a-card game foster mindset, growth mindset because of like it's cause perseverance. Um, and uh, the thing thinking outside the box to solve this problem eventually. Otherwise if you just struggled and then give up quickly, easily then, then you just give up the opportunity to learn And then also, they kind of foster a creative and critical thinking for them by challenging them through the rigorous task and, uh, allowing them to struggle and tell them the importance of learning from mistakes. Because you as a teacher, you have to kind of establish that kinds of positive learning environment where students know those norms of learning
Valuing Mistakes	How that would foster a growth mindset? Um, I think first the trial and error thing, that process you're teaching them, not just like give up as, as soon as you can't find a solution that's kind of my [inaudible] [00:12:39] or um, a like social learning thing for them to realize giving up. It's as soon as you give up, you give up opportunity to learn. So it's pretty important for them to have

	that kind of positive, positive thinking about learning.
Use gamification to help address negative dispositions in math	Because math can be very stressful and um, a lot students do struggle nowadays. So it's kind of relief, some stress when they doing the game, but along with that game to learn the content I want to be very creative, like all those, um, game, game, we create, were pretty, uh, engaging and very creative very creative way too. And that's what my ultimate goal in teaching in the future is. Uh, making lesson, um, fun and creative way that student won't get bored of the lesson. Gamification is definitely, I think it's very, um, very beneficial tool in future education or nowadays education in the classes where students, they can learn from enjoyment, not just simply learning like in a bored way. They don't want to learn because a lot you know secondary education, they are forced and I don't want to say forced, but it's required. It's not what they choose to, to pursue Most students have that kind of mindset think, oh I go to school just because I have to. It's not, I choose to. So like implementing this kind of game game method of teaching will engage them and motivate them to learn and maybe also they will find some kind of interest in that process.
RQ2: What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	
Engagement	I really like that Cut a card, um, activity in the game, online game thing. It was very, uh, you know, to and to see a different way, kind of different perspective to approach a problem. I think it's interesting. First, it's really more visually learning? I think I'm, I learn better by seeing picture or stuff. So that's why a picture worth a thousand words. When I saw that picture, I thought, that's fun and it's hands-on experience and that's why I chose it I really enjoyed that on Kahoot creating question thing. It took me a long time because I really think deep about and provide me some kind scenario like I put a lot of scenarios
Experiential Learning	And at first it's very challenging and I struggle a little bit like how to get into that kind of a shape. And at first I kind of like this is impossible. There is no way to cut-a-card to like that. Um, after trial, trial and errors and kind of analyze a little bit how this missing part still like still standing up or like the other side it's not

	missing but it's like on the top of that card, which it was really complex but then like through trial and error as I say, and then eventually I found a way like by flipping over the card. That cut-a-card game foster mindset, growth mindset because of like it's cause perseverance.
Autonomy	I think Kahoot it's more broader, broad. Where you are the inventor right now. You can invent the question. You create the question for others to learn from you. So that's taking, that's shift from that cut-a-card game from where you re-invent like recreated, what others already recreate. Like you learning something from somebody already established. But where as Kahoot game it's you learn some information and to apply those information to create something new. I think actually do something that's my, my own work It definitely is shifting from um, learning the knowledge of the growth mindset and fixed message into creating my own works. You'll see my own words and you'll see my own examples. It's really helped. Helpful, more memorable too in the future. Gamification is definitely, I think it's very, um, very beneficial tool in future education or nowadays education in the classes where students, they can learn from enjoyment, not just simply learning like in a bored way. They don't want to learn because a lot you know secondary education, they are forced and I don't want to say forced, but it's required. It's not what they choose to, to pursue. Most students have that kind of mindset think, oh I go to school just because I have to. It's not, I choose to. So like implementing this kind of game game method of teaching will engage them and motivate them to learn and maybe also they will find some kind of interest in that process. I think you said three different categories like computer hacker, social media, - And game design. Yeah. That definitely a offers student choice. And they still learning. - That um, it helps me a lot when I have my own choice to, to um, to use what information I learned and the um, how I got to express my learning into the audience. So it's really, I think it's really important for teachers to think about what different ways of information you can present to students. Also, what, uh, what kind of expressions you allow student to use

	Provide, um, different instruction for students. So they like you putting a lot resources, different resources, either a video to help the student who are visual learner, who, who learn better by listening and stuff like that. And that also you put articles, maybe a lot of people is fast reader. They can like learn much better with the context with the words that's written in the paper. So differentiate instruction. Um, how like different you provide me different materials, like material in different ways to help students learn subject. And, and now that it's the output, this is input different ways of input that. But what kind of output you allow student to deliver to you? What, like the, uh, presentation expression, what kind of expression? They can use a picture, draw a picture to, to, uh, indicate their understanding or they can written in words. Just provide as many as ways of delivering their understanding.
Social Interactions	The card, I think we all alot of us around that table kind of did that together.
Game Structure/ Design	I really like how the information was displayed in a way student learn first I really liked how you said you have to earn at least a hundred. This give a benchmark of what they have to accomplish by the day. So it's still every student accomplish what you addressed them to do, but for the more competitive students they will do more. So, I really liked the idea of like, at least giving the minimum of point, having them to do. So it also formed some kind of competition. Yeah. Some kind of competition for students to compete each other, but in a good way, which they learned. And uh, also like for the competitive student, they would do more and they will learn more, but for other students, They also can like learn from this activity Technology: especially for students now a day, technology is a big thing. Almost everyone knows how to play games
RQ3: What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?	
Development of Some Critical Understandings	I think probably like that website you can gradually adding more kind of stuff for people to explore and learn. And actually I think it's, it's going to be very good resource for people to see what kind

of things that a lot of people already done and what they can learn from those activities. Maybe some like [inaudible] [00:29:43] or just post any kind of like [inaudible] [00:29:45] questions to **involve their thinking even mathematically or scientifically questions**

Variety of Resources

Maybe the Kahoot game can be frustrating at first because you have to create that many of questions and you feel like growth mindsets only one big idea of this. It's hard to come up with many questions, but after **thinking more deeply** like you looking, searching more specific information about that, it's easier to come up with more questions. So more you know the more questions you can come up with.

Maybe you can encourage them or share more kind of resources for them to read about in order to help them come up with better questions to ask I think.

Appendix H

Will's Data Analysis Table

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Providing Challenging Learning Experiences and Tasks	After reading it, um, I know that it talked a lot, like the entire project was growth versus fixed mindset and um, one of the like instructions for the challenge was to see how the this activity could foster either growth or fixed mindset and um, this was just one activity that could definitely foster the growth mindset. So, um, a lot of students, if they don't get something right away, they give up. Uh, it's kind of the fixed mindset way. Um, a challenge like this, that's like real world applicable. It has like you may not necessarily need to ever figure this out, but it's still tangible. It's something that you can relate back to. Um, it gives like the idea of it, there has to be a solution out there. So, um, especially with like this problem, you could always tell your students that there is a solution and um, to just, I guess persevere until you found out what it is. Even if that's by trial and error, or I think, I don't remember what the number of pennies was, but I mean, if it's trial and error up to like 90 times, at least you can eventually get it. And, um, I think that's just a good way to foster that growth mindset The foldable inside the classroom, um, students who have that fixed mindset may try something once and then it didn't work, so they shut down or give up. But, um, with like the foldable, having to try it multiple times until you get it, it's just that it teaches you that being wrong is okay. Um, you learn from your mistakes, you try again until you eventually get it Another thing would be just like some of the activities that we were able to do, it's like you would never think that a random YouCubed challenge could foster this growth mindset, but in reality it was a big difference Having the kids create their own unit rate. So, um, after that we are going to allow the other students to solve like one student's unit rate. Um, but that's going to lead into a discussion of how each of our unit rates that we came up with can be, um, all equally correct because it was based on whatever you thought. Um, so there's not always one right answer to a math problem.

	Not everybody's answer will always be the same and that's okay So, um, that's going to lead to a discussion of why everybody's price per skittle isn't the same. And just to talk about like not all the time, people's answers are going to be the same in math
Sending Growth Mindset Messages	The process of math rather than the correct answer. I think that gets students because just like the little bit of praise of you didn't get the right answer, but you had all of this correct can make the difference in Students shutting down and never wanting to like not wanting to look at math again for the day or the student like continuing to do that problem and trying to solve the problem that they're working on. I definitely know that I will foster more of a growth mindset versus the fixed mindset in my own classroom. Um, just because I can see now how helpful that is. Just like looking between my friend and myself - seeing that where I am now and like how I like math versus like her absolutely hating math. I think it was a lot to do with how our teachers treated us as students and my teachers were always good about mmm, going after like you didn't get it fully correct, but here is the things that you did correctly. So, um, I hope that I can be the same way. Um, and just overall helpful to any student in math and try to get them away from the fact of they can't do math and show them that they actually can do the math."
Valuing Mistakes	The foldable inside the classroom, um, students who have that fixed mindset may try something once and then it didn't work, so they shut down or give up. But, um, with like the foldable, having to try it multiple times until you get it, it's just that it teaches you that being wrong is okay. Um, you learn from your mistakes, you try again until you eventually get it I think it's not about the correct answer. It's about how you get there. So, um, the process of getting to the correct answer is what's important. And even if you tell your students that in high school or Middle School, elementary school, I don't, I think it matters the process and not so much the correct answer. The importance of process and how you get there. Let students know that if they don't get it right away, then it's fine. Um, not everybody is a quote unquote math person. So some people it's going to take longer to understand the material, but if teachers are willing to work with students and help them out, then I think we

	would see a lot more students enjoy math rather than see it as a burden. So I think teachers fostering that just mindset of, uh, I guess the growth mindset would be really beneficial to their students as well as the teachers because they'll see, I believe in improvement in the students' grades as well.
RQ2: What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	
Engagement	I thought it was interesting . Well, to be honest, I thought it was going to be easy , but um, it wasn't as easy as I thought, but after a while it just became like determination to figure out how to do it. So you start because of something, it was also looked in like interesting . So you start with something that looks interesting and possibly easy and then you learn that it wasn't easy. But at that point my mindset was just that I had to get it done because of determination and curiosity.
Experiential Learning	We had a lot of trial and error based problems. Well a lot of trial and error in this problem. Uh, eventually me and a group of students were able to make the correct cuts and folds to make it look like the model. I thought it was interesting. Well, to be honest, I thought it was going to be easy, but um, it wasn't as easy as I thought, but after a while it just became like determination to figure out how to do it. So you start because of something, it was also looked in like interesting. So you start with something that looks interesting and possibly easy and then you learn that it wasn't easy. But at that point my mindset was just that I had to get it done because of determination and curiosity. Successful So just like to quote unquote work on something for a long time, granted the timespan and then figure it out it's just a good experience to have.
Autonomy	The amount of ways that you can present material is substantial, especially like with these, with this topic, there was so many options of like just activities to do to familiarize ourselves with growth versus the fixed mindset. The fact that you had so many different options, um, you wasn't limited to, um, one task or whatever. You could literally go into whatever profession that you chose and it didn't matter what profession you chose, it didn't matter what activity you chose, you was still learning about the concepts of growth versus fixed mindset.
Game Structure/	So one of the articles that I ended up reading about fixed and growth

