Incremental, Spaced Repetition and StudyMate Flashcards: The Impact on College Student Memorization of Measurement Conversion Standards

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DEDICATION

This thesis work is dedicated to the beloved people who have meant and continue to mean so much to me. First and foremost, to my husband Harry, who has been a constant source of support and reassurance throughout the challenges of pursuing my Doctorate degree. Your love has been a never-ending source of hope and faith. It has been a long road these last few years, but we got through it together. Thank you for all the dinners out that forced me to step away and regroup. To my Dad, who watches over me from Heaven: you were right, Dad, I can do anything I put my mind to. To my Mom, who was with me when I started this journey, but now looks down from Heaven, thank you for your love and encouragement; without those, I would have postponed fulfilling this dream. To my son Alex, thank you for your love and your belief that I could do this. I appreciate you listening to me and helping me clarify my thoughts. Who knew we would have so many academic conversations as peers or that you’d be finishing your master’s at the same time I was finishing my Doctorate? To my siblings John, Nancy, and Jeanne, thank you for enduring the endless phone calls and helping to calm me through the rough patches and tears. To my few friends who were privy to this undertaking and who have been my cheerleaders throughout this process, your pom-poms will forever have a special place in my heart. Lastly, I want to dedicate this to myself for having the tenacity and fortitude to push forth and complete this “bucket list” desire despite the chaos that life threw at me during this adventure.
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ABSTRACT

The purpose of this action research was to evaluate the impact of and student perception of incremental, spaced repetition of StudyMate electronic flashcard use on memorization of measurement conversion standards for an online Mathematics in Health Sciences course. Online college classes require more self-direction and usually do not allow for partner or group work. These characteristics of online classes may hinder students’ ability to memorize crucial information, increasing their cognitive load and leading to feelings of inadequacy. This mixed methods study assessed the impact of incremental, spaced repetition of StudyMate flashcard use on college math students’ memorization of measurement conversion standards and explored student perceptions of StudyMate flashcard use for memorizing measurement conversion standards.

Participants in this study were 18 students in an online Mathematics in Health Sciences course at a midwestern community college. The intervention consisted of incremental, spaced repetition use of StudyMate flashcards to memorize measurement conversion standards in an online course. The quantitative data collected included Measurement Conversion Standards Assessment pre- and post-test scores as well as student perception survey responses. Qualitative data was collected from interview responses. Data for this study was analyzed separately and then integrated for a comprehensive finding.
The finding indicated that incremental, spaced repetition use of electronic flashcards for memorization of measurement conversion standards resulted in significantly higher mean scores on the Measurement Conversion Standards Assessment and significantly lower standard deviation among the scores. In addition, data analysis enabled identification of certain factors that impacted the efficiency and the effectiveness of studying with flashcards, and revealed that students who used electronic flashcards for memorization of measurement conversion standards developed positive attitudes towards using flashcards. The findings suggest that students in online college math classes can successfully memorize conversion standards through the incremental, spaced repetition use of electronic flashcards. Implications and limitations of this study are discussed.
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CHAPTER 1

INTRODUCTION

National Context

Every year, more college students in the United States are enrolling in online classes and completing degrees online. Even prior to the COVID-19 pandemic, more than 95% of higher education institutions with enrollment over 5,000 were offering online courses (Bourdeaux & Schoenack, 2016). Six million students were taking online courses as early as 2010 (Bawa, 2016). In Spring 2020, colleges and universities moved most classes online in response to the COVID-19 pandemic, impacting 22.3 million college students in the United States alone (“Back to school statistics,” 2020). Although in-person classes are the standard once again, the numbers of students taking online classes is still high. More and more students are moving to courses delivered online, and most say that they want online options to remain available in the future (McKenzie, 2021).

Whether it is called distance learning, distance education, online learning, eLearning, eCourse, or internet learning (“What is eLearning?,” n.d.), online education has become a fixture of the college landscape. In this study, the term online courses refers specifically to courses designed to deliver educational content entirely online via the internet, with no direct face-to-face, structured, synchronous instruction. In such courses, the instructor-student interaction can take place through video or phone conferencing, email exchange, or any combination of these modalities. At most institutions, instructor-
student interaction currently takes place primarily via video conferencing or email exchange.

Many students attend college to obtain a credential, certificate, degree, or additional education to improve their employment and financial situation. Especially for students who are balancing jobs and family responsibilities along with their education, the convenience and greater accessibility offered by online learning is appealing (Bourdeaux & Schoenack, 2016). Students who face time constraints because of employment responsibilities, family responsibilities, long commutes, or logistical issues due to geographic location or transportation obstacles want convenient access to college programs (Gaytan, 2013). This is a major reason why, even before the COVID-19 pandemic, online learning programs in higher education have increased in popularity: they provide flexibility, convenience, and ease of access for students (Holder, 2007). Another factor enhancing the appeal of online learning is that it enables students to choose from a wider variety of colleges: regardless of where they live, students can now attend any institution of higher education in the world online. Online course modules allow students to demonstrate their new knowledge in several ways, replicating the in-person experience (i.e., tests, portfolios, and presentations) (Miller, 2019).

The increasing availability of online higher education reflects the increasing demand for higher education in general (Shea & Bidjerano, 2016). Yet as enrollment in online learning courses continues to grow, so do attrition rates. Student retention rates are much lower in online courses than in face-to-face educational settings (Gaytan, 2015): the dropout rate among online students is at least 6–7% higher (Gaytan, 2015) and may be 10–20% higher (Holder, 2007) than the dropout rate among students in traditional
face-to-face classes. Student achievement and success rates likewise remain lower in online courses (Gaytan, 2015). The inability to persist in college leads to financial burden as students who fail to complete a degree or certificate are left to repay student loans without the additional earning power (Heibutzki, 2017) or employment opportunities (Elejalde-Ruiz, 2016) that they would have been afforded by completion.

Given that ever larger proportions of students are expected to enroll in online higher education in the years to come, this presents a significant challenge for students, instructors, and institutions. To ensure that student success rates remain high, it is crucial for institutions and faculty to identify the factors leading to lower success and completion rates in online courses and to mitigate as many of these factors as possible. Many of the traits and behaviors that help students achieve success and completion in face-to-face college courses also lead to success in online courses: having direction and the ability to stay focused on specific tasks, choosing to initiate effort on specific tasks, choosing to expend a determined amount of action needed to read a specific number of pages or spend a certain amount of time studying, and continuing to apply a consistent level of energy toward academic achievement (Farley, n.d.). Online students, however, face the additional challenge of having to maintain these behaviors in the absence of direct instructor oversight. They must practice effective time management and self-discipline in order to work independently without face-to-face interactions (Adams & Blair, 2019).

Appropriate class placement is another key factor in student success: students who are not adequately prepared for college struggle with the academic demands, especially in online courses (Bawa, 2016). Remediation is thus often necessary, especially in the community college context.
One field in which many students are underprepared for college work is mathematics (Butrymowicz, 2017). The National Center for Education Statistics, which administers the National Assessment of Educational Progress (NAEP), reports that the gap is widening for students struggling with mathematics: of the high school seniors who took the NAEP in 2015, only 37% performed well enough to be ready for freshman college mathematics courses (Sparks, 2020). According to the 1992 National Adult Literacy Survey, 26% of adults surveyed were unable to execute the most rudimentary quantitative skills, while an additional 32% of the adults surveyed “had only basic skills” (Rothman et al., 2008).

Many students enter college without sufficient numeracy. Numeracy is mathematical literacy, or the possession of sufficient skills and knowledge to perform the mathematical tasks that are necessary for everyday life and work, including the ability to identify the appropriate math skills to apply to a given situation (Rothman et al., 2008). Numeracy is linked to college persistence and the completion of degrees and certifications (J. Mains, personal communication, November 2020). Limited numeracy, in contrast, contributes to an overall feeling of unpreparedness, which may lead to anxiety and failure in course work that is required for students’ intended careers (Woolcott et al., 2019).

Limited numeracy is particularly problematic for students intending to enter the health care field. Health care workers who lack numeracy skills cannot perform their jobs safely or effectively, leading to significant medical errors and patient safety issues (“Numeracy for Health,” n.d.). Fractions, decimals, ratios and proportions are common areas of struggle for college students (Budgen & West, 2018), yet a thorough
understanding of these topics and the measurement standards derived from them is a critical skill that must be mastered to ensure accurate drug calculations, infusion rate calculations, and overall safety in the health care field (Jukes & Gilchrist, 2006; “Numeracy for Health,” n.d.). When students enroll in health care degree and certificate programs without the proper numeracy skills to succeed in their intended careers, the college must teach these skills quickly and effectively, whether students are pursuing their degrees in-person or online. How can institutions of higher learning support college students enrolled in online courses in developing the numeracy skills they need to succeed in health care careers?

Local Context

In Ohio, a popular new means of addressing the falling completion rates at higher education institutions is the Guided Pathways Model. This initiative, developed through an Ohio Department of Higher Education grant, aims to support student completion efforts by outlining a clear goal-oriented academic plan (“pathway”) for each college student, simplifying student decision-making to ensure that the student enrolls in every class that is required for the intended credential or transfer plan in a timely manner (Sinclair Community College, 2018).

Success at the local community college goes beyond individual student success, however: leaders within the local community want to attract and retain an educated workforce (Sentz & Stout, 2018), and part of the college’s work is to provide that workforce. A community college’s core mission is to work with its community partners to recognize, tailor, and refine its programs not only to benefit the school’s mission but also to address and support the regional economy’s specific needs (Irwin & Patrick,
To that end, community colleges partner with local businesses to help provide job-oriented and on-the-job training (Bawa, 2016). In this context, the increase in community college courses being offered in an online learning format has revolutionized workforce development and technical and vocational training and made an impact on local and regional economic development (Barrington, 2020).