Design	mindset was like fixed mindsets they just think that they can't do math and that there's no learning math. And that's like exactly how she sees math. She says that she's not math minded and that she can't do it But, um, I think as a whole the thing was pretty well put together. Technology: Something that was really helpful, um, was the YouTube videos that was embedded within the, um, I guess game. Um, so I think the YouTube videos were extremely helpful The YouTube videos and that's embedded within are super important and helpful I think because, um, the more we get like the older, I guess our generation gets and the upcoming generation, the less they want to read. So if they can have somebody explain it to them in a youtube video, it's going to be really helpful. Most of it was all in the two or three YouTube videos that I watched. So I mean, YouTube videos are the most helpful thing. I mean there was the question you had to think about the question and try to figure out the answer. Um, it's just like any other quiz or study guide I guess you could say. Um, a lot of our study guides now are either Quizlets or Kahoots, um, so it was just like a big study guide. If you didn't know the answer, it gave it to you right away. Um, if you did know the answer, you kind of felt rewarded because you got points for knowing the answer.
RQ3: What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?	
Time Constraints	Yeah, I thought about a video. Um, and then due to just a lot going on that week, I didn't think I would have time to put in the effort that I would like to put into a video So I just switched to, um, stuff that I could do during class rather than outside of class material.
Clarity of Game Structure	I think when like us as students see like computer hacker or stuff like that, we figured that, um, maybe it would be more oriented towards that profession, I guess you could say. So like, um, computer hacker and like coding. So maybe like a game or something on coding or, um, just things that go more with like the profession that you choose, I thought would be more beneficial I guess

Appendix I

Lily's Data Analysis Table

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Providing Challenging Learning Experiences and Tasks	Something coming to you right away and struggling through it and then getting the answer, I mean, if that's two different people doing that, I mean, they both got to the answer. It doesn't mean you can't do it. And like struggling means that you're being challenged and you're being, um, pushed to learn more information. If you're, if you're never struggling, then you're not really learning anything new. You're not being appropriately challenged. And so it was like struggling is important Struggle to like not just figure out the problem, but kind of like prove why it's that way and you're struggling to find the solution and to explain the solution, which can be challenging but important. But, like feel like the success and like, okay, look, I solved this problem and I was, it was hard but I did it and I still did it and I like powered through. And I think But then I mean I'm going to make sure that they're all successful. I mean, it's all about, I'm not stuck not knowing this, like I, I, I'm not a math person so I can't do this. It's more, it's um I'm going to put the effort in to solving this problem and I might need some help along the way, but I'm going to do it. And, um, I want them all to be successful. I obviously want to learn, want them to learn the information, but like it's a little bit of a struggle and um showing them their own effort can help them get to the solution. Showing a video, like kind of, and like, even like the whole first week kind of like, doing like an activity, like the cut-a-card activity where that's not really like tied into any curriculum. You're not, you know, but like that kind of thing. And like thinking outside of the box and getting students used to that. And so then they're used to struggling a little

	bit. And so then when they actually are faced with like a math word problem or something, it's okay that you're struggling. Yeah and like make sure everyone's appropriately challenged so everyone's feeling that struggle. So, everyone can grow. But it can be really interesting and you can learn a lot of problem solving skills and a lot of skills that transfer outside of the math classroom. And so I think that that's something that, um, teachers can think about. And I think a lot that also comes with it like teaching a growth mindset.
Sending Growth Mindset Messages	I like can see some of the students asking me a lot of questions about it. And I think by questioning back to them, instead of just saying, this is the answer and this is how you do that, kind of like directing them and saying like, I know you can figure it out. You got to work on it. I think it's like that part of the lesson is like the struggle. Um, I think um, positive attitudes towards your students is really important because um, if you are acting negatively when for whatever something a student is doing, I mean they're not gonna they're going to think they can't do it. And so being encouraging and not and saying like, I mean like praising effort over ability, effort over like your grade Even if somebody isn't, a student is struggling in their grades, I mean if they're working hard, and like pointing out, but that's a strength that they have. That I see that you're working hard, then hopefully they can, they're still going to stay motivated to keep working hard and hopefully understand more and more every time they come into your classroom and not see math as like a scary thing that they can't do. I think I liked the video. I could see like not even that specific video, but I could see myself in this future planning like a video about growth mindsets or something on like the first day of class, like that first day you don't really do anything, so you might as well like start building this idea of what a growth mindset is to your students. Like this is our class, it's going to be like this.
RQ2: What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	
Engagement	Like looking at the picture, like I had absolutely no idea like how that worked. And so I wanted to know how to, how to, how the card was like that. I think is why I picked that because I wanted to know how.

	But like I could see what other people were doing too and like, that was just helpful to have other people doing it too. But I'd already like looked at it and was like, huh? How is it like that?
Experiential Learning	It was exciting. I was like, oh my gosh, that makes so much sense. Like not even, it makes sense, but like it is possible. Like I was kind of like, I can even do it. Like I'm not even sure if it's real. But once I think once I figured it out, it was a little bit of a sense of accomplishment I already knew some about mindsets. I think that like doing that card activity and like experiencing that. Like that was like actually like a simulated student doing a math problem and struggling and then finally getting to the answer. Like that was just like a nice reminder of that, it's actually like real, we're not just reading all these articles about students struggle and then they get there and you feel good. You know, like it, like it does feel good when you solve a problem and it motivates you to solve the next problem too. So it's nice to like feel that But, like feel like the success and like, okay, look, I solved this problem and I was, it was hard but I did it and I still did it and I like powered through. I think like the beginning activity of like everybody doing the same thing was also helpful because like that gave me information that I needed to get to understand growth mindsets and then like my activities I chose kind of helped me experience them more.
Autonomy	I think this time around learning in the game, like having to write those reflections and like, I saw, and I did the Twitter thing, I saw a lot of different tweets and I was able to pick out ones that I resonated with the most. Like I could see myself like feeling this way about my classroom like using the same in my classroom Um, I liked that I had choice. Um, because I could pick the activities that I wanted to do and so I wasn't, I chose to solve the problem of why the card was that way, not like forced to do it. So that's also I'm more motivated to do it and to experience that like growth mindset activity of like this is hard. And then, oh look, I did it. Whereas I wasn't like forced to, which I think is um, like an important part of having a growth mindset is that, I mean even if you are like, it is a required assignment and stuff, like there needs to be motivation to get to the end of the road. I

	think the choice helped me to be motivated Because there was still a little bit of choice. Like with like the padlet, I think there are a few things you could choose. Like you didn't have to watch every single thing or read every single article I think. I think keep a lot of options and choices. I found and that makes it seem like it's more of a game to me to have a lot of choices. Um, I really liked, that was my favorite one.
Social Interactions	So there was a group of us that were um doing it at the same time and I think that if it had just been me the whole time trying to look at it and figure it out, I might not have, it would have taken me a lot longer A, and B I wouldn't have, I might not even have gotten there. Like I might've given up. But I've found it helpful to like talk about my ideas and like other people were like there to hear what I was saying like, oh wait no let's do it this way and stuff. But like I could see what other people were doing too and like, that was just helpful to have other people doing it too. But I'd already like looked at it and was like, huh? How is it like that? I just think sometimes you can't, you might not get there on your own, you know, like you're just, you're, if you're not like talking about, I find it really helpful, at least in my experience to talk about it. Even if I am like super confused, at least I'm like bouncing off my ideas and like my ideas are being heard from someone else and it kind of gives us a starting point to work together to get there. And it's, I mean it's just a lot more of like a, this is a challenge and we are going to get there rather than like, I'm sitting here on with it on my desk with one lamp on like struggling over this problem and it's going, it's lonely and dark and sad. Whereas like in a group it's to me seems more like, like less of like less pressure I guess.
Game Structure/ Design	I think I liked the video The video, I think the video talked about how our brain actually changes is that? I think I liked the video. The video, I think the video talked about how our brain actually changes I've seen the mindset in a lot of students that they have all the answers on their phone or their computer. So why do I even need to go to school and learn? Um, so because you don't know everything and your phone

	doesn't know everything, whether you think it does or not. Um, so showing students how technology can be used for education, not for entertainment, I think is important. And discussing the um challenges and responsibilities that come with technology as well and how it can be used to solve real world problems in the math community. And I think in the math classroom we should take technology away, but also give it to them as a tool, not as a form of entertainment. So that that mindset changes a little bit from, you know, I'm secure and I have all my information here to maybe I don't know how to use technology. Maybe I can figure out how to use it to a benefit and not just play this flappy duck game or whatever.
RQ3: What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?	
Clarity of Game Structure	I think at first I was confused how it worked, but then once I actually started doing it, I got like I got what I was trying to do. Like I was like, okay, each I just need to pick a number of activities that will get me these points. But like initially I was kind of confused, but like once it actually was doing it, that was kind of, that kind of went away. I guess there was like no way where I could like see like my, the points I was going to get like accumulating I think, I don't know if you could do that in the future Kind of like a, um, like a map, so to speak, of like this is the starting, cause we had to do the starting and then like we got up in the classroom. And so I was confused about what happened in between. What that would look like. And then once I realized, oh, I just need to get those points to get to 100 and I already have these points here. I'm going to have to do these, so I already have those. But like I think I wanted, I was like confused about the bigger picture