Sinclair Community College is an urban community college in Dayton, Ohio, with its main campus located in the Dayton city center. Sinclair Community College also has four smaller satellite campuses within a three-county radius to enable access for students who desire to attend classes closer to where they live or work. Not all courses are offered at the satellite campuses due to space constraints or equipment needs. Courses are offered in various term lengths and delivery options, such as eight-week, 12-week, and 16-week courses in traditional face-to-face, online/distance learning, and blended modalities. In the Spring 2019 term, Sinclair Community College had a total enrollment for all campuses of 18,525 students. Of those, 7,082, or 38% of the student population in that term, were enrolled in at least one online course (Sinclair Community College Enrollment Statistics Report, 2019). For one specific course, MAT 1130, Mathematics in the Health Sciences, the enrollment for spring term 2019 was 541 students, or 3% of total college enrollment. Of the 541 students taking the course, 210, or 38.8%, were enrolled in an online section of MAT 1130 (Sinclair Community College Enrollment Statistics Report, 2019). Twenty-eight of the 210 online MAT 1130 students did not complete the course with a 70% or better (Sinclair Community College Enrollment Statistics Report, 2019); this indicates a failure rate of 13% for the online sections of this course.
Each online section contains students with a variety of ages, genders, ethnicities, and previous college experience. While student demographics thus vary among the course sections, the overall breakdown for all students enrolled in at least one online course in any subject at Sinclair Community College in Spring 2019 is as follows: 61.2% were under age 25 while 38.8% were over age 25; 34.7% were male while 65.3% were female; 0.7% identified as American/Alaska Native, 3.1% identified as Asian, 10.6% identified as Black or African American, 3.3% identified as Hispanic/Latino, 72.6% identified as white, and 9.7% identified as other (Sinclair Community College Enrollment Statistics Report, 2019). The average class size on Day 30 of the course was 32 students (Sinclair Community College Enrollment Statistics Report, 2019). In the ten online sections of MAT 1130 specifically, 58% of the students were under age 25 while 42% were over age 25; 27% were male while 73% were female; and 17% were taking their first online course while 83% of the students had taken at least one online course prior to the Spring 2019 semester (Sinclair Community College Enrollment Statistics Report, 2019).

Students in online courses at Sinclair Community College are expected to access course information such as the syllabus, course outline, learning modules, and practice tests online through the Brightspace Learning Management System. Online students are expected to study the course material independently, reading and studying the modules without instructor oversight, then complete online homework assignments and online quizzes as well as traditional pencil and paper assessments at the testing center on campus or an approved site. In Mathematics in the Health Sciences (MAT 1130), students are expected to follow the online studying, homework, and testing policies, and
to memorize the measurement conversion standards used in the health care field. These measurement conversion standards are provided to the student in the required textbook *Math Basics for the Health Care Professional* by Michele Benjamin-Lesmeister.

Memorizing these measurement conversion standards helps prepare students for the Test of Essential Academic Skills (TEAS). The TEAS is used to assess each student’s academic readiness to complete the health care program requirements. The math portion of the TEAS test requires students to use algebra, measurement, and numeracy skills to solve a variety of problems encountered in the health care field. Difficulty or failure in memorizing the measurement conversion standards negatively impacts student success on the TEAS test as well as acceptance into and completion of college health care credential programs (J. Mains, personal communication, November 2020). Memorizing the measurement conversion standards is a necessity for health care workers to succeed in their jobs. While it is essential for online students and face-to-face students to memorize the measurement conversion standards, it can be more challenging for online students, who are working independently, to memorize the content due to the absence of partner work, quizzing exercises, and memorization activities opportunities in a face-to-face classroom setting.

An informal review of assessments from MAT 1130, including quizzes in which the students were asked to demonstrate their success in memorizing the measurement conversion standards, showed that students who had memorized the measurement conversion standards earned higher scores on Test 1, Test 2, and the Final Exam and also earned higher end-of-course grades, regardless of whether they had been in face-to-face or online sections. A comparison of students enrolled in traditional face-to-face sections
with those enrolled in online sections showed that students in face-to-face sections were more successful in memorizing the measurement standards; this is in keeping with the observation that face-to-face students had significantly higher pass rates on Test 1, Test 2, the Final Exam, and the course overall. The data for these comparisons were gathered from the face-to-face and online sections taught by the author during Fall Semester 2018, Spring Semester 2019, and Summer Semester 2019. [There is no data for Fall Semester 2019 as the author did not teach any online sections that semester. Data for the face-to-face and online sections taught by the author in Spring Semester 2020, Summer Semester 2020, Fall Semester 2020, and Spring Semester 2021 were not collected or considered due to the unknown impact of the COVID-19 pandemic on the success rates of various delivery modalities and overall student success.] Detailed comparisons of pass rates in the face-to-face and online sections of MAT 1130 in Fall Semester 2018 through Summer Semester 2019, including Test 1 scores, Test 2 scores, Final Exam scores, and final course grades for all students, can be found in Appendix C. Figure 1.1 presents a comparison of overall MAT 1130 pass rates among face-to-face and online students in Fall 2018, Spring 2019, and Summer 2019: in all three semesters, a significantly higher proportion of students in face-to-face sections passed the class with a 70% or higher as compared to students in online sections. This demonstrates the need for interventions to increase numeracy and success among online students in this and other gatekeeper mathematics courses.
The students in the face-to-face and online sections have access to the same learning materials, including lecture notes, PowerPoint presentations, and measurement conversion review activities, and are assessed using the same homework assignments, quizzes, and tests. In the face-to-face sections, students complete the measurement conversion review activities with partners during class time as a warm-up activity. In the online sections, students have access to the measurement conversion review activities and answer keys but do not complete the activities with partners. Partnered activities are not possible in the online sections as these sections are asynchronous: students work through the material on their own schedules, completing assignments by or before specified deadlines.

An informal review of the measurement conversion activity scores in the face-to-face sections revealed that students who did not have the measurement conversion
standards memorized tended to score at or below 70% on the measurement activities and to score below 70% overall in the course. Figure 1.2, Figure 1.3, and Figure 1.4 illustrate the proportions of face-to-face students averaging above and below 70% on the measurement conversion activities for Fall 2018, Spring 2019, and Summer 2019, respectively.

*Figure 1.2*
Fall 2018 Measurement Conversion Activity Averages (*N = 101*)

*Figure 1.3*
Spring 2019 Measurement Conversion Activity Averages (*N = 14*)

*Figure 1.4*
Summer 2019 Measurement Conversion Activity Averages (*N = 9*)
Measurement conversion review activity averages for the online sections are not available since there are no partner activities in these asynchronous sections. See Appendix D for detailed score information for the measurement conversion activities in the face-to-face sections.

Thus, we can see that there is a consistent difference between the online and face-to-face pass rates, that the format of the measurement conversion activities is one of the only material differences between the online and face-to-face modalities, and that success in the measurement conversion activities is linked to success in the course. Together, this evidence suggests that the in-person activities supporting the memorization of the measurement conversions increase the success rates among face-to-face students. The purpose of this study was to provide online students in this course with an activity involving incremental, spaced repetition to support memorization of the measurement conversions and to assess its impact.

**Statement of the Problem**

The problem is that online students in MAT 1130 fail to demonstrate mastery of the measurement conversion standards, placing them at a disadvantage relative to face-to-face students. Numeracy is required for students to meet the professional standards of their chosen careers (Budgen & West, 2018), and successful memorization of the measurement conversion standards is particularly crucial for health care students.

**Purpose Statement**

The purpose of this action research was to evaluate the impact of and student perception of using StudyMate flashcards to encourage incremental, spaced repetition for
the memorization of measurement conversion standards in an online Mathematics in Health Sciences course at a midwestern community college.

**Research Questions**

Two research questions guided this study:

1. How and to what extent does incremental, spaced repetition through StudyMate flashcard use impact MAT 1130 online students’ memorization of measurement conversion standards?

2. What are the perceptions of MAT 1130 online students regarding incremental, spaced repetition through StudyMate flashcard use in memorizing the measurement conversion standards?

**Statement of Researcher Subjectivities and Positionality**

I am an educator with 32 years of teaching experience. I have taught students in the fifth through eighth grades in an urban public school district. For the last 22 years, I have been teaching mathematics at the collegiate level, specifically, at the same local community college. Over the course of my teaching career, I have experienced many changes in curriculum design and delivered curriculum through various modalities. I have designed courses, curricula, and ancillary materials for self-contained classrooms, content-specific classrooms, and face-to-face courses. Within the last five years, I have been recruited to design courses, curricula, and ancillary materials for online and blended courses. This role has allowed me to recognize the value of completeness, simplicity, and deliverability of content in each of the three different learning modalities (face-to-face, online, and blended). I believe that the purpose of educational technology is to use technological resources to facilitate learning, and that, when used correctly, educational
technology is a tool that can help students better appreciate and value the course content that they will use in their lives. I believe that teaching and learning are ongoing processes that are uniquely personal experiences. As someone who has always had to work hard at learning, and now as an educator, I strive to find ways to help others discover that learning can be easy, fun, and inspiring. As an educator, I have an inherent goal to increase students’ desire and excitement for learning new things in school. I have a passion for helping others discover their inner strength, enthusiasm, and ability to learn new things.

At the same time, I do not believe that there is only one right way to discern the truth or to understand the world around us. As a very practical person, I look at the world through a pragmatic paradigm, interpreting my daily experiences through my own philosophical, abstract beliefs and understandings about the world I live in (Creswell & Creswell, 2018). Other people, including my students, see the world through different paradigms. I believe that each person’s understanding of reality is 100% real to that individual. Truth and our understanding of it are intertwined such that all facts and experiences are colored by individual interpretation. Knowledge and understanding, therefore, cannot come exclusively from the qualitative end of the research spectrum or the quantitative. Rather, knowledge and understanding come from both ends of the research spectrum, and the same truth can be reached via different approaches. Action research, which involves developing practical solutions to local issues, can follow a qualitative or quantitative approach or a combination of the two.

My engagement with this research study is as both an outsider and an insider. My main positionality within my research, specifically in my interactions with the
participants, is that of an outsider in collaboration with insiders (Herr & Anderson, 2005). The participants’ interactions with me are primarily interactions of consultation. As such, my outsider role permits me to gather the data without being a participant, that is, an insider, thus requiring no specific negotiation. With respect to other stakeholders, however, my main positionality within my research is as an insider in collaboration with outsiders. As an insider, my role includes identifying the background information, stating the study’s purpose, determining the methodology to use, collecting and analyzing the data, developing conclusions regarding the meaning of the data, and determining a course of action moving forward. I believe that my positionality with regard to the other stakeholders, the recipients of said information, requires no specific negotiation.

I am a very optimistic person. I tend to be a troubleshooter. If something is not working or if an initiative is not effectively achieving a goal, I will make changes to address the problem and attain that goal. I am also a reflective person who constantly examines what is working well in a given situation and what is not. I acknowledge the negative aspects of such situations, but I do not dwell on them or overthink them. I prefer to channel my energy into focusing on how to turn each negative aspect into a positive attribute. When an approach is not working well, I continually ask why this is so and what can be done to improve student learning. By redirecting my thinking, I look for an optimal learning approach that will allow students to more successfully reach their academic and personal goals. My research may be biased by my optimistic outlook and the speed at which my mind works. As I continue to move towards improving student learning, I will need to slow my thought process down to more thoroughly examine the “what and why” of each negative aspect before I move on to asking how I can modify
what is not working well in order to help students achieve their goals. Here, I will use information from the literature as well as data collected in this study to help direct diagnostic decisions as well as recommendations on how to move forward into addressing the current problem in practice.

**Definition of Terms**

Automaticity – automaticity is the ability to recite or state a measurement conversion fact immediately without mental effort (Allen-Lyall, 2018).

Fluency – fluency is the smooth and effortless ability to recall measurement conversion facts, or more broadly, the quality or state of smooth and effortless flow (Burns et al., 2019).

Fluidity – fluidity is the ability to recall measurement conversion facts immediately and with ease (Allen-Lyall, 2018).

Incremental repetition – incremental repetition is an intervention technique, exemplified by flashcards, in which new, unknown concepts are introduced a few at a time and intermingled with known concepts for repeated practice until all concepts are known (Swehla et al., 2016).

Long-term memory – long-term memory is the part of the brain where learned information, after being moved from the working memory, is stored for later recall and retrieval (Leahy & Sweller, 2019).

Measurement conversion standards – each measurement conversion standard represents the relationship between one measurement unit and another. Examples of measurement conversion standards include 1 foot equals 12 inches, 1 kilogram equals 2.2 pounds, 1 teaspoon equals 5 milliliters. Conversion standards exist for
conversions within the same measurement system (e.g., from inches to feet, both of which are units in the English measurement system) or across systems (e.g., from inches, a unit in the English measurement system) to centimeters (a unit in the metric measurement system) (Benjamin-Lesmeister, 2018).

Memorization – memorizing and memorization denote committing measurement conversion facts to memory or learning measurement conversion facts by heart (Hoque, 2018).

Recall – recall is the ability to bring a measurement conversion fact to the forefront of one’s thought or conscious mind (Karpicke, 2012).

Retention – retention is the ability to keep a measurement conversion fact in the long-term memory for later retrieval and use (Karpicke, 2012).

Retrieval – retrieval is the ability to locate or recall a measurement conversion fact in one’s memory and bring it to the conscious mind (Karpicke, 2012).

Spaced repetition – spaced repetition is an intervention technique that involves increasing the time intervals between practice sessions using flashcards (Schmidmaier et al., 2011).

Working memory – the working memory is a temporary, limited-capacity storage location where facts such as measurement conversion standards are held while being processed before they are moved to the long-term memory (Leahy & Sweller, 2019).
CHAPTER 2
LITERATURE REVIEW

Introduction

The purpose of this action research will be to evaluate the impact of and student perception of incremental, spaced repetition of StudyMate flashcard use for the memorization of measurement conversion standards in an online Mathematics in Health Sciences course at a midwestern community college. This study’s specific research questions are:

1. How and to what extent does incremental, spaced repetition of StudyMate flashcard use impact MAT 1130 online students’ memorization of measurement conversion standards?

2. What are the perceptions of MAT 1130 online students regarding the incremental, spaced repetition of StudyMate flashcard use in memorizing the measurement conversion standards?

A wide variety of key terms were used to conduct a literature search on the numerous relevant topics. For clarity, the key terms searched are grouped according to topic as follows: (a) memorization, (b) theories, (c) strategies, (d) flashcards, and (e) technology. In addition, several combinations of terms were used to narrow the search scope specifically to college-level math courses in general, such as college algebra. Table 2.1 outlines the search groups and the associated keywords.
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<tr>
<th>Search Group</th>
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As the initial combinations were too restrictive and yielded results not relevant to the specific search topic, the combination of terms was broadened to increase the search results. The primary search was for articles published within the past five years, which yielded fifty-five articles relevant to this study. This timeframe was often stretched to include articles from within the past seven years, resulting in an additional sixteen articles relevant to this study. Additionally, I mined the references cited in the most current articles, which led to additional resources dating back to 1993 that provided additional foundational knowledge. The references for this literature search were obtained from the following databases: Academic Search Complete, APA PsycInfo, CINAHL, Education Research Complete, Education Source, ERIC, and Google Scholar.

This literature review chapter contains five main sections: (1) memorization, (2) memorization in math education, (3) strategies to improve college students’ memorization and recall, (4) flashcards, and (5) technology.
Memorization

Memorization, a central component of the foundation for successful learning, is achieved through receiving and encoding sensory input, holding that input for a short period in the working memory, then moving it to the long-term memory for future retrieval (“Memory Process,” n.d.). Three terms used frequently in connection with memorization are retrieval, recall, and retention. Retrieval is the act of accessing information stored in the long-term memory and moving it to the conscious mind, specifically, the working memory (“Memory Process,” n.d.). Recall is the ability to retrieve stored information, that is, to access it in the absence of cues of any kind (“Memory Process,” n.d.). Retention is the ability to preserve information in the long-term memory for retrieval and use at a later date (“Merriam-Webster Dictionary,” n.d.). The memorization process occurs when fundamental information is received and moved to the long-term memory (McLeod, 2013). Memorization of information enables automaticity in connecting one piece of information to another (Klemm, 2007), as memorized information can be recalled or retrieved from the long-term memory to be recited, used, written, or performed instinctively or without the necessity of thinking about it. Memorization and retrieval of information present a challenge for the brain (Hoque, 2018) but make more advanced learning easier. To better understand the importance of memorization in learning, I will focus on three key ideas: (a) memorization and the Cognitivist Learning Theory, (b) the significance of memorization for college students, and (c) college students’ challenges with memorization. Each of these points provides a foundation for this study.
Memorization and Cognitivist Learning Theory

Cognitive theorists focus on how information is received, processed, organized, stored, and retrieved by the mind as the core of the learning process (Ertmer & Newby, 1993). Cognitivist learning theory stresses the idea that learning occurs through the acquisition of knowledge and the use of internal mental structures. Specifically, this school argues that learning consists of the building or rearranging of cognitive structures as the brain processes and stores information and experiences (Mergel, 1998). The information enters the mental structures, is processed in the working memory, and is then transferred to the long-term memory for storage and eventual retrieval (Mergel, 1998). Learning is the process by which the internal mental structures organize new information for storage and retrieval.

Cognitive Load Theory, rooted in this cognitivist approach, posits that learning takes place in the way we process information within the internal knowledge or cognitive structures (Mergel, 1998). Cognitive Load Theory identifies three aspects of cognitive load, each of which affects the complexity of the learning process: (1) the intrinsic load, or the inherent level of difficulty associated with a specific topic; (2) the extraneous load, or the level of difficulty associated with a particular presentation of the material such as teaching style; and (3) the germane load, or the difficulty associated with the processing and construction of schemas (de Araujo Guerra Grangeia et al., 2016). Cognitive Load Theory focuses on managing the burden on the working memory, which has a limited capacity, during learning activities (de Araujo Guerra Grangeia et al., 2016). When unnecessary cognitive demands are placed upon the learner, cognitive load increases and working memory is more burdened, which hinders effective learning. Efficient
management of the cognitive load, on the other hand, leads to more efficient use of the working memory (Sweller, 2016).

Cognitive Load Theory can help us identify methods of supporting learning that improve working memory capacity and long-term memory storage (Akgün et al., 2016). Cognitive Load Theory posits that information must be sufficiently processed in the working memory before it is moved to the long-term memory for the brain to be able to recall it accurately later (Chen et al., 2018). For memorization to occur, then, knowledge must be held in the working memory and thoroughly processed at the time of learning (Leahy & Sweller, 2019). Yet because the working memory has a limited capacity, the new knowledge must then be transferred to the long-term memory to preserve space in the working memory and avoid overloading the cognitive structures. When information is successfully processed in the working memory and transferred to the long-term memory, it becomes available for immediate future recall. This ability frees up brainpower in the working memory, thus avoiding cognitive overload and allowing for the continued learning of new material (Allen-Lyall, 2018; Berrett & Carter, 2018; Chen et al., 2018).

Improved ability to memorize information thus reduces cognitive load.

**Significance of Memorization for College Students**

For college students, who are constantly working to learn new material, memorization is particularly significant because it reduces cognitive load. Memorization allows for fluent recall of previously learned information when the student is later engaged in more complex applications, reducing the need to spend time and brainpower on less relevant tasks (Hoque, 2018). The ability to recall memorized information directly reduces the cognitive load on the working memory, freeing up the working memory for
new learning (Berrett & Carter, 2018). Thus, students who have memorized foundational information can allocate additional brainpower to higher-level learning (Hoque, 2018). The ability to immediately recall memorized information from earlier in the student’s career reduces the expenditure of mental energy during more complex applications later in the student’s career: instead of spending mental energy on recall, the student can devote it to learning new material, allowing for more productive learning to occur.

In this way, the internalization of necessary foundational information frees up brainpower that would otherwise have been used to discern and retain basic facts so that this brainpower can be allocated to more complex learning (Allen-Lyall, 2018). Immediate recall of basic facts allows for more effective and efficient use of working memory capacity in new learning situations. Memorization can enhance learning by preserving working memory energy for higher-level thinking applications.

In college mathematics classes, for example, memorizing basic mathematics facts and techniques allows for automatic and instantaneous recall of this information, leading to more effective and efficient use of the working memory while the student is learning new material. The ability to automatically recall basic math facts reduces the cognitive load on the working memory by eliminating the student’s need to perform basic calculations. A student who has memorized multiplication and division facts to the point that she can rely entirely on semantic long-term memory to retrieve them no longer has to compute these facts using finger counting or a calculator (Berrett & Carter, 2018). Thus, the student’s cognitive resources, specifically, the working memory, can be applied to learning new material: in this example, solving more complex math problems (Berrett & Carter, 2018). Memorization of basic facts reduces cognitive load so that the working
memory can allocate more resources to processing and understanding the nuances of number relationships required for more complex mathematics (Allen-Lyall, 2018).

An example of how memorization can save time and energy in mathematics can be seen in the use of memorized multiplication and division facts in solving proportions. The process for solving a proportion is to cross-multiply, then divide to isolate the variable. A student who has not memorized the relevant multiplication and division facts must begin by calculating these by hand or on a calculator. A student who has memorized them, on the other hand, can proceed directly to solving the proportion, saving time and mental energy. When foundational concepts and information such as multiplication and division facts have been adequately processed and moved to long-term memory, the student can progress to more complex learning instead of spending time performing simple mathematical calculations (Hoque, 2018).