Appendix J

Austin's Data Analysis Table

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Providing Challenging Learning Experiences and Tasks	Just activities like this, like not necessarily once a day, but like the card game, the index card, um, just showing kids that at the beginning of the day automatically gets them thinking about something. So, and especially something challenging like that it's going to stretch their brain and it's going to leave them open for information and leave them wanting answers so they're going to be more engaged. So just, it doesn't have to be the card thing everyday, but giving them a problem or something that makes them think that then that then that will promote a growth mindset. I love these activities. I would do, I would do the index card trick or things like it just to have their mind going about something, even if it doesn't pertain to the lesson necessarily just something that helps them think for a second, then they're more open to receive the information
Sending Growth Mindset Messages	Just think, I love these examples, um, changing stuff from saying I can't do it to I'm on the right track. Just a positive outlook on what you're doing is very beneficial for students and it supports a growth mindset Um, that was a question I had was, you, you have a student that may be saying something like that. What's something you could say back to them and make that supports them
Instructional Strategies	Using it as a real world application- So, one of the questions I'm, I'm having in my exit ticket is having them write out of word problem to describe like a situation where they'd find circumference or they'd use circumference. Yeah, just has them go a little bit beyond what they're learning- Um, just seeing that math isn't about numbers, all the like, it's about numbers, but it's about applying numbers also. So I, I think a lot of times teachers just give their students the equations and stuff like that, but then they don't reflect it into the real world sometimes so just having, having that outlet opens up their minds and lets them go, oh, this relates to this, so I could use this

	Giving them a wide range of problems to do. Because if you, you have one standard set of like problems that you're working with like maybe a worksheet with all the same kinds of problems, then students are just going to be in a rut and they either, they either understand it fine or if they are not being challenged enough or it's too challenging for them. So if you don't have a diversity of problems that you're working with, then you're missing two thirds of your class or you're missing a third of your class and you're weighing down another third of your class. I'd use the Internet first because it's full of different perspectives. So I try to find like a different perspective on how to teach them that they didn't, if they couldn't figure it out through, um, process A maybe process B will work. If that doesn't work, process C. Just keep going. You just got to keep working with them.
RQ2: What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	
Engagement	So I thought when I began the project I had a path in mind, but then I completely changed as I was doing it. So the card one caught my attention after I saw it and wondered what was going on. So I wanted to figure that one out first because it's very interesting Just the unnatural appearance of the index card as it was being cut. And I thought that's a cool trick to show your friends too, because it blew my mind. So they, because all my friends, they're like, Oh [Austin], your math, you get, that's cool or whatever. And they, they think it's lame or whatever, but then you show them something like this and I'm like, what? That was done with math somehow? And you're like, yeah, I guess so it's just interesting party game I guess The card one was fun, so I wanted to do a fun one. And the, I think the Twitter one helped me learn definitely. And I thought it was easy also because you had such a large list of people that you could easily just grab a quote from or grab a picture from
Experiential Learning	You really had to think about how it was made that way. Because if you look at an index card, it's just normal. But then when you looked at this one, it was cut so strangely and the fold was weird that you'd have to think about it or it would just bug you. You'd have to find out the answer until it just bugged you to death But the fact it was taped down to where you couldn't move it or work backwards with it, it, um, it was hard to figure out, but eventually, eventually I could see it without having to move the paper physically. I

	could think it in my mind and like move the paper. And then I saw the cuts. Figured it out.
Autonomy	The game itself split up well to give you multiple options to do stuff. So one thing was, if you didn't understand a growth mindset through one option, you had multiple options that work for it. So what I did was I went through each one individually and I said, which one looks easiest? Which one looks fun? Which one looks like I'm going to learn the most out of it. Um, so just having the option out of it, very help helped a lot, taking what I wanted to do and the ones that I picked helped me Letting me able to choose what I wanted to do, engaged me more so I was more susceptible to receiving the information that was given to me in these projects Along with having the optionality, I like the variety, like what was asked of us to do because the Twitter one you're looking up stuff and the card one you were working with something physical, so just doing different things like you could have, you could have told us to do just the, like you could have had a lot of options to do things, but they were all Twitter based or they were all physical based. But having a variety of different outlets to go find a growth mindset out of was interesting and helpful. Um, that was a question I had was, you, you have a student that may be saying something like that. What's something you could say back to them and make that supports them
Social Interactions	The Twitter, the Twitter one was very helpful because it could, you could see everybody's different perspectives. So if I was thinking growth mindsets is just blank, then maybe I wasn't capturing the full effect of a growth mindset. But having these different inputs, I now have all these definitions to work with to get a good visual of what a growth mindset is. And I have all these new tools that I've found, like with the visuals and the quotes and stuff like that to implement it into the classroom So the, the person sitting next to me also did the same challenge. After looking at her project, I noticed that all these people had different ideas about growth mindset. They were all very similar, but they all had like a different experience with it or they had a different perspective on it. So I wanted to see how people were thinking differently as well. So there were a couple of quotes in a couple of visuals that I thought were very appealing that answered some of the questions that I had about it or they gave good examples of what a growth mindset looked like.

Game Structure/ Design	Technology: The visual with quotes on it And I found some good quotes and some good visuals that represented a growth mindset.
RQ3: What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?	
Time Constraints	Um, one of them was making, I think making a video or something and I just thought that would take too long in my busy schedule. I couldn't do that one because I didn't have time to do it. It sounded fun though, but um. Just, just having to go through the process of designing a video, making a video and then editing it, uploading it, all that stuff just seemed like a little bit too much. But it was worth a lot of points.
Clarity of Game Structure	The subcategories that you chose, I forget what it was like a game developer or social media outlet. I didn't necessarily understand why you chose those titles or whatever. Maybe if they were, maybe if you just had every option just in one list or something instead of splitting them up into three different categories cause it, um, it wasn't hard to look for stuff to do but having to go through each tab and like looking through all of them and then picking one and then having to go back to it or some navigating through the page might be a little bit simpler. Just if you had a list of all the activities on one page

Appendix K

Danielle's Data Analysis Table

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Providing Challenging Learning Experiences and Tasks	Present the material in such a way that it challenges all students to appropriate levels. Cause if you're challenging only the low students and everyone else is just floating by, then you're not helping progress the students that are higher achieving. But vice versa, if you only, if you're, you're presenting the material at a challenging level for your higher achieving students, your low achieving students are, are going to be so lost that they're just going to fall further behind. So making sure to like present the information in such a way that every student is appropriately challenged. If students aren't able to like grasp it at all to where they're like, it's so far over their head, they're going to be, that's going to push them into a fixed mindset because their entire life they're gonna never get it. Um, and while productive struggle is helpful that like if you never feel that light bulb moment, you're just, you're going to be wandering around in the dark for the rest of your life. Um, so, you know, we need light bulbs along the way to light our path Cause if they can see their own growth, if they can see, I started here and through my own hard work, I'm now here. Like that's going to show to them. And if it's, this is a consistent thing, they're gonna realize, oh, I can keep going. If I put in the work, I'm going to get the results. Um, rather than a student who's constantly, like, they feel so overwhelmed or like I'm trying, I'm studying and I'm still not getting it. Um, kind of talks about that whole concept of like productive struggle and teaching students to put in the work. In order to get, in order to learn cause you can't, you can't spoon feed them information, but you also can't, you know, put the information on top of Mount Everest and expect them to climb it, if you don't give them any like climbing gear and stops along the way.
Sending Growth Mindset Message	You oftentimes get as a teacher, students who are just like, I can't do this. Um, so just really focusing on like with them [inaudible] [00:24:53], let me break down the problem and see where you're tripping up and let's, let's change that I can't do this to like, I don't

	know how to do this yet and then work towards, I can do this. Because so often once kids get in their brain that I can't do this. They're right, they can't do it. Cause if you, if you don't think you can do it, then you're not going to be willing to put in the effort to learn how to do it. Um, and so really sitting down with a student and encouraging them and if they see that you still have faith in them, then they're more likely to still have faith in themselves. But so often they've, like, I mean there's even teachers that will tell students, you know, it's okay, you're just not good at this. Um, and then that's going to cement in the kid's brain forever that they're not good at this. Um, so really just making sure to encourage them and like, you can do this, you will get it, you just have to keep trying.
RQ2: What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	
Engagement	So I really did enjoy that you could kind of like personalize it Honestly cause that's just how the math worked out. Cause like I wanted to do those two cause I did the cut-a-card and that was already 30 and then like I wanted to do something, like I said, using the material and not just kind of like applying it. And so like the Kahoot kind of sounded like the one I wanted to do and the math just happened to add up and like if the Kahoot had been just enough to put me at a hundred, I still would have done it. It just happened to go over. It just doesn't fit with my personality and what I like to do with things. Um, and again, like the paper one was one where it's just like I could do it, but these other ones sound like more fun, um, while still like covering and learning the same basic things.
Experiential Learning	I personally started, I was just like, let me make a cut or two in here and see how I can fiddle with this. At first when I saw it, I saw that the picture wrong. So I thought it would literally just be two cuts and pulled it out. But then I realized that caused like a twist in the paper that wasn't in the actual paper. Um, and so it was just for me, it was a lot of just kind of trial and error of like looking at it, I can kind of generally see that there's been some cuts in these areas. So then let me see where I can go from here. Um, there's a lot of thrown away note cards cause they ended up getting cut in half or cut wrong. But, um, I enjoyed it, um, in the sense that like, it really puts you in the mindset of the student who was doing activity Tried the Kahoot to go along with it because that one was more almost