Many college students struggle with memorizing information or fail to memorize key ideas. The inability to recall previously learned information may lead to disappointment and a feeling that time is being wasted on trying to learn the material (Hopkins et al., 2016). When this happens, students experience frustration (Terenyi et al., 2019), which can have a considerable impact on college persistence and completion. In this way, failure to memorize foundational information can be not only detrimental to learning but also career-altering. The failure to memorize information for quick recall can significantly impact successful college learning, leading to a profound impact on career choices.

The inability to recall information learned in college can impede the student’s career after graduation as well. Immediate access to memorized information is essential
when time is of the essence or when it is otherwise not possible to look up basic facts in a reference book (Hoque, 2018). Automatic recall of a cumulative body of knowledge is necessary for success in disciplines such as health care, such that careers can be derailed by poor retention and recall of foundational information (Hopkins et al., 2016).

**College Students’ Challenges with Memorization**

College students are required to memorize new material as one of their many academic tasks. Memorization can be particularly useful as part of a college education as it trains the brain to learn memory schemas that facilitate future learning. Yet college students are exposed to so much new material in a relatively short time that the sheer volume of information may make memorization difficult. College students quickly lose their ability to recall much of the information learned in their classes; this is especially problematic in disciplines where long-term retention of cumulative foundational content is necessary for success, such as health care or engineering (Hopkins et al., 2016).

Although students are willing to commit time to review, learn, and memorize new material, their judgment about what is most important to memorize from among the vast amounts of information may be unreliable (Lindsey et al., 2014). For example, student judgment about which information is most essential to memorize may be overridden by the desire to learn new material as opposed to revisiting and restudying relevant material that they previously learned (Lindsey et al., 2014). As a result, college students face significant challenges in retaining, retrieving, and recalling learned knowledge, especially given the large quantities of information that need to be retained, retrieved, and recalled.

A second factor that can affect students’ ability to memorize information is the number of opportunities they have to practice recalling and applying the learned
information. College students struggle with memorizing information for retention when they do not have ample opportunities to recall it and apply it. This factor may be compounded by the abovementioned factor, as the more information a student has to learn, the less time the student will have to practice recalling each fact. Thus, providing enough opportunities to practice recalling learned information can significantly improve memorization. In many courses, structured opportunities for retrieval or recall of information are limited to formal assessments such as homework, quizzes, and tests (Hopkins et al., 2016). The resulting scarcity of opportunities for retrieval of foundational information is incompatible with the necessity of memorizing this information for future learning (Lyle et al., 2020).

Given the vast amount of information learned in college and the limited opportunities to retrieve and apply it, an appropriate study strategy is key to enabling effective memorization. Learning results from processing information in the working memory and storing information in an organized and meaningful manner in the long-term memory (Ertmer & Newby, 1993). College students therefore need study strategies that will maximize their ability to process new information in the working memory and then transfer that information to the long-term memory. When working memory is not effectively used to process new information, college students experience a heavier cognitive load and struggle with memorization. Later, instead of automatically recalling essential information, these students must devote cognitive resources, namely, working memory capacity, to recalculating or retrieving it, diverting those cognitive resources from higher-level thinking (Berrett & Carter, 2018). When the working memory capacity is exceeded, cognitive overload occurs, resulting in significantly reduced learning and
memorization (de Jong, 2010). Effective use of the working memory when the student first encounters new information, therefore, will save space in the working memory later, when the student is trying to recall that information and use it as a foundation for higher thinking. Effective study strategies are therefore an important part of any curriculum in which new knowledge builds on prior knowledge.

Student-chosen study strategies that are less effective and less efficient include rote memorization, hoping that some kind of magical mental osmosis will convey the information in their brains, and not having a strategy at all (Hoque, 2018). These practices lead students to struggle with memorization. Another common problem is overestimating their own knowledge level: students routinely overestimate the quantity of information they remember and subsequently underestimate the need for and value of further studying (Hoque, 2018). Students do not typically study their course material using methods that promote long-term retention and recall of foundational information (Lyle et al., 2020). College students therefore struggle with memorization and rapidly forget what they learn because their preferred study strategies tend to increase retrieval of information from the short term memory but not consolidation of learning in the long-term memory (Lyle et al., 2020). Efficient and effective study strategies can make a huge difference in students’ ability to memorize information.

**Memorization in Math Education**

Memorization of basic information is a necessary component of learning and the development of more advanced skills. The following discussion of memorization in math education will focus on (a) the impact of math fact memorization on subsequent math
learning, (b) memorization in college-level math education, and (c) the need to improve memorization teaching techniques for online math courses at the higher education level.

**Memorization of Math Facts and Subsequent Math Learning**

As described above, the attainment of automaticity with math facts constitutes a solid foundation for pursuing higher thinking skills such as solving equations, proportions, and formulas, and engaging in problem-solving (Allen-Lyall, 2018). Additionally, developing memorization skills early on in the educational process yields a greater capacity to focus on more advanced educational tasks by training the mind to attend to and focus intensely on content (Hoque, 2018). Memorization of mathematical knowledge prepares the brain to create memory and learning schemas that will facilitate future learning (Hoque, 2018). In this way, memorization of math facts early in the educational journey provides a solid foundation for future learning (Burns et al., 2019), namely, applying and synthesizing these essential facts in higher-level thinking and problem-solving. The acquisition of basic foundational information thus becomes the portal to authentic mathematical literacy, leading to subsequent proficiency and advancement in mathematics (Allen-Lyall, 2018; Berrett & Carter, 2018). The automaticity of recall provides a springboard to future learning.

**Memorization in College-Level Math Education**

Likewise, memorization in college-level math courses can impact success in the acquisition and mastery of subsequent skills. As at the primary and secondary levels, fluency of foundational college-level knowledge creates an easier path to the understanding and proficiency of higher-level skills. When foundational knowledge is internalized, mental computations become more efficient, reducing confusion and the
possibility for computational error in higher-level and multi-step problem-solving activities (Allen-Lyall, 2018). Math fact and foundational knowledge fluency are essential for future success in more complex mathematics (Berrett & Carter, 2018). Memorization of basic mathematical knowledge may have a direct bearing on students’ capacity to attend to and focus on additional educational endeavors (Hoque, 2018). When the foundational mathematical knowledge has been memorized, more advanced, higher-level opportunities become available to all students. Yet despite recent improvements, math proficiency scores among American high school graduates remain low; this trend could be linked to limited basic math fact knowledge (Berrett & Carter, 2018).

**The Need to Improve College Students’ Memorization in Online Math Courses**

While memorization and fluency are important in both traditional face-to-face courses and online courses, the need for instantaneous recall and fluidity of memory is especially important in online learning, which requires students to be more self-directed and self-disciplined when it comes to initiating and facilitating their learning (Buelow, Barry, & Rich, 2018). In a face-to-face classroom, the instructor has more of a traditional instructional role, whereas the student is more of a passive recipient of knowledge; in an online course, on the other hand, the instructor has more of a facilitator role, and the student must take a more active role in his or her learning. Online students, who cannot be in the same room participating in activities with the instructor and classmates, must assume more control of their own learning (Plews, 2017) rather than simply following along with the class. Thus online students need to take the initiative to learn and memorize the required information. Whether they succeed in doing so can open or close doors to future career possibilities: successful advancement in some disciplines is
dependent upon students possessing and retaining a cumulative body of knowledge (Hopkins et al., 2016). In mathematics specifically, successful retention of foundational knowledge can lead to increased self-confidence, which in practice opens a wider range of college major and career options (Allen-Lyall, 2018). Inadequate competence, recall, and retention of this knowledge, in contrast, can thwart career options and defeat personal aspirations (Hopkins et al., 2016). Memorization of basic foundational math concepts can be the pivot point between achievement and disappointment.

**Strategies to Improve College Students’ Memorization and Recall**

Recognizing that college students struggle with memorization and recall is an essential first step in overcoming the barrier that this struggle presents. It is possible for instructors to improve college students’ memorization and recall ability by providing them with proven study strategies. The following section will focus on two strategies: (a) incremental repetition and (b) spaced repetition, also referred to as spaced practice or distributed practice.

**Incremental Repetition**

Incremental repetition, also referred to as incremental rehearsal, is a flashcard technique in which new concepts or facts to be learned are added to previously mastered content incrementally or in stages. Each new concept or fact that is introduced is interspersed with known concepts, at a ratio such as one new concept for every seven to nine known concepts (Burns et al., 2019). This technique enables students to repeat or rehearse new facts quickly and efficiently (Swehla et al., 2016) and can be an effective learning strategy.
Incremental rehearsal is known to be an effective approach for improving the acquisition and retention of math facts (Swehla et al., 2016) as it leads to increased recall of math facts (Burns et al., 2019). The use of incremental practice to learn new concepts or facts significantly increases the long-term retention of knowledge (Senzaki et al., 2017). Weaving together opportunities to learn new content with opportunities to rehearse previously memorized information is an effective approach to improving recall and retention of new content.

**Spaced Repetition**

The practice of spaced repetition relies on the observation that gradually increasing the amount of time between opportunities for information retrieval improves long-term memory retention. The amount of time between instances of information retrieval is related to long-term retention. Lengthening the intervals between retrieval opportunities when learning new information increases long-term retention (Hopkins et al., 2016), as concepts and facts are remembered better when they are repeated after a brief interval than when they are repeated in immediate succession (Mulligan & Peterson, 2014). Thus the spaced repetition of new material has a powerful impact on long-term memory. Distributed practice, a practice involving intentional variation of time intervals, is especially effective in boosting the long-term retention of knowledge (Schmidmaier et al., 2011). There is no mention in the literature as to the minimum or maximum useful interval between retrieval opportunities in spaced repetition of new material, however.

Spaced repetition is particularly valuable when it is the student’s chosen strategy for studying. Notably, a student’s preference for a particular study strategy is a significant factor in the successful acquisition and retention of information. Thus spaced repetition
enhances learning and memory more effectively when it is the student’s self-chosen study strategy than when it is not (Mulligan & Peterson, 2014). When spaced repetition is contrary to the student's chosen or preferred method of study, in contrast, its benefits are less significant (Mulligan & Peterson, 2014).

**Flashcards**

A familiar study technique that allows students to reap the benefits of both incremental repetition and spaced repetition is flashcards. Studying flashcards involves active learning, which improves memory. The following section will focus on (a) an operationalized definition of flashcards, (b) the benefits of using flashcards, and (c) the challenges associated with using flashcards.