	like of a meta sense of like let me make the questions about mindsets, um, which really required me to go back and like look back at those videos and the like, um, PowerPoint that you posted and whatnot to really like understand the information so that way I can regurgitate it as a question and then come up with answers as well to the question, um, whereas with the first activity (Cut-a-Card task) was more, let me put these mindsets into action and to think a little more like about what's actually covered in material of growth mindset
Autonomy	I thought it would be good to have like just for myself, like two different things. -So I thought it'd be fun to do something to where I was actually like talking about the material rather than just implementing material. I liked that we were given like the information about it beforehand and then like kind of given like a bunch of options. So I liked the variety in terms of like, well there's one that I was thinking about doing where like you reacted to the video where there was one where you could make a video. So that's somebody who's more like creative. I'm not a super creative person and I don't like to like film myself and so like that the one where you film a video of yourself seems like, you know, I'd be tortured, like please don't make me do that. But I'm sure other people are like, oh my God, that sounds like so much fun. So I really did enjoy that you could kind of like personalize it
Social Interactions	We kind of worked on it as a group Cause [Will] and I were sitting next to each other. Did you want to work with partner, we should be together and he was like sure. And that one was like he said like, let's do the cut-a-card. Okay. It was kind of his idea
Game Structure/ Design	Going through the process of like learning it all, but then like having to regurgitate information in like the reflection sections, on the Kahoot questions, and things like that really like helped like solidify it because like reading about it and hearing about it is one thing but then like reproducing that information like in my own words and like applying it to other situations and things like that was really, like helps, like learning the information put all the puzzle pieces in front of you and then like they just like went together as I was like working through the game. One of the math mindset slides - Um, kind of talks about that whole concept of like productive struggle and teaching students to put in the work.

	Technology/visual: I don't remember if it was the first video or the second video, maybe it was both because they were fairly similar, but, um, I didn't know that your brain can actually change I really liked, I don't remember if it was the first video or the second video
RQ3: What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?	
Time Constraints	There's also the thing, I think it'd be interesting to like make this more like a long term thing to like meet with freshmen and do something like this, like their very first class as a teacher and like periodically like check in and do sort of mindset type things throughout rather than just like, you know, one like week long thing. And then like you know we're done. I think some of those would have been more helpful in like a bigger class because with only nine people. Like it was hard to like tell if anybody was going to do any of those
Development of Some Critical Understandings	I'd almost make it so that you have to do three things and not just two. Just make them all like worth less points I guess. Or some of the big ticket ones worth less point because in terms of like, I don't know, it almost felt like I did the two things and then I was just like done and like, I don't know when you're talking about like gaining 100 points in my head I thought that was going to be like a bigger thing than it actually ended up being because especially mmm like after [Will] like did my Kahoot which is another ten points. So that one assignment was already like I think like 60 of hundred points or something like that. Um, I'd almost be interested from like a math perspective to do a study of like people's answers on that mmm questionnaire thing before and after. - Yeah. Just to see if like their questions changed um, at all. That's just because I like to analyze data.- Yes. So, I really liked that concept. I wish I could've gotten to see my answers, because I don't remember what I clicked on. That'd be interesting. Variety of Resources: I think the one, one thing it's just kind of repetitive, especially just the information at the beginning because there's, like three videos and then

	like the two articles were one thing. And then like beyond that, there's that whole list of like other options and a lot of, I mean a lot of them at that point are kind of just repeating the same information It (STEM article) was just very discombobulated. Like they started talking about mindsets a little bit and then I went off to do this study about gender and then like there's other study and then again there's like two sentences again about mindsets and it just felt very... And I, I know like talking to other people in class, they had fairly similar takes on it though.
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Appendix L

Travis' Data Analysis Table

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Providing Challenging Learning Tasks and Experiences	And generally I'm not a great test taker, but I wasn't failing, you know, I was passing and, and that's the key word or the key statement actually now in reflection of what I just said. I wasn't failing. I was passing, passing is succeeding. So my mind was changing. My mindset, instead of saying I can't do math, I said to myself, I obviously can do math.
Sending Growth Mindset Messages	You are good at math because you wouldn't be in this class if you weren't good at math. You've already gotten here so you're not bad at math, you can do it. I just wanted to make sure that you are choosing the right path because it's not going to get any easier. And all at once I was encouraged and challenged and that, that was like the key point, that little bit of encouragement of someone saying you wouldn't be here if you couldn't do it, you can do it. That's even in my video, that's, that is my statement. They can say, oh, I can't do that. But like, oh no, no, you can do math. You've just not met the teacher who can teach it to you yet. And I mean that's, that to me is the whole idea behind changing a mindset. I find that I have heard many times from, more so from the parents of, of, uh, younger people, um, I, I can't do math. You know, I've never been able to do math. Uh, and, and like I mentioned a moment ago, you know, I just, if we've just never met the person who can teach it to you, um, what better way, I find that what's personal story, you know, the human narrative is something that we can all connect to. So since my video was essentially my story, I, I shared it with a couple people. I shared it with a couple friends and they said, are you gonna like put that on YouTube? Like, I want to, other people should see this. Like, I mean, I hear, I've heard word that I might've brought a couple people to tears. I started to think about what one of my, my grand ideas was, uh, as far as how I can, not only help my students when I do have my own classroom, but half of the battle of teaching a younger person that's also teaching their parents how to help them learn. Uh, especially with busy career oriented lives or maybe a fixed mindset, you know, you have to provide

	tools.
RQ2: What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	
Engagement	As far as the creator challenge, the video, um, when you first introduced the game to us I just immediately saw that out of, out of every single thing that was an option. Um, that was the one I wanted to do. I am, I've made, I've made movies throughout my life. I'm a creator. I've been a professional artist for a large part of my life It was laid out very nicely. Um, there were a couple of fun little things like go make yourself an Avatar and make your game portfolio. Um, those are, uh, like modern nuances to our online presence that, you know, the, these, uh, it's, I mean, that's fun. I mean, it's kinda fun to do and anybody can, even someone in my age group can be like, Oh, well, I've never done that before. I wonder how I would do that. So it was fun and it got me involved instantly. So the layout in general I think was very beneficial as to actually get your participant involved. It was a, the flow was laid out like just do this first, then do this, then do this. It was playful. It was, and when I say playful, it was, there was no any sort of point where you go, uhhh this is discouraging. Everybody else I saw interact was, was happy to do so. They enjoyed what they did so people love games
Experiential Learning	Um, I took it as a challenge because I instantly knew what I wanted to do. I made my mind up on what I wanted to do. I had very little time to do it, but I had made a commitment to do it and it required me again to fix my mind, I guess to change my mind because there was a point there where I was like, I can't do this. I had to go through the experience again just to even complete it. And when I was done, I found success and I'm very happy about that.
Autonomy	It was very diversified in the tasks. Uh, not everyone is like me and tries to jump for the biggest thing on there. And that's good. Like some people need small bites, some people need big bites You had three different sort of mindsets within that game, so that it was a little easier for someone to say, you know, I'm a, I'm a creator I think that was a great idea. Uh, plus it allowed like me to take myself out of the classroom environment and work at my own speed. I mean, I couldn't make a video like I did in that classroom with everybody standing around me

Social Interactions	I wanted to, to help one of my fellow students along Like to participate in other people's work. I learn from other people. Um, so when, when my fellow student asked if, uh, if I would take the quiz, I just thought, why not? You know, I'm a I'm a team player, so I just wanted to be involved The challenges were, there were challenges that were extremely accessible. The fact that you can also since you're working towards a point base, uh, work with other students. That was really great, uh, participating in other people's quizzes and games that they were creating
Game Structure/ Design	The way it was titled, it allowed, um, let's say a certain flow, uh, of reasoning. So I think I saw other students who were involved in, uh, in the project, you know, very easily find things that they wanted to do. Um, and I found it wasn't hard for me to find what I wanted to do either. it was brilliantly laid out actually You can tell that there was a lot of thought put into it. So it's not like it was just thrown together in a couple of hours. Technology/Videos: I used the references that were provided, um, on the, for the game activity. Uh, there was, uh, one or two videos on mindsets and there was a couple more Um, so we're going through Google educator certification. Um, and then I thought, well, since mindsets is actually so important to me, maybe I should just make a whole other page on my website about, you know, the kind of the neuro science of education. So I ended up posting the videos. The first thing, it's a very simple website at this point. The reason why I said that it was like a Google website, right? Because again, that's where I got the idea of creating my Google website. I was like, I think that was a site. I, I wonder if I could just kind of put some stuff because you made a website for us to go to and do this thing. I was like, well, what if I made a website for students to go to and do this thing? And I did have an application for it at the moment.

RQ3: What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?

Clarity of Game Structure

Technology/Accessing:

Getting the **personal game portfolio together and getting the link shared the correct way** that that's, unless you're very, very fluent and like how you share things and make sure that it's public. I mean cause we're on like an academic server, so making sure that things are shared a certain way. **I found this was a difficult too when I was making my website too**

Cause like if you got a UT email address, it's easy, but everything is defaulted to that.

I'm not the only person out of the group who couldn't find the link a second time. Sometimes emails disappear. Cause the emails disappear sometimes. Um, maybe the, the only real, and it's not even a criticism, but the only real suggestion is uh, uh, some way to make that site link a little more accessible.

Cause it wasn't posted on Canvas. If it was posted in canvas, that would have been nice and making sure that, uh, one of their educators you're involved with or if it's just you yourself, somehow make that a little bit easier to get to because having the links in the email

Cause I had to go and search three weeks back in my internet browser history. And then provide that to a couple other students.

Appendix M

Keanna' Data Analysis Table

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Providing Challenging Learning Experiences and Tasks	But also activities. I know activities are really important to instill growth mindsets, like the folding card activity that I did The struggle, the seeing other students struggle and then figuring it out. Because I mean, I think we had like two students in the classroom that day that just kind of tried it and then gave up and walked away. And then when they realized that, uh, me and another student were able to do it, they were like, what? You can do it? I was like, yeah, we just sat here 15 minutes until we figured it out. You know, you just got to sit here and figure it out sometimes. Um, and you just have to have that tenacity to keep going back and like trying to do it again. I think that's an important idea to instill in students through activities like that.
Sending Growth Mindset Messages	I think the video (My Favorite No) honestly was a big aha moment. Like, wow, you know, it's impactful. You can use language as a teacher. I'd hope that when I had a classroom, I'd be doing growth mindset language every day. You know, you can do this, you know, this is not, I have a problem in tutoring every day saying this is a really hard problem, um, but you can do it. I, I try not to start it with this is a really hard problem and just say, you know, you can do this one, instead of saying it's a hard one. And then so little things like that that I'm getting better at and what language to use is something that I need to practice. But that would be my biggest idea I guess, of how to use it in the classroom is just making sure that my language is consistent with a growth mindset Not just in the classroom, maybe in the whole school. I mean, I've seen schools that maybe [Washington] is the example of the school I saw where they had growth mindset on the wall in like big letters and then like all the different things underneath it that talks about how famous scientists had a growth mindset. When they couldn't figure it out, you know, this is what, they kept going and now we have the light bulb. You know, it took so many tries for so many people until somebody finally figured out it was the light bulb. Um, and I think that

	was at [Washington]. So even in the whole school, not just in the math classroom. I think it's important for sure. If I could give this, this game to my students, even to show them, like teach them what a growth mindset is. Maybe not this game exactly, but I think students would really enjoy something like this where they can see themselves, what a growth mindset looks like. Maybe like a first day activity, first day in the classroom, have a discussion about growth mindset and like this is the type of mindset we're going to have this year. You know, we're gonna get through the year. It's going to be hard for some of you. It might be easier for others. And that's okay. We're all going to get through it together. It's a classroom. Um, I think that would be a good like first day conversation The reason that I want to be a teacher in my philosophy of education in general is that we need to raise our posterity to be better than we are. And I think part of that is teaching a growth mindset because maybe we, we might not have it and might not think that we can succeed now, but we need to instill in the next generation for growth, um, for just the world. I know that sounds like a really big mission that I have, but even if I can do it on a small scale and affect a certain number of students to think that they can achieve something great then maybe they're the person that discovers the next great thing. I'm not saying that I'm going to be directly responsible for that. Maybe not even me, but another teacher. If we're all instilling growth mindsets, then maybe everybody will start thinking that they can do great things.
Valuing Mistakes	It was important that she said it was her favorite no, because saying that you know, that this is wrong has a different connotation than I like how this is wrong. But it seemed like the students were more willing to answer or talk about things because they were willing to get it wrong because getting it wrong is okay. And I think sometimes there's a lack of discussion in the math classroom for the reason of, you know, I'm just going to be wrong if I say something. So I'm just, might not say anything versus I'll be wrong if I say something, but it'll be okay. You know, because it will, we'll grow after that. It won't just be you're wrong, next. So I liked that aspect of it I think that connects to the second activity (Cut-A-Card Challenge)I did too, growing and learning from your mistakes. Almost like process of elimination, but not always in that aspect. It's not always you get this wrong, so don't do that, move to the next thing. Sometimes you learn something specific within your mistake. Maybe in a

	sense of like solving two step equations. I multiplied by two first, but my friends subtracted this over first. You know, which way was easier. It's not necessarily the wrong way, but we can learn from the things that we do to get better and faster or understand more. So making them, those mistakes, they might not even be mistakes. They're just, you know, errors or things that you can learn from. I could see that especially with the, you know, binder activity because that forced you to go back to the topics that you didn't do so well in like the quizzes that you didn't do so good on. She made you pick those topics if you didn't do well. And so it's like going back and having to understand in order to do your final project is kind of like forcing us to have a growth mindset. Instead of just forgetting about that topic we didn't know how to do, you can figure it out. Just spend some time on this project and put it together. So I guess that's a good example in the math classroom.
RQ2: What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	
Engagement	The mindset resources. I didn't want to move on to what we were doing because I spent so much time on the mindset resources, just looking at all of those. And I guess it's cause they were all just right there for me to just move around and open one and then just close it. And, um, I think that was a really good starting off point because I saw all the peer reviewed articles and things like that about mindsets that there are. You know, it's a big field and it's important and I could see that from those articles or videos in that section. I think that part was really helpful. I liked it because it was, uh, actually been a teacher doing mindsets in the classroom and I didn't really know what that kind of looked like
Experiential Learning	I think like the beginning activity of like everybody doing the same thing was also helpful because like that gave me information that I needed to get to understand growth mindsets and then like my activities I chose kind of helped me experience them more.
Autonomy	The mindset resources. I didn't want to move on to what we were doing because I spent so much time on the mindset resources, just looking at all of those. And I guess it's cause they were all just right there for me to just move around and open one and then just close it. And, um, I think that was a really good starting off point because I saw all the peer reviewed articles and things like that about mindsets

	that there are. You know, it's a big field and it's important and I could see that from those articles or videos in that section. I think that part was really helpful. I picked the favorite no, because it was actually a teacher, you know, representing what a growth mindset looks like in the classroom. And I wanted to see what that was first to kind of help me understand what it was a little more.
Social Interactions	I did the paper activity. I did that one because I saw somebody trying to figure it out and I wanted to figure it out. Um, and we kind of like played off each other to figure it out. But I did that one cause it was kind of attracted me the most at the time. I liked it because it was, uh, actually been a teacher doing mindsets in the classroom and I didn't really know what that kind of looked like besides in the VolsTeach, uh, classes that I've taken because in our classes they tell us about growth mindset and you know, all that stuff. But I never really seen it in my actual math classes.- I picked the favorite no, because it was actually a teacher, you know, representing what a growth mindset looks like in the classroom. And I wanted to see what that was first to kind of help me understand what it was a little more. The ones that I can see the teachers or students doing work were the ones that I liked to pick. Like my favorite no was a teacher in the classroom And then even the paper folding was, I saw another student doing it and I wanted to work with them. An then [Yvette's] Kahoot I chose as a, as a time thing. Um but I was kind of gravitated to the ones that had more interaction between me and somebody else or me and another person in the video or something.
Game Structure/ Design	I think it's pretty clear you go step by step through and then at the very end go back to the beginning and do the surveys. I thought it was pretty clear. Visual/Technology: I think the video (My Favorite No) honestly was a big aha moment If I'm allowed to keep the link then I'll probably keep going back and looking at those resources.
RQ3: What aspects of the online gamification tool do PSTs perceive as limiting their	

understanding of mathematical mindsets?	
Time Constraints	And then [Yvette's] Kahoot I chose as a, as a time thing I needed 10 more points and I knew that I could do a quiz to get the 10 more points. And there weren't, I don't know if there was any of the other ones that had like a small amount of points for an activity. So it was more like just finishing up. Having more time to look at it. So if I'm allowed to keep the link then I'll probably keep going back and looking at those resources. There was an activity that asked for like a two page paper and I just didn't pick that because I thought it would take too long. But if I was given more time, I don't think that it would pose an issue at all. It would be a great activity to write a paper about mindsets. Um, but I just didn't choose that one because I thought it would take too long. Um, but I thought all of the activities were really enriching. If I had time to do them, I would definitely do all of them. I couldn't find any of them that I would be like, oh, I don't think this would show me what a growth mindset is. Um, it was just picking the ones that would fit into the time period that I had that day, was really the idea
Developing Some Critical Understandings	I know activities are really important to instill growth mindsets, like the folding card activity that I did. Um, so I guess I need a little bit more knowledge and research on my half to know what kind of activities are good in the classroom.

Appendix N

Caitlyn' Data Analysis Table

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Providing Challenging Learning Experiences and Tasks	I originally just like tried to like go down the line, like starting with one and I thought it was going to go just like one, two, three, four, five, all the way down to 20. Um, didn't happen that way? Because some of them are a little bit hard at like seven and 11. Um. And one thing that I was able to do was have some of them patterned. So like 11 and 13 had very similar answers, but instead of adding something I subtract it and while working beside my other partner, I came to realize like we had like different ways of representing the numbers such as like 16. She was like, oh this is super easy, you can just add four, four times. And I did something extremely complicated, four to the fourth power divided by four times four. Um, and so, uh Yeah. Cause like that's still the same answer. So I thought that was like really important, just like that's something like important in math. Um, not every single problem is like, it has like an exact same pathway to an answer and there's like different ways of representing it. Um, so I thought that was pretty cool. Like with the four fours, that just like be something that like you could give students in I think several age groups. Um, and also maybe change that up in a way that it'd be easier for younger students. I do want to encourage growth mindset and not allow students to, uh, give up, like we said earlier and challenge them in different ways. Um, and the, YouCubed. I would definitely want to look more at just like the different activities that they have there and like use that specifically with students. No, I think I heard of it. But not really looked into it. I think it would be interesting. So like I did the Four Fours and have students do it individually and um, they may be in groups or as a classroom, share our answers and have people kind of like explain like how they got it. Um, and also just like have that struggle if we need to. Um, and that way like students can like see like how like differently the answers are and also just like see each other's struggle and that be okay. I want students to be able to ask questions when they want to.