**Operationalized Definition**

A flashcard is a card, originally made of paper but now also available in digital form, bearing a cue on one side and, on the other side, the correct response or corresponding information, which can be briefly displayed or “flashed” to aid in memorization. One definition of a flashcard is “a card bearing words, numbers, or pictures that are briefly displayed usually as a learning aid” (“Merriam-Webster Dictionary,” n.d.). A second, similar definition of a flashcard is “a small piece of stiff paper with a word, picture, or question on it that is to teach something” (“Cambridge English Dictionary,” n.d.). The essence of a flashcard, therefore, is a two-sided “card,” paper or digital, with information on both sides that can be flipped over and back again to facilitate repetition so that the user learns to connect two ideas in a single memory to improve recall.
Benefits of Using Flashcards

Using flashcards to improve memorization is a method that actively engages students in meaningful learning, enhancing the ability to retain and recall information (Senzaki et al., 2017). This technique produces deep, meaningful, long-term learning by requiring students to actively and repeatedly retrieve information (Karpicke, 2012). I will focus on the benefits of using flashcards with respect to their effectiveness (a) as a learning aid, (b) as a performance improvement tool, (c) as an information acquisition tool, (d) as a self-testing tool, (e) as a broadly accessible tool, (f) as a tool for assessing what is known and what is unknown, and (g) as a convenient study strategy.

As a Learning Aid

Flashcards are a well-established learning aid and strategy for improving memorization and improving retention. Students use flashcards as an active engagement educational tool to help memorize information (Murray et al., 2018). Using flashcards requires engaging the brain to create long-term memories that are easily accessible for retrieval. Engaging with new information repeatedly strengthens memory and improves information retrieval (Schmidmaier et al., 2011). The repetitive nature of flashcard use makes it a more effective learning strategy than reading the same material over and over (Murray et al., 2018). The active engagement that results from using flashcards can positively impact improving recall and retention.

As a Performance Improvement Tool

Flashcards are beneficial for improving performance on assessments and can be designed to enhance performance on assessments that examine a variety of skills, from basic recall to synthesis. Flashcards help prepare students for questions that measure
retention, comprehension, and application (Senzaki et al., 2017). Spaced repetition through flashcard use results in an increase in long-term learning compared to mass learning (Murray et al., 2018).

As an Information Acquisition Tool

Flashcards are an effective method of mastering the factual knowledge (i.e., vocabulary, sight words, math facts) from which new and more advanced skills are constructed (Schmidmaier et al., 2011). Using flashcards for incremental rehearsal is an effective method of improving the acquisition and retention of math facts (Swehla et al., 2016) and other basic information that serves as the building blocks for higher-level learning.

As a Self-Testing Tool

Flashcards actively engage users in self-testing, providing students with the opportunity to assess their own mastery of a subject as a guide for further study. Self-testing using flashcards enables students to assess their retention of specifically studied material (Murray et al., 2018). The usefulness of flashcards for both initial studying and subsequent self-testing (Senzaki et al., 2017) makes them an effective strategy for promoting long-term knowledge retention (Schmidmaier et al., 2011).

As a Broadly Accessible Tool

Flashcards are a broadly accessible tool as they are effective for various age groups and learning capacities in various settings. Because anyone capable of understanding written words and symbols can use flashcards, they are a universal study strategy (Schmidmaier et al., 2011). Students of different ages and different learning
capabilities can use flashcards to enhance their learning experiences and improve performance and retention (Murray et al., 2018).

As a Tool for Assessing What is Known and What is Unknown

Flashcards are an efficient and effective method for students to assess what information has been memorized and what information still needs work. They can be used to monitor learning by identifying information that needs additional attention for memorization to occur (Sage et al., 2019). By facilitating the discovery of weak points in the retention of information, they enable students to focus future study on the information they are least familiar with (Schmidmaier et al., 2011). Flashcards provide the opportunity to quickly assess what has been mastered and where additional effort needs to be expended to improve retention.

As a Convenient Study Strategy

Flashcards offer a convenient way to study, memorize, and retain information. Flashcards, whether in paper or digital form, are more convenient to carry than a heavy textbook. They are ideal from the perspective of on-the-go convenience: paper versions can be tucked into a pocket, while digital versions can be accessed from laptops and phones (Sage et al., 2019). Paper flashcards are easy and inexpensive for students to make on their own. Digital flashcard platforms such as StudyMate and Quizlet save time as premade templates can be customized for different content (Sage et al., 2019). Flashcards are thus convenient and easy to use as well as being effective in a variety of ways.

One benefit of using flashcards is that the student controls the speed at which content is covered. Student control over speed of viewing the flashcards puts the student
in control of the load on the working memory while the repetition of flashcards helps to move the content from working memory to long-term memory (Murray, Phelps, & Altabbakh, 2018). A second benefit of using flashcards is that it allows for self-testing of one’s knowledge through formative assessment and self-identification of progress and errors, thus improving memory retention (Murray et al., 2018; Sage, Krebs, & Grove, 2019).

**Challenges Associated with Using Flashcards**

Although flashcard use has many benefits, it is not without challenges. The following section will focus on (a) inefficient usage, (b) the time element, and (c) cost and satisfaction factors.

**Inefficient Usage**

Students may not be capitalizing on the benefits of flashcards if they are using them ineffectively or inefficiently. Students tend to be unaware of the impact of flashcard utilization on their learning and subsequent memorization of information (Murray et al., 2018), and to have limited knowledge of the most effective ways of using flashcards to learn new information (Murray et al., 2018). Flashcards could provide additional benefits for students if the optimal ways to use them, specifically, incrementally introducing content and spacing repeated practice, were more widely promoted and known.

**Time Element**

Because they rely on incremental repetition, flashcards do require a significant investment of time. In incremental repetition, new concepts or facts are combined with previously mastered content in small doses; this technique is therefore time-consuming (Swehla et al., 2016). Incremental rehearsal with flashcards has been criticized for its
inefficiency due to the time required to sufficiently incorporate all content (Burns et al., 2019). Although incremental repetition does require an investment of time, that time can be used efficiently when incremental, spaced repetition is built into the small pockets of study time in any study schedule.

Cost and User Satisfaction

Both the paper format and the digital format of flashcards have pros and cons in terms of cost and user satisfaction. Digital flashcards are more easily repurposed than paper flashcards since a new paper flashcard needs to be created for each new fact (Sage et al., 2016). Yet paper flashcards are less expensive than any of the devices required to use digital flashcards; if the student does not already have access to a digital device, the cost of a device may prevent the use of digital flashcards (Murray et al., 2018). Digital flashcards can be manipulated to display text and images at any size, but the inability to physically manipulate digital cards, in contrast to paper flashcards, can result in dissatisfaction and a feeling of diminished control (Sage et al., 2019). The choice between paper flashcards, digital flashcards, or a combination of both comes down to personal preference.

Technology Acceptance Model

Classroom technology has changed the way teachers teach and the way students learn. Digital learning tools such as computers and hand-held devices have transformed teaching and learning (Education, 2019). One advantage of technology is that it is available to support student learning 24 hours a day, seven days a week. Another is that it can be used to create immersive environments that engage learners (Pourhosein Gilakjani et al., 2013) by allowing students to personalize their learning (Education, 2019). If
technology is perceived to be helpful and user-friendly, technology may be considered an acceptable tool for studying. The Technology Acceptance Model (TAM) is used to understand the factors that affect student acceptance of technology. The TAM is designed to measure the core variables of user motivation such as a technology’s perceived usefulness, its perceived ease of use, and attitudes toward the technology (Davis, 1989; Scherer et al., 2019). The TAM has become a well-established model for predicting user acceptance (Venkatesh & Davis, 2000). It is important to illustrate the connections between technology, constructivism, and student perceptions. The following section will focus on student perceptions and the Technology Acceptance Model (TAM).

Consideration must be given to student perceptions of incorporating technology into learning. Two main factors influence a person’s decision to use any new form of technology: how useful it is and how easy it is to use (Davis, 1989). The Technology Acceptance Model (TAM) is a framework for investigating how students come to accept and use a technology based on its perceived usefulness, its perceived ease of use, and their own attitudes towards learning (Gao, 2005). A number of studies support the TAM’s validity and reliability (Gao, 2005; Lewis, 2019; Scherer & Teo, 2019). Figure 2.1 is a diagram of the TAM based on the work by Davis et al. (1989).

**Figure 2.1**
Technology Acceptance Model (TAM) (Davis, 1989)
Chapter Summary

Memorization is a critical element in building a foundation for learning. Cognitivist learning theory underscores the importance of internal mental structure and organization and highlights the need for new information to be processed in the working memory before it is transferred to the long-term memory. When there is sufficient space in the working memory for adequate processing of new information, cognitive overload is avoided, and information can be successfully stored in the long-term memory. Memorization is achieved when a student can successfully recall and retrieve information from the long-term memory.

The academic path of a college student consists of thousands of small tasks; many of these tasks center around the memorization of information. Unfortunately, successful memorization can be thwarted by obstacles such as the tremendous amount of information that college students are inundated with, the lack of opportunities to practice and apply newly acquired information, and the lack of effective and efficient study strategies to memorize information. Surprisingly, there is little published information on how these obstacles can be overcome in the college setting and especially online. The literature thus indicates that instructors must identify and convey strategies that can improve student success at memorization in online college-level math courses. In this context, digital flashcards are emerging as a promising tool to reduce cognitive load and improve long-term learning through memorization. The present study will investigate how incremental spaced repetition using StudyMate digital flashcards can improve math fact memorization in an online college course.
CHAPTER 3

METHODS

The purpose of this action research was to evaluate the impact of and student perception of incremental, spaced repetition of measurement conversion standards using StudyMate flashcards in an online Mathematics in Health Sciences course at a midwestern community college. Prior to this study, many MAT 1130 online students failed to demonstrate adequate memorization of the required measurement conversion standards. This study sought to answer the following two questions: (1) To what extent did the use of StudyMate flashcards impact MAT 1130 online students’ memorization of measurement conversion standards? (2) What were the perceptions of MAT 1130 online students regarding the use of StudyMate flashcards in memorizing the measurement conversion standards?

Research Design

 Whereas traditional research methods seek generalizable answers, action research has the more specific goal of connecting theory to practice to improve education (Mertler, 2017). Action research aims to change what we do to educate others and how we reflect on our practices (Kemmis, 2009). The present study is considered an action research study because “action research is characterized as research that teachers do for themselves” (Mertler, 2017, p. 4). Action research was the most appropriate way for me, as an educator, to study my environment and practices to help students successfully memorize the measurement conversion standards. I conducted this action research study
for my own purposes: I wanted direct, informative, and immediate feedback on my specific situation so that I and other teachers could take steps to improve our students’ memorization strategies, which will ultimately benefit the students, their future employers, and the community.