Sending Growth Mindset Messages	Students could be discouraged if they don't do it in the same way that their other classmates are. And also just like being able to explain it in their own way. Um, I think is important because if you introduced this idea early on and maybe like students are working together on a problem and this one student says, oh, I got it this way. And then another student says, I did it this way. Um, maybe they'll be able to explain to each other and why they worked it out the way that they did. Instead of somebody being like, Oh, you're wrong if my answer is right. So, uh, yeah, just encourage them not discourage them in their work Encouraging students and not just like saying that they're wrong, um, in their answers. Um, if they have it represented in different ways than people and also just like, even if they are struggling with some of them, like still, lead them like in the right direction so that they're just not defeated by not getting the answer.
Valuing Mistakes	I heard one of, one of my teachers, I think he said the other day that like the homework and stuff, like it's just telling him like what it is that he has or hasn't taught us well. Um, and just like having the homework or any activities, just like show what you do know so that I can help you further, um, understand different concepts. So like not just like giving an assignment and just marking it wrong and never go back to it.
RQ2: What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	
Engagement	I did, one of them was the Kahoot game. Um, and that was fun trying to put questions that weren't just like super easy, but um, allowed students to think a little bit harder about what growth mindset actually is and the difference between the fixed mindset. Similar to it - we had to represent numbers in a different way. I think it was using three nines. Um, and it was just an extra credit opportunity for us. Um, so yeah, I thought I'd enjoy doing that again. I just think that was the one, that I was most interested in and that kind of catered to my thinking as well.
Experiential Learning	So it's like we were learning about it while doing it as well. And so I liked that. Definitely like something that was kind of in my mind but, um, hadn't really thought about growth mindsets as much, but spending more time on it and it's kind of like gave me more time to reflect on it and thinking about using it in the classroom.

Autonomy	I kind of liked how within like the growth mindset game and having um encouraging, like something being challenging or things represented in different ways. You were able to work through that, um, within it. So we had the critical thinking or the game designer, social media. And so people were able to work in areas that they wanted to, um, and able to learn about growth mindset. So it's like we were learning about it while doing it as well. And so I liked that. We were doing like, uh just like doing different representations of things and also just like there not just being like one way of learning about growth mindsets, um, and discussing it.
Social Interactions	We kind of like worked side-by-side and would compare and maybe like if we were really struggling on one, we would help each other out. I remember when we were sitting there, um, sometimes we would figure out one before the others, like, oh you got that one, it's like, wait, let me see if I can figure it out first.
Game Structure/ Design	So in choosing the questions, I was just kind of looking through the mindsets game website and looking at different powerpoints and documents to see like what would I want students or anybody to know about growth mindsets. I think I used the PowerPoint a lot. It was like easier to like look at in chunks And like how the resources either had like had the document or the presentation or the video.
RQ3: What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?	
Developing Some Critical Understandings	I'm trying...it was one of my [program area] classes, but I can't specifically remember which one. Um, not exactly. But I just remember talking about, uh, encouraging the growth mindset in the classroom. Not that I can remember off the top of my head. Um kind of. I'm trying to remember when I did learn it, what did we do to really introduce it? -It was probably more hands-on and not on the computer and um, yeah, I can't remember exactly what we did.

Appendix O

Yvette's Data Analysis Table

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Providing Challenging Learning Experiences and Tasks	There were definitely some activities that I found in there, which I would like to at least introduce in the classroom to like kind of help grow their minds a little bit. Like the Four 4s thing. That was like utterly amazing and I really enjoyed doing that. Yeah, I really liked that one. So I would want to like if not have it as an assignment maybe as like bonus points or just like, you know, introduce it to my students because it is like so much fun and it really gets you to like problem solve with so little to go off of, you know? Kind of for the same reason, like learning all the things in school is important because like even if you don't necessarily use what you've learned in say history in your everyday life, just learning about new concepts will grow your mind. Even if it like shrinks back down afterwards, you will have had that experience and it will be so much easier to relearn that and apply whatever it was that you learned to your everyday life. And for stuff like math you, like because it all is like, it's just a bunch of puzzles. So you learn problem solving skills. Like that's why Sudoku helps you with math, even if it's like, it's numbers, but it's not, it's not actually math. It's just that mind growing and that, that logical puzzle solving. That's what actually changes in the mind, you know.
RQ2: What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	
Engagement	Mainly because I knew it would knock out a huge chunk of the points right off the bat, but also because I knew what Kahoot was, so I was already drawn to that and the whole neuroplasticity thing, like really interests me. So because that was directly related to it, I was kind of drawn to that I really enjoyed that one because it was, it was so puzzle-like. And I really enjoy puzzles,
Autonomy	So something that I did like about it and you should definitely keep that was that you had like different genres of like you had the computer

	hacker, you had the social media manager, you know you had like, as far as I can tell, those are almost like different, um, what are they called? Like learning techniques or whatever. - Learning styles. That's it. They're almost like the different learning styles. Not totally, but somewhat. Um, I do like the amount of options I knew what Kahoot was, so I was already drawn to that and the whole neuroplasticity thing like really interests me. So because that was directly related to it, I was kind of drawn to that
Game Structure/ Design	Technology/Videos: I watched the two videos that it gave us to work with for the neuroplasticity
RQ3: What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?	
Time Constraints	Ten points for an entire video given how little time we have as students. That seems like a really small amount and I know this isn't like a super serious thing, like I don't think this is, was this for a grade, I can't remember. But it's like, it wasn't like a super like terrible thing that's like what only 10 points for a video. But it's like, if this were more, what's the word I'm looking for? Weighty. I guess. It had more to do with the grade and that was like one of only a few options or whatever. Then that would be like, okay that's like really not cool. That's like here, write this like five page paper for like a 2% boost to a quiz in this giant class. Do you think I got time for that? So that sounds really simple in like, it sounds simple in practice, but then when I'm actually like visualizing, how would I do that? Then I would have to like, I would either have to hold it and do it as I do it like. Sorry, film as I perform each of the problems, which could get like really awkward or I would have to film it and just try to explain it without visually representing it. So then if I wanted to do both, explain it and do it, then I would have to prop it up on something and it's just like I overthink things a lot to be fair. Yeah. I Dunno. Just 10 points plus there's, how would we like upload that? So then we'd have to go to the trouble of rendering it on YouTube and uploading it to there. And then having to link that and everything. And then having to link that and everything. Uh, I think a bit of a, some of the points where a bit skewed So I would say either do it earlier in the semester or give like a slightly

	bigger time frame to do it.
Clarity of Game Structure	I really enjoyed that one because it was, it was so puzzle-like. And I really enjoy puzzles, but like I said, it needed to like, it needed you to like do a video. I think I put my responses that I would have done like the Four 4s, except that involved like making a video and being in college that was a bit much. Oh my gosh, I totally read that wrong then. Like for the Four 4s, like there, there were some things where it was like just a little confusing as to what the actual thing was and that very well could have been my fault because I either read too slow or I scan and I don't catch everything so Or perhaps you could put like bonus options in like a different color or a different font or something. Just like to visually separate it other than like just 10 bonus points use da da da, you know. Oh yeah I did the thing it's just, because I read the thing wrong, I thought we would have to like do the video and whatnot, but like, yeah, when I like found it in class I just like did it for fun and it was awesome.
Developing Some Critical Understandings	Um, I feel like if this were the first time I were learning about growth mindset, I probably would have had, you know, more pivotal moments. But um, because I had learned about it before, this is more like a nice refresher than like an eye opening super re... feeling experience, you know, revelatory. That's what I was looking for. But it was kind of eye opening just seeing like, wow, some people are just like totally don't agree with this or they don't see it that way. So I dunno. I, I, I wouldn't say I learned anything totally mind blowing from this if only because I already knew some of the stuff in it. But, um, I do like what I did learn from it if only to know like, okay, I'm not the only person that kind of sees it this way the whole neuroplasticity thing.

Appendix P

Brandon's Data Analysis Table

Theme	Supporting Quotes
RQ1: What are PSTs' understandings of mathematical mindsets and practices that foster students' growth mindsets?	
Sending Growth Mindset Messages	Decorate your room with folks like that and to also just like in the beginning stages, like how I mentioned earlier, you connect with your students. I think that's important. Connect with them and then have like a, like your first couple of days, like I know a lot of classes in high school and even middle school, the first couple of days aren't really that important. So why don't you make them important and try to ingrain the growth mindset ideas and talk about, use kind of some kind of example of, um, I don't know what word I'm looking for. I don't know. Just maybe even play this game or something and like try to like show them why it's important to understand math and understand that you shouldn't give up and all these types of ideas. I had not seen some of the other quotes, and I thought a lot of the quotes were pretty almost inspirational, you know, and I think that's key to use for not only as a student but also for teachers to use for students. So I think this, a lot of, there's a lot of ideas in here that help create a, um experience for you to learn. As a student you might see the Einstein thing. I think, wasn't Einstein like, he, didn't he struggle at some point in school, but now he's like one of the most known smart people? You know. So just like inspirational things like that and you can learn that you don't need to give up. Like you just keep, keep trying, keep giving out your full effort and it'll work out for ya. I think it's more important now that I have been through this experience a little bit and I think I would use some of these ideas. I would try to put some quotes in my room. I would try to emphasize it on the first day, like what things I want to like accomplish as a teacher, not just like, or not even as a teacher, as a person. Like how to help them understand certain ideas that they need to understand as people. It's an important idea to like and bring it to students because if they don't have this growth mindset, they might go away from math because math is a hard subject for a lot of people and if they don't get it, they just there's that, that stereotype, the stereotypical idea that either get math or you don't

	get math and I don't, I don't believe in that at all. I think that's, it's just we need to like try to go away from that. And I think one way to get away from it would be to teach the growth mindset to students so they won't believe in that, that idea that you can't understand math for whatever reason. I think you could like almost do the same thing with the growth mindset, kind of incorporate that on the first day, second day or whatever. Whenever you have time to do it. And like it'll eventually like, I don't know what the word you use like, it'll, it'll get into the minds of the students and they'll learn through the growth mindset I think if you incorporate it early. Like starting at the very beginning of the year, similar idea like making sure everyone knows that it's a safe place. You can talk. We're going to learn.
Valuing Mistakes	I never lose, either win or I learn. Yeah, I like that quote as well because, when you lose you, you shouldn't think of it as a negative. You shouldn't think of things negatively. You should try to like, if you do great, that's awesome. But if you don't, you should take it as a learning experience and just get better. Like I had a teacher who always said, don't get, don't get bitter, get better so. Albert Einstein's quote about you never fail until you stopped trying and that you thought this was powerful for students and could inspire students to not, or to give effort and never give up Well, if you give up then you're just, you're not motivated. You might not be, it might, it might be one topic, but in math, typically one topic leads to another topic and leads to another. If you give up at any one point, you're just, you're not going to understand, you're not conceptually understanding
RQ2: What aspects of the online gamification tool do PSTs perceive as benefiting their understanding of mathematical mindsets?	
Engagement	And I liked that one specifically the most, cause I found one, um, tweet, it had like a, like a almost like a bulletin board and it had a quote from like a bunch of famous people like Albert Einstein or like a Michael Jordan, a famous athlete or a president or something like that. People that you know and they like all, all the quotes were a growth mindset type of quotes. So it was really interesting to read some of those The points, how long I thought it would last. And then if I, which ones I knew, like how, like if I had to sit there, sit there and think about what am I actually going to do for this or like how, when I saw the Twitter one I was

	like, oh that can't be hard . Let me just go to Twitter right quick because I love Twitter . I'm a big Twitter user . And then I, I guess that was another reason I picked it because I connect with Twitter because I understand Twitter. I use it all the time .
Autonomy	Definitely the Twitter one because even, I picked those three but there were also several others that I read. I can't remember what they were specifically, but there were just so many quotes that you could apply in math or even science. It didn't matter. They were all, or even other classes that aren't math or science, but they felt like they're all applicable to any school level, any school class, anything like that.
Game Structure/ Design	I did catch on to what I was trying to do, what, what points were what I was trying to accomplish, you know. So I, I kind of understood what I was trying to do and like why I was doing it, so I understood it pretty quickly. Technology/Video: I remember that video specifically. I don't remember everything that was talked about in it, but I definitely like the ideas that they were talking about it I think it's a good thing, especially nowadays, how technology is and how I think a lot of people are trying to incorporate technology in the classrooms. I think that's a good idea. So I think it'd be a good way to incorporate the growth mindset through technology since a lot of kids probably know how to use technology So like kids know how to use technology now. So I think it's a good thing to try to incorporate this idea through technology because they know how to use it and they like using it. So why not try to incorporate something important.
RQ3: What aspects of the online gamification tool do PSTs perceive as limiting their understanding of mathematical mindsets?	
Time Constraints	Some of them I didn't quite understand what to do and some of them I um, I was wondering how long it might take. Yeah, unless that you were doing it that day we had met initially, but I don't think anyone had time because I think most people did one thing and they might've ran out of time to do anything else because were short on time, I think.
Clarity of Game Structure	Think it was this one, cut-a-card. I don't think I knew what it wanted. Maybe just the instructions on it be a little more, or even instead of being more specific maybe sometimes I think instructions can be a little too

	complex, maybe shorten them and maybe just quick bullet points because a lot, I think a lot of people will understand short and easy steps. Sharing/ Access: I think one thing about this one about connecting, because I guess some people had trouble trying to connect because, I'm in, we have a group meet in our class and like some people are like can you help me do this or whatever. And like some people are like, oh I'm already done or some people didn't even respond and so, maybe if there's a, I don't know how to apply it to where people can definitely go do it because it's only 10 points. It's real quick, real easy. So if there's like a better way to make it to where people can do that specific one because I know a lot of people are like, well I, I definitely want to do this, a quick easy 10 points that I can get for the game
Familiarity	Well I knew I didn't want to do the video mainly because I don't like really listening to my voice on recordings like so I was like I don't want to do that. So I just, I cancelled that one even though I thought it was a cool idea, but I just, I kind of went away with it because I think the Kahoot was basically the same idea as like trying to teach people about the idea. So I was like, I'll just stick with Kahoot since I don't have to record myself or whatever and just I went with that instead. The Kahoot thing ended up being a little longer cause I thought too hard on the questions. Some, some of them and some of the questions might've even been a repeated, repetitive and I knew we had to like get a certain number of questions. So I was trying to focus on things that I definitely understood

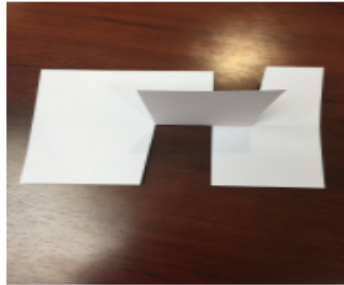
Appendix Q

Student Work Samples for Cut-a-Card Challenge

Creator Challenge 3- 30 Points *Cut-a-Card*

1. Compare how you think someone with a fixed mindset versus a growth mindset would respond to the "Cut-A-Card" task?

I think students with a fixed mindset will think this cutting activity is impossible and get very frustrated. They might not even want to try it out since they consider this is impossible to accomplish

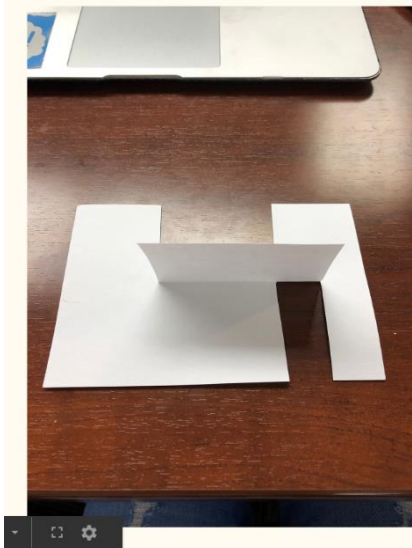


or give up as soon as they can figure it out at first time. Students with a growth mindset will probably view this as a challenging activity that they hope to figure out this by trials and errors. They persist longer on challenging problem like this, and willing to learn from mistakes.

2. How does this task foster a growth mindset? The following article may be helpful (it details 5 teaching practices that foster a growth mindset):

I think this activity definitely will foster a growth mindset. Firstly, this activity looks impossible at first glance, but after students can figure this out by themselves, they will understand better why perseverance is very important for activity like this and more willing to believe that intelligence can be improved through hard work and persistence.

Creator Challenge 3- 30 points

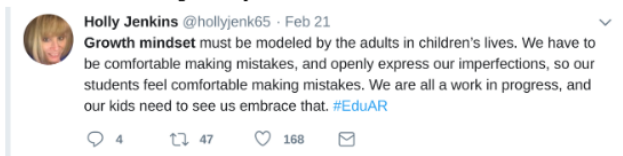


- I think someone with a fixed mindset would get much more frustrated with this task. I imagine someone with growth mindset would also get frustrated, but not give up as easily as someone with a fixed mindset.
- Ways this activity promotes a growth mindset:
 - All students can achieve success with this activity. They may not be able to do it on their own, but collaborating with other students can help them to understand the idea and individually recreate the card.
 - Students will undoubtedly struggle with this activity. When they finally do succeed, it provides a great example of how struggling in the classroom does not mean that you will never succeed.

Appendix R

Student Work Samples for Twitter Growth Mindset Search Challenge

Communicator Challenge 2- 40 pts.



I agree with this post from @hollyjenk65 that suggests that mistakes are what makes people strive to be better and improve. They also suggest that this definitely needs to be modeled by adults because adults are those with the experience and thus are appropriate leaders for children when they come across these mistakes and are looking for improvement. This post summarizes a main point about growth mindsets that mistakes are important to develop properly and that imperfections show there is room for improvement.



The graphic posted by @engagewilkins to the left shows the process for development and improvement. If students are unwilling to leave their comfort zone then they will not be able to improve, and although as the graphic shows, students/ people in general will have to move through zones of "fear" to be able to learn and grow. I think the graphic makes an excellent point that in order to grow, one must understand what they fear, and that is the "learning zone" they reference. Fear is a term they define as finding excuses and worrying about the opinions of others and what they perceive,

which is something students/ people should move away from in order to develop properly and seek out the things they want and like based on what they learn. Then, learning about these new things will allow them to grow and move on to other topics and interests.



This graphic posted by @Teacher_Msc displays some common quotes that should be implemented as alternatives to certain phrases that do not promote a growth mindset. The point the graphic is trying to make is that having a growth mindset means being open to experiences and not being discouraged when something seems difficult. Mistakes will eventually become improvements, and beginning practicing implementing growth mindsets in the classroom is very important for the development of the students.