The present study used a mixed-methods research design, defined as a design that involves “the combination of at least one qualitative and one quantitative component” (Schoonenboom & Johnson, 2017, p. 108). This approach is based on the presumption that a combination of the two methods will provide more insight than either approach on its own (Creswell & Creswell, 2018). Triangulation of the data was applied to merge the qualitative and quantitative findings and give equal emphasis to the findings obtained by both methods (Mertler, 2017). The quantitative and qualitative data were evaluated independently before being evaluated collectively to ascertain the consistency of the results.

The convergent parallel mixed-methods approach used in this study required that quantitative and qualitative data were collected during the same research phase. The quantitative data was collected and analyzed independently of the qualitative data, and the results of each method were weighed equally before the results were interpreted (Schoonenboom & Johnson, 2017).

**Setting and Participants**

**Setting**

This study took place at an urban community college located in the Midwest. This study specifically targeted the online course sections of MAT 1130, Mathematics in the Health Sciences. This students in these sections did not meet in a physical space on the
college campus, nor was there any in-person interaction with the instructor. Most, if not all, contact was via email. Zoom video conferencing was available for virtual office hours and individual conferences at the student’s request.

In this asynchronous course, students had specific deadlines for assignments. Students had the option to self-pace: they could complete assignments ahead of the deadlines or at the established deadlines. MAT 1130 online students were expected to electronically access course information such as the syllabus, course outline, learning modules, practice tests, and assessments. They were also expected to read and study the learning modules, memorize the measurement conversion standards used in the health care field, and independently complete online homework assignments, quizzes, and assessments.

The health sciences programs at the college where this study was conducted consist of open enrollment general education and division-specific courses as well as program-specific courses with limited enrollment. Many health sciences programs have restrictions on the number of students who may start the limited-enrollment program-specific courses due to space constraints and accreditor guidelines. The open enrollment courses may be taken before the student is accepted into a specific program and before registration in the limited-enrollment courses is granted. Several programs including Veterinary Technology have a competitive selection process for granting eligibility to register for limited-enrollment courses. Through this competitive process, access to limited-enrollment courses is awarded based on grade point average (GPA), prerequisite course completion, and the Test of Essential Academic Skills (TEAS) score rather than on a first-come-first-serve basis. Other programs, including Nursing, offer an accelerated
admission track that rewards students who have been highly successful in general education and division-specific courses with priority entry into the program and access to limited-enrollment courses. As MAT 1130 is a prerequisite course for most health sciences programs, including Nursing, Veterinary Technology, and Pharmacology Technology, MAT 1130 performance affects program acceptance and access to limited-enrollment courses.

MAT 1130 has three main themes: arithmetic review, application of arithmetic skills, and real-life applications of arithmetic skills and concepts. The theme of Test 1 is an arithmetic review of addition, subtraction, multiplication, and division with whole numbers, fractions, and decimals. The arithmetic review is focused on computational skills without the use of a calculator. Also included in Test 1 are the metric and customary systems of measurement. This portion of the curriculum includes the conversion standards for converting within the metric system, the conversion standards for converting within the customary system, and the conversion standards for converting from one system to another.

The theme for Test 2 is the application of the arithmetic skills reviewed in Test 1. Test 2 concepts include the usage of signed number operations, expressions, equations, proportions, percentages, and ratios. Test 2 requires students to use arithmetic skills with whole numbers, fractions, and decimals in various ways, including translating words, phrases, and sentences into mathematical problems to solve for an unknown value. Proportions are introduced as a method of solving for an unknown value and as a method of converting measurements within the customary system of measurement, within the metric system, and between the metric and customary systems.
The theme of Test 3 is real-life applications in health care fields. This unit’s topics include reading drug labels and other measurement tools, general intravenous fluid administration calculations, and several types of dosage calculations, including parenteral, bodyweight, and age-related dosage calculations. Test 3 brings together the arithmetic skills and concepts into real-life health care situations.

One of the skills necessary for the successful completion of MAT 1130 and success in subsequent courses in the health care programs is the memorization of measurement conversion standards (e.g., 1 inch = 2.54 centimeters, 2.2 pounds = 1 kilogram, 1 tsp = 5 milliliters) (Benjamin-Lesmeister, 2018). See Appendix C for a complete list of the measurement conversion values taught in this course. At the beginning of each term, students are provided with a list of the measurement conversion standards that must be memorized. At the start of this study, there was no prescribed instructional strategy recommended to students in the online sections to support their memorization of the measurement conversion standards. The students were expected to memorize the measurement conversion standards as soon as possible using any study strategy they chose. At that time, the course design provided no exercises, practice sheets, PowerPoint presentations, lecture notes, or other activities to engage and support memorization of the measurement conversion standards.

Participants

The participants for this action research study were students enrolled in any of the online sections of MAT 1130 taught by the author. They were purposefully chosen to be invited to participate in this study because they were enrolled in an online section as opposed to a face-to-face section of MAT 1130. Accordingly, they were the most
appropriate source of information and data regarding college student memorization of measurement conversion standards. They helped me understand the topic of investigation, namely, the struggle that online students experience with memorizing measurement conversion standards (Creswell & Creswell, 2018). As students enrolled in my online sections of MAT 1130, these students were best suited to help me answer the research questions regarding the impact of incremental, spaced repetition using StudyMate flashcards on online students’ memorization of measurement conversion standards. This purposeful sample also allowed me to gain insight into student perceptions of StudyMate as an interactive learning tool to help them memorize the measurement conversion standards (Creswell & Creswell, 2018).

Each online section of MAT 1130 had a maximum enrollment capacity of 32 students. The demographics of the students varied from section to section, but the total population was comprised of males and females ranging from 17 to 65 years of age. The students’ previous college experience also varied: for some, this was the first college course; for others, it fell towards the middle or end of their college experience. Some students had professional health care experience or were currently working in the health care field, while others did not have any health care experience. Table 3.1 provides an overview of the demographic data of the participants of this study.

Table 3.1

<table>
<thead>
<tr>
<th>Participant Demographic Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic Component</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>18-20 years old</td>
</tr>
<tr>
<td>21-25 years old</td>
</tr>
<tr>
<td>26-35 years old</td>
</tr>
<tr>
<td>36-45 years old</td>
</tr>
<tr>
<td>46 + years old</td>
</tr>
<tr>
<td>Ethnicity</td>
</tr>
<tr>
<td>African American</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Total number of credit hours taken this term</td>
</tr>
<tr>
<td>6-11</td>
</tr>
<tr>
<td>12-15</td>
</tr>
<tr>
<td>Total number of credit hours taken overall</td>
</tr>
<tr>
<td>19-36</td>
</tr>
<tr>
<td>37-52</td>
</tr>
<tr>
<td>53+</td>
</tr>
<tr>
<td>Field of Study</td>
</tr>
<tr>
<td>Nursing</td>
</tr>
<tr>
<td>Other Health Care Field</td>
</tr>
<tr>
<td>Pharmacology</td>
</tr>
<tr>
<td>Veterinary Technology</td>
</tr>
</tbody>
</table>

I invited all of the students in each of my multiple online sections of MAT 1130 to participate in this study. Participation in this action research study was voluntary, with no consequences for non-participation (National Commission, 1978). No privileges, rewards, or incentives were offered for participation. Eighteen students opted to participate.

**Intervention**

This action research examined the impact of an intervention, namely, requiring students to engage in incremental, spaced repetition using StudyMate digital flashcards, on MAT 1130 online students’ memorization of the measurement conversion standards used in health care. In the following section, a brief review of Cognitive Load Theory provides information on how and why learning and memorizing can be enhanced using flashcards. A description of how StudyMate digital flashcards are used is followed by an explanation of how this study method incorporates the learning strategies of incremental
and spaced repetition. The implementation of the intervention in the present study and the specific measurement conversion standards to be learned are also described.

Learning Theory

Cognitive Load Theory

Cognitive Load Theory guided the design of this intervention. In keeping with the idea that students construct their knowledge through internal management within their working memory, this study applied incremental and spaced repetition using StudyMate digital flashcards and assessed the impact of this technique on memorizing the measurement conversion standards. The flashcard approach to memorization puts the control of active learning in the students’ hands, allowing for management of cognitive load on the working memory and thus leading to improved, meaningful learning. This cognitive load management technique may have ultimately increased students’ ability to retain and recall information (Senzaki et al., 2017). Table 3.2 depicts the relationship of the relevant tenets of learning theory to various elements of the applied intervention.

Incremental and Spaced Repetition

The strategy for implementing StudyMate incorporated a combination of incremental repetition and spaced repetition. Incremental repetition is a flashcard technique in which unknown concepts are incrementally introduced and intermingled with known concepts for repeated practice until all concepts are known (Swehla et al., 2016). Spaced repetition involves interspersing time intervals between flashcard practice sessions, which results in a boost in long-term retention and content mastery (Schmidmaier et al., 2011).
This intervention required students to use StudyMate flashcards for a minimum of 10 minutes per day, three days a week for five weeks. This schedule was consistent with the principle of incremental repetition (Burns et al., 2019): the flashcard tool continually reinforced the known concepts through repetition while incrementally exposing students to unknown concepts intermingled with known concepts. The goal of commingling the unknown and known concepts was the gradual mastery of all concepts. Using the flashcards for a minimum of 10 minutes each day on three different days during the week was consistent with the principle of spaced repetition (Hopkins et al., 2016): brief intervals of time between retrieval opportunities leads to better recall and long-term retention when compared with the same number of retrieval opportunities in immediate succession (Mulligan & Peterson, 2014).

Table 3.2
Learning Theory Overview and Intervention Actionability

<table>
<thead>
<tr>
<th>Learning Theory</th>
<th>Theory Tenets</th>
<th>Intervention Actionability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Load Theory</td>
<td>• Managing the cognitive load in the working memory increases learning (Sweller, 2016).</td>
<td>• Incremental, spaced repetition using StudyMate flashcards was used to introduce information in data sets of 14 items each rather than introducing all 56 items at once, limiting exposure to new information and thus maintaining an appropriate cognitive load in the working memory.</td>
</tr>
<tr>
<td></td>
<td>• The transfer of information to long-term memory reduces the</td>
<td>• Incremental, spaced repetition using StudyMate flashcards was used to introduce new data sets in</td>
</tr>
</tbody>
</table>
cognitive load, allowing the working memory to be more efficient in learning new information (Chen et al., 2018).