Communicator Challenge: 40 Points



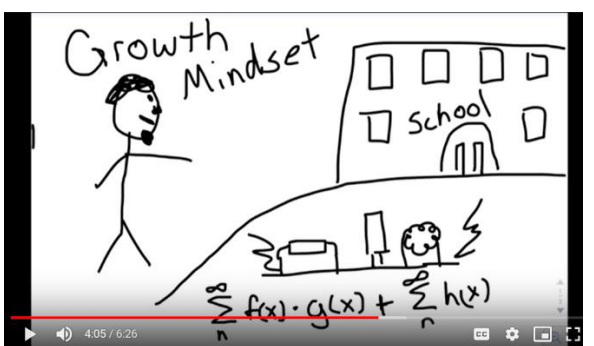
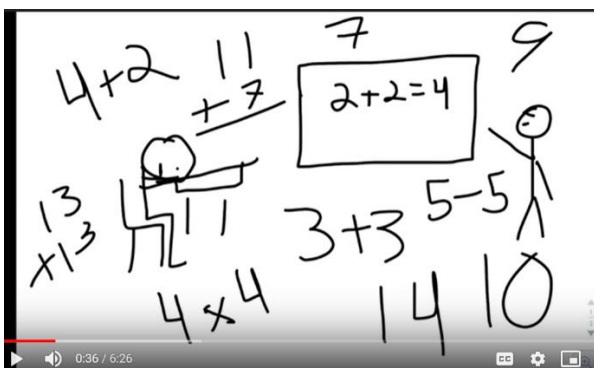
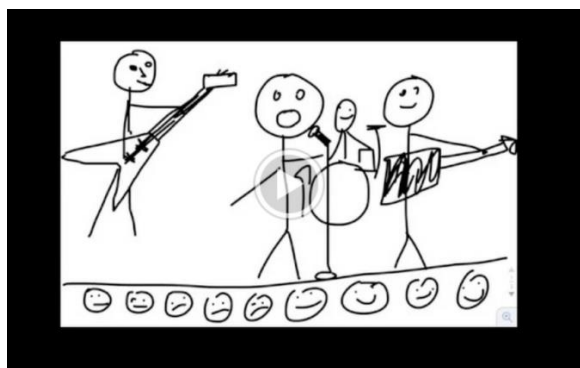
includes several images of a bulletin board. This board shares several growth mindset quotes. One of my favorites comes from Albert Einstein: "You never fail until you stop trying." This quote is very powerful in my opinion. If a student, or anybody in general, believes that that failure only occurs when you give up, then this is likely to inspire students to give effort and to never give up. Another great quote is from Michael Jordan: "I've failed over and over again in my life. And that is why I succeed." This quote shows that even famous people struggle in life. It is important to view failures as an opportunity to get better.

The second tweet includes a diagram that educators should use to inspire a growth mindset. Students must be able to get out of their comfort zone in order to grow as students. Reaching the growth zone is where students can achieve their goals. Staying inside the comfort zone could prevent a student from success. It is important to get outside of your comfort zone and to explore new ideas. This can lead to students to changing from a "I can't do it" mindset to a "I can do anything" mindset.

The third tweet is related to the Michael Jordan quote. This quote states: "I never lose; either I win or I learn." This tweet shows that failure and losing should not be viewed in the negative way that we associate them as. Instead, failure and losing should be viewed as an opportunity to learn from mistakes and to get better.

Appendix S

Student Work Sample for Video Creation Challenge



Appendix T

Student Work Samples for YouCubed Challenge

Critical Thinker Challenge 2- 30 point

<https://bhi61nm2cr3mkgk1dtaov18-wpengine.netdna-ssl.com/wp-content/uploads/2017/03/Penny-Collection.pdf>

There could be 91 pennies. 91 pennies would satisfy the requirements for the groups specified. $91/2$ has a remainder of 1. As does $91/3$, $91/5$ and $91/6$. Thus 91 works for the situations.

This game would help to develop a growth mindset because of the trial and error that can take place while doing the exercise. It can show students that not getting the correct answer the first time does not mean that they should give up.

The Four 4's

$1 = \frac{4}{4} + 4 - 4$	$11 = \frac{4!}{\sqrt{4}} - \frac{4}{4}$
$2 = 4 - \sqrt{4} + 4 - 4$	$12 = 4^{4-4} - 4$
$3 = \sqrt{4} + \sqrt{4} - \frac{4}{4}$	$13 = \frac{4!}{4} + \frac{4}{4}$
$4 = \sqrt{4} + \sqrt{4} + 4 - 4$	$14 = 4^{4-4} - \sqrt{4}$
$5 = \sqrt{4} + \sqrt{4} + \frac{4}{4}$	$15 = 4^{\sqrt{4}} - \frac{4}{4}$
$6 = \sqrt{4} \cdot (4 - \frac{4}{4})$	$16 = 4^4 \div (4 \cdot 4)$
$7 = \frac{4!}{4} + \frac{4}{4}$	$17 = 4^{\sqrt{4}} + \frac{4}{4}$
$8 = \frac{4!}{4} + 4 - \sqrt{4}$	$18 = 4^{4-\sqrt{4}} + \sqrt{4}$
$9 = \frac{4}{4} + \sqrt{4} \cdot 4$	$19 = 4! - 4 - \frac{4}{4}$
$10 = \frac{4 \cdot 4}{\sqrt{4}} + \sqrt{4}$	$20 = (4! - 4) \frac{4}{4}$

Appendix U

Student Work Samples for Creating an Online Quiz/Kahoot Challenge

1. What is the growth mindset?

- A. Believe brain can grow and performance can be improved through hard
- B. Believe intelligence is determined and cannot be changed
- C. Believe memory can be strengthened by repetition
- D. Believe motor skills can be improved by doing extra practices

2. Which of the following is NOT a description of fixed mindset?

- A. Tend to give up easily
- B. Think you're not good enough
- C. Think your intelligence is defined and cannot be change
- D. Perseverance in solving problems



3. Who coined the terms fixed mindset and growth mindset?

- A. Carol Dweck
- B. Jean Piaget
- C. Erik Erikson
- D. Sigmund Freud

4. Why is growth mindset so important for students to have?

- A. will promote students' learning and increase achievement
- B. can help students to make more friends and be more socialized
- C. can improve EQ
- D. can improve motor skills



4. Why is growth mindset so important for students to have?

- A. will promote students' learning and increase achievement
- B. can help students to make more friends and be more socialized
- C. can improve EQ
- D. can improve motor skills



6. Consider the following virtual characters.

Andy has learning disability. His math teacher spend extra time outside of class to help him understand the math concepts. Eventually, he gets better and better in math through hard working.



Simon is a gifted child. He could understand Algebra and Geometry when he was 5. Many people think the only reason that he can learn things so fast at the young age is because of his high IQ. In fact, Simon is fascinated by beauty of mathematics which he spend abundant time explore and learn mathematics at home.

Who has growth mindset?

- A. Andy
- B. Simon
- C. Both
- D. Neither of them

7. Which of the following is NOT a strategy to support a growth mindset?

- A. Having students to memorize the math formulas without explaining why these formulas make sense
- B. Assigning challenging problems for students to solve
- C. Encourage students to expand their answers
- D. Provide opportunity for students to explore the new content



9. Can growth mindset be fostered?

- A. No, mindset is already determined at birth
- B. No, it is impossible to change mindset because human's brain is fixed
- C. Yes, doing same type of math problems can foster growth mindset
- D. Yes, neuroplasticity suggests that brain is malleable and changeable throughout an individual's life



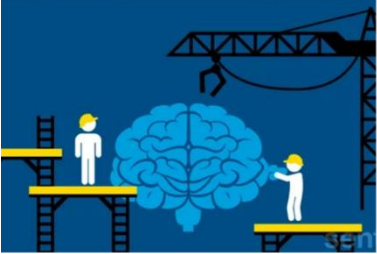
8. Why teachers don't want their students to have a fixed mindset?

- A. Students with fixed mindset have a tendency to distract the class
- B. Students with fixed mindset get frustrated easily when they get stuck which result in low achievement
- C. Students with fixed mindset usually can't focus learning
- D. Students with fixed mindset have no motivation to learn which they never participate in class

10. It is important for not just students to have growth mindset but teachers as well. Which of the following is NOT an example of the teacher revealing their growth mindset?

- A. I believe you can do it, try your best!
- B. It's ok, not everyone is good at math.
- C. It is not you don't know, It's you don't know yet.
- D. Think about why you made this mistake and what do you learn from this mistake?





Growth Mindsets: le Kahoot

Play Challenge

A public kahoot
#growthmindset #mindset #fixedmindset #voisteach #UTK #teacher

Questions (8)

Show answers

1 - Quiz
The term for how the brain changes and adapts over a person's lifetime is called...?



20 sec

2 - Quiz
If the brain is a connected power grid or series of roads, recalling a memory over time...?



20 sec

3 - Quiz
When we learn/experience something new, the brain does what with this info/memory?



20 sec

4 - Quiz
When anyone is born, regardless of physical prowess/disabilities or prematurity, they...?



20 sec

5 - Quiz
If you fail, that means that you...?



20 sec

6 - Quiz
The most beautiful, complicated concepts in the entire world...?



20 sec

7 - Quiz
If a boy is more interested/practiced in English, then when it comes to math or science...?



20 sec

8 - Quiz
If a girl's brain is "more geared" toward STEM than history (regardless of how), then...?



20 sec

VITA

Rebecca Doty Layton was born and raised in Middle Tennessee. After graduating from Cheatham County Central High School, she attended the University of Tennessee in Knoxville where she earned a Bachelor of Arts in Geography and a Master of Science in Middle Grades Education with a concentration in mathematics education. Upon receiving her master's degree in 2010, Rebecca began teaching middle grades mathematics in a high needs school in Knox County. During her time teaching, Rebecca earned an Educational Specialist degree in Educational Leadership from Lincoln Memorial University and served as a technology assistant coach. After six years of teaching middle grades mathematics, Rebecca decided to return to the University of Tennessee to pursue a Doctor of Philosophy in Education with a concentration in mathematics education and educational technology.

While at the University of Tennessee, Rebecca gained a variety of experiences throughout her four-year graduate assistantship. She taught mathematics education and educational technology courses, supervised interns, served as the Media Specialist for the East Tennessee STEM Hub, and worked with the Office of School-Based Experiences and the Office of Professional Licensure. She was involved with managing teacher placements, conducting mentor teacher and UTK supervisor orientations, and assisting the data director with UTK's teacher preparation accreditation process. Her research interests center on best practices for technology integration in education and teaching practices that support student growth mindsets in mathematics.