- Fluent recall of basic math facts reduces cognitive load so that the working memory can allocate cognitive resources for more complex applications (Berrett & Carter, 2018).

- Incremental, spaced repetition using StudyMate flashcards was used to manage the cognitive load in the working memory by integrating new data set information with information that had already been transferred to long-term memory.

- The third and fourth data sets introduced through incremental, spaced repetition using StudyMate flashcards were the converse of the first and second data sets; this association between the data sets reduced cognitive load by relying on fluent recall of previously memorized information, which freed up working memory for application of information.

### StudyMate Description

The tool for this intervention was incremental, spaced repetition using StudyMate digital flashcards, a learning tool from Respondus® (“StudyMate Campus,” n.d.). StudyMate is a Windows-based tool featuring 11 different interactive learning activities and games, including flashcards, to support learning (“StudyMate Main Page,” n.d.).
Interactive learning involves student interaction and engagement with the content through either hands-on activities or technology. A learner-centered approach where students regulate their learning through actively controlling their engagement with content and subsequent learning is a component of interactive learning (Schroeder-Moreno, 2010); another component is a high-quality learning environment that actively engages the learner, thus promoting deep learning (Cairncross & Mannion, 2001).

**Intervention Implementation**

There were 28 measurement conversion standards to be memorized. Their converse values also needed to be memorized. As an example, for the conversion standard 12 inches = __ ft, the converse was 1 ft = __ inches. The 28 measurement conversion standards and the converse of each standard totaled 56 flashcards. The 56 flashcards were divided into four data sets, each containing 14 items. In weeks one and two, the 28 conversion standards were introduced, while weeks three and four covered the 28 converse values. Each subsequent week’s flashcards were added to and intermingled with the previous week’s flashcards. No new flashcards were added in week 5. Figure 3.1 depicts a mock-up of the front of one StudyMate flashcard, while Figure 3.2 depicts a mock-up of the back of the same flashcard.
The measurement conversion standards included conversions from one unit to another unit within the standard system (e.g., inches to feet), converting from the standard system to the metric system (e.g., pounds to kilograms), and converting from the metric system to the standard system (e.g., milliliters to teaspoons). The students were presented with a table containing all the measurement conversion standards, shown in Appendix E, at the beginning of the course. The measurement conversions were grouped
by type of measurement (i.e., time, weight, linear measurement, and liquid measurement).

The data sets were created to keep the measurement groupings of time, weight, linear measurement, and liquid measurement together as much as possible while staying within the parameters of having fourteen conversion standards in each data set. The liquid measurement category was split, with the standard-to-standard conversions assigned to Data Set A and the standard-to-metric conversions assigned to Data Set B. Two of the six time conversion standards were assigned to Data Set A, while the other four time conversion standards were assigned to Data Set B to maintain the balance of fourteen conversion standards in each set. Data Set A contained the weight conversion standards, while Data Set B contained the linear measurement standards. Data Sets A and D contained the same information since Data Set D contained the converse information of Data Set A. Similarly, Data Sets B and C contained the same information since Data Set C contained the converse information of Data Set B. An outline of the conversion standards in each data set, the converse data set information, and the week of release for student use is presented in Table 3.3.

Table 3.3
*Data Set Content and Release Timeframe*

<table>
<thead>
<tr>
<th>Conversion Standards in Data Set</th>
<th>Converse Data Set</th>
<th>Released</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Set A 1 teaspoon = ___ milliliter(s)</td>
<td>Data Set D</td>
<td>Week 1</td>
</tr>
<tr>
<td>1 tablespoon = ___ milliliter(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 fluid ounce = ___ milliliter(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 cup = ___ milliliter(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 pint = ___ milliliter(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 quart = ___ milliliter(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 inch = ___ centimeter(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 foot = ___ inch(es)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 yard = ___ foot/feet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 yard = ___ inch(es)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 day = ___ hour(s)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1 week = ___ day(s)
1 year = ___ week(s)
1 year = ___ month(s)

Data Set B
1 tablespoon = ___ teaspoon(s)
1 fluid ounce = ___ tablespoon(s)
1 cup = ___ ounce(s)
1 cup = ___ tablespoon(s)
1 pint = ___ cup(s)
1 pint = ___ fluid ounce(s)
1 quart = ___ pint(s)
1 quart = ___ fluid ounce(s)
1 gallon = ___ quart(s)
1 ounce = ___ gram(s)
1 pound = ___ ounce(s)
1 kilogram = ___ pound(s)
1 minute = ___ second(s)
1 hour = ___ minute(s)

Data Set C
3 teaspoons = ___ tablespoon(s)
2 tablespoons = ___ fluid ounce(s)
8 ounces = ___ cup(s)
16 tablespoons = ___ cup(s)
2 cups = ___ pint(s)
16 fluid ounces = ___ pint(s)
2 pints = ___ quart(s)
32 fluid ounces = ___ quart(s)
4 quarts = ___ gallon(s)
28.35 grams = ___ ounce(s)
16 ounces = ___ pound(s)
2.2 pounds = ___ kilogram(s)
60 seconds = ___ minute(s)
60 minutes = ___ hour(s)

Data Set D
5 milliliters = ___ teaspoon(s)
15 milliliters = ___ tablespoon(s)
30 milliliters = ___ fluid ounce(s)
240 milliliters = ___ cup(s)
480 milliliters = ___ pint(s)
960 milliliters = ___ quart(s)
2.54 centimeters = ___ inch(es)
12 inches = ___ feet/foot
3 feet = ___ yard(s)
36 inches = ___ yard(s)
24 hours = ___ day(s)
7 days = ___ week(s)
52 weeks = ___ year(s)
12 months = ___ year(s)

Data Set B (already released)

Data Set A (already released)
Table 3.4 provides an overall picture of the intervention implementation schedule.

<table>
<thead>
<tr>
<th>Week</th>
<th>Student Activity</th>
<th>Conversion Data Set(s) Available in StudyMate</th>
<th>Total Number of Flashcards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Use the StudyMate flashcard tool for a minimum of 10 minutes three times a week</td>
<td>Set A</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>Use the StudyMate flashcard tool for a minimum of 10 minutes three times a week</td>
<td>Set A, Set B</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>Use the StudyMate flashcard tool for a minimum of 10 minutes three times a week</td>
<td>Set A, Set B, Set C</td>
<td>42</td>
</tr>
<tr>
<td>4</td>
<td>Use the StudyMate flashcard tool for a minimum of 10 minutes three times a week</td>
<td>Set A, Set B, Set C, Set D</td>
<td>56</td>
</tr>
<tr>
<td>5</td>
<td>Use the StudyMate flashcard tool for a minimum of 10 minutes three times a week</td>
<td>Set A, Set B, Set C, Set D</td>
<td>56</td>
</tr>
</tbody>
</table>

It was crucial to ensure that each pair of data sets was given an equal amount of practice time. Releasing Data Set A in Week 1 provided five weeks of practice opportunities. Releasing Data Set B in Week 2 provided four weeks of practice opportunities. Releasing Data Set C in Week 3 provided three weeks of practice opportunities. Releasing Data Set D in Week 4 provided two weeks of practice opportunities. The release schedule shows that Data Sets A and D, which contained the same information, had a total of 7 weeks of practice opportunities. Similarly, Data Sets B and C, which contained the same information, also had a total of 7 weeks of practice opportunities. Table 3.5 provides an overview of the practice time assigned to the data pairs.
Table 3.5  
*Practice Time Opportunities*

<table>
<thead>
<tr>
<th>Data Pair</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Total Number of Practice Opportunities for the Pair of Data Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set A</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>7</td>
</tr>
<tr>
<td>Set D</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Data Pair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set B</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>7</td>
</tr>
<tr>
<td>Set C</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

The students determined which days and times worked best for each of their own schedules to meet the requirement of a minimum of 10 minutes each time, three times a week for five weeks. Fulfilling this minimum requirement of 10 minutes each time, three times a week for five weeks was part of their grade, and their activity was tracked through the StudyMate instructor tools. Students accessed the StudyMate flashcard tool through the course learning shell. Once the student had opened StudyMate in the course learning shell, the student clicked on the flashcard icon to open the StudyMate flashcard tool. Each flashcard presented a standard conversion, with part of the conversion missing. The student completed the conversion with the correct answer and “clicked” on the flashcard to flip it over to verify the correct answer. Each student was able to choose whether to orally review the measurement conversion information on the flashcard or to write it down. After the student verified the correct answer, the student repeated the process with the remaining measurement conversion standard flashcards. The students were not required to document their use of the StudyMate flashcard tool; their activity
was tracked through the StudyMate instructor tools. I collected information weekly from the StudyMate instructor tool and verified the data during the data collection phase.

**Data Collection Methods**

The mixed-methods research study focused on evaluating the impact of incremental, spaced repetition using StudyMate digital flashcards on students’ memorization of the measurement conversion standards for an online Mathematics in Health Sciences course. The sources of data collected for this study included (a) Measurement Conversion Standards Assessment (MCSA) pre-test and post-test scores, (b) StudyMate flashcard tool data on frequency and duration of use, (c) responses to the student perception survey, including demographic data responses, and (d) responses from student interviews. Table 3.6 shows the alignment between the research questions and the data sources.

Table 3.6

*Data Source Alignment*

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How and to what extent does incremental, spaced repetition using StudyMate flashcards impact MAT 1130 online students’ memorization of measurement conversion standards?</td>
<td>- MCSA Pre-test and MCSA Post-test scores</td>
</tr>
<tr>
<td>2. What are the perceptions of MAT 1130 online students regarding the incremental, spaced repetition achieved through StudyMate flashcard use for memorizing measurement conversion standards?</td>
<td>- Student Perception Survey - Student Interview Responses</td>
</tr>
</tbody>
</table>

**Quantitative Data**

The quantitative data collected for this study included (a) Measurement Conversion Standards pre-test and post-test scores, (b) StudyMate flashcard tool data on
frequency and duration of use, and (c) student perception survey data, including demographic data.

**Measurement Conversion Standards Assessment (MCSA)**

Students were required to memorize 28 measurement conversion standards from the required textbook, *Math Basics for the Health Care Professional* (Benjamin-Lesmeister, 2018). See Appendix E for the complete list of the measurement conversion standards. The students were expected to memorize each conversion both ways: for example, the students were to memorize the fact that 2 cups = 1 pint and its converse, 1 pint = 2 cups. The MCSA is an instructor-created assessment consisting of 56 completion-type questions intended to assess student memorization of the measurement conversion standards. See Appendix F for the MCSA. I created the MCSA in 2015 for use by the Math Department to gather evidence of student proficiency in memorizing the measurement conversion standards. The content of the MCSA has been validated and deemed reliable by five full-time faculty members who teach MAT 1130 and have used the MCSA in their courses for the last five years. The MCSA was formatted in MyMathLab, an online homework tool, for students to complete electronically. Two example questions were: (1) Complete the following conversion: 1 inch = __ centimeters and (2) Complete the following conversion: 1 kg = __ pounds. The correct responses are 1 inch = 2.54 cm and 1 kg = 2.2 lbs. To succeed, the student must type in “2.54 cm” and “2.2 lbs.”, including the labels. All appropriate abbreviations were expected. The number of correct responses out of the 56 problems was the assessment value. The MCSA pre-test and the MCSA post-test assessments have the same content, but the question order is scrambled for each assessment administration.
StudyMate Flashcard Tool Usage Report

Quantitative data on the frequency and duration of use of the StudyMate flashcard tool was collected from the StudyMate instructor tools and is available as supplementary data. The instructor tools in the StudyMate software allow instructors to view statistical data on students’ StudyMate flashcard tool usage. Using these instructor tools, I tracked and collected specific data including frequency of use, duration of use, and scores ("StudyMate Main Page," n.d.) for each student who accessed the digital flashcards. These data provided evidence on student behaviors regarding the frequency and duration of StudyMate flashcard use, factors that could potentially impact student memorization of the measurement conversion standards. Data on the frequency and duration of StudyMate use were collected to verify that each student had fulfilled the study’s requirements regarding flashcard use. Student access to the StudyMate flashcard tool was granted on the fourth day of the course after the MCSA pre-test was completed. Data on the frequency and duration of use were collected weekly from the fourth day through the end of the fifth week.

Student Perception Survey

Quantitative data was collected using an adapted version of the Technology Acceptance Model (TAM) developed by Fred Davis in 1989. The TAM is an information technology framework for understanding a person’s acceptance of technology (Portz et al., 2019). The TAM gathers information on a person’s perceptions of the usefulness and ease of use of a specific technology and their attitudes towards it (Scherer & Teo, 2019). A number of studies have indicated that the TAM is valid (Lewis, 2019). The purpose of using the TAM in an education research study is to better understand student perceptions
of the usefulness and ease of use of an educational technology tool and their attitudes towards it, and to determine whether more effective learning occurs when students use that specific technology tool (Van De Bogart & Wichadee, 2015). Questions from the TAM that measure perceptions of usefulness and ease of use as well as attitudes were incorporated into the student perception survey. See Appendix G for the TAM questions used by Gao (2005) which were adapted for the present study. Two colleagues and two MAT 1130 students reviewed the adapted questions to ensure that their intent was clear and that they would gather the information I sought. The language used in the student perception survey reflected the students’ experience with incremental, spaced repetition using StudyMate flashcards. The survey captured students’ perceptions of usefulness and ease of use of the StudyMate flashcards and their attitudes towards incremental, spaced repetition with the StudyMate flashcards. Each question’s response choices were on a Likert scale ranging from (1) strongly disagree to (5) strongly agree. See Appendix H for the Student Perception survey. The student perception survey responses were used to inform the semi-structured interview process in this study's qualitative data collection section.

Additionally, demographic data were collected through the student perception survey. The demographic information collected included student characteristics such as age, gender, ethnicity, the number of credit hours taken in the current term, the total number of credit hours taken, and major or field of study.

**Qualitative Data**

The individual interviews sought more in-depth student feedback on their overall perceptions of incremental, spaced repetition using the StudyMate flashcard tool.
Student Interviews

All students who engaged in incremental, spaced repetition using the StudyMate flashcard tool were invited to participate in the interviews. The interview invitation was purposeful to include participants who knowledgeable and had experience with incremental, spaced repetition using the StudyMate flashcard tool. Purposefully selecting students to participate in these interviews allowed me to gather data to understand and address the research questions (Creswell & Creswell, 2018). While all students were invited to participate in the interviews, a limited number of students actually volunteered to sit for an interview due to a spike in COVID-19, which caused a number of students to withdraw from the course and from the study due to contracting COVID-19. All five participants who volunteered for interviews were interviewed.

The individual interviews followed a semi-structured interview format that allowed for changes to the question order, rephrasing of the questions, and the inclusion of questions to clarify or probe for additional responses when appropriate (Creswell & Creswell, 2018). An interview protocol was used to develop interview questions aligned with the research questions (Creswell & Creswell, 2018). See Appendix G for the Interview Protocol. In keeping with the protocol, the interview questions addressed the research questions through open-ended questions regarding student perceptions of incremental, spaced repetition using the StudyMate flashcard tool. Flexibility was afforded by the option to ask follow-up questions as needed to explore responses further. Although no specific learning theory or instructional approach was used to design the interview protocol questions, the interview protocol questions aligned with the research questions. The interview questions reflected specific information that was sought to
answer the research questions. Two colleagues reviewed the interview questions to verify an adequate correlation between the interview questions and the research questions. In addition, two current MAT 1130 students reviewed the interview questions to confirm their relevance and their clarity of phrasing. See Table 3.7 for a summary of the alignment between the research questions and the interview questions.

Table 3.7
*Research Question and Interview Question Alignment*

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Interview Question</th>
</tr>
</thead>
</table>
| RQ2: What are the perceptions of MAT 1130 online students regarding incremental, spaced repetition using StudyMate flashcards for memorizing measurement conversion standards? | 1) Please describe your perceptions of the usefulness of the spaced and repeated practice using the StudyMate flashcards to memorize the measurement conversion standards. (RQ2)  
2) Please describe your perceptions of the ease of using the spaced and repeated practice of the StudyMate flashcards to memorize the measurement conversion standards. (RQ2)  
3) Please describe your overall thoughts and attitude regarding the spaced and repeated use of the StudyMate flashcard tool to memorize the measurement conversion standards. (RQ2) |

The five individual interviews were conducted virtually and recorded using Zoom videoconferencing software for transcription. The interviews lasted approximately 20 minutes and were conducted between the eighth and ninth week after completing the MCSA post-test and the student perception survey.

**Data Analysis**

The two types of data collected in this study were analyzed independently, and the results were then merged to show how the two types of data either converged or diverged
Figure 3.3 illustrates the flow of the convergent parallel mixed-methods approach. 

![Flowchart of Convergent Parallel Mixed-Methods Approach](image)

**Quantitative Data and Results** + **Interpretation** → **Qualitative Data and Results**

Source: Mertler, 2017

**Figure 3.3**
Convergent Parallel Mixed-Methods Approach

The quantitative data analyzed in this study included (a) MCSA pre-test and post-test scores, and (b) student perception survey data. The qualitative data collected and analyzed in this study consisted of the individual student interview responses. The quantitative and qualitative data analyses were conducted according to the method outlined in Table 3.8, which summarizes the alignment between the research questions, the data sources, and the data analysis methods.

**Table 3.8**
Data Analysis Method Alignment

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Sources</th>
<th>Data Analysis Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How and to what extent does incremental, spaced repetition using StudyMate flashcards impact MAT 1130 online students’ memorization of measurement conversion standards?</td>
<td>- MCSA pre-test and post-test scores</td>
<td>Quantitative - Descriptive statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qualitative - Inferential statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Paired samples t-test for pre-test and post-test</td>
</tr>
<tr>
<td>2. What are the perceptions of MAT 1130 online students regarding incremental, spaced repetition using StudyMate flashcards for memorizing measurement conversion standards?</td>
<td>- Student perception survey</td>
<td>Quantitative - Descriptive statistics</td>
</tr>
<tr>
<td></td>
<td>- Student interviews</td>
<td>Qualitative - Inductive analysis</td>
</tr>
</tbody>
</table>
Quantitative Data Analysis

Descriptive and inferential statistics were used for the quantitative data analysis. Descriptive statistics were used with (a) MCSA pre-test and MCSA post-test scores, (b) data on the frequency and duration of StudyMate use, and (c) Likert scale responses from the student perception survey. The use of descriptive statistics resulted in organized, simplified, and summarized numerical data for presentation to facilitate distribution of the study’s findings (Mertler, 2017). Inferential statistics, which allow researchers to draw conclusions beyond the immediate data and inferred broader generalizations about the data (Trochim et al., 2016), were used with the MCSA pre-test and MCSA post-test scores. JASP software was used to analyze the quantitative data. The findings are presented in tables and graphs.

MCSA Pre-test and MCSA Post-test

Descriptive statistics were used with the MCSA pre-test and MCSA post-test to determine central tendency measures, specifically, the median score. A median score is the exact middle of a set of data values; in this study, each median test score represents a division between the upper 50% of students’ test scores and the lower 50% of students’ test scores (Adams & Lawrence, 2019). The purpose of collecting and analyzing MCSA pre-test data was to determine the median student performance prior to the intervention, which served as a baseline for student knowledge of the measurement conversion standards prior to engaging in incremental, spaced repetition through the StudyMate flashcard intervention. MCSA post-test data was then collected and analyzed to determine the median student performance after the students engaged in incremental, spaced repetition using StudyMate flashcards.
Inferential statistics were used with the MCSA pre-test and MCSA post-test scores for a paired t-test to compare the means of the MCSA pre-test and MCSA post-test scores. The paired t-test at $\alpha = 0.05$ was used to determine whether there was a statistical difference between the mean scores for the MCSA Pre-test and the MCSA Post-test. The rationale for using a paired t-test was to compare the repeated measurement on the MCSA to see if the intervention impacted students’ ability to recall the measurement conversion standards. The means and standard deviations for these data are presented.

**StudyMate Data**

Descriptive statistics were collected in the form of data on the frequency and duration of StudyMate use to determine whether each student had accessed and used the flashcards as often and for as long as stipulated in the class requirements and the guidelines of the study. This data provided evidence of the study’s validity through triangulation of information. All students did access and use the flashcards at the required frequency and for the required duration.

**Student Perception Survey**

The student perception survey Likert scale responses were used to determine measures of frequency: specifically, students were grouped according to their responses to the student perception survey questions. The purpose of collecting the student perception data was to measure the frequency of each response regarding student perceptions of the incremental, spaced repetition using StudyMate flashcards. The data collected provided additional insight into student perceptions and aided in designing the student interview questions.

**Qualitative Data**
The interview transcripts were subjected to inductive analysis. This qualitative data analysis was conducted using two cycles of coding. Coding involves the development of a system for organizing, categorizing, and reducing the volume of raw qualitative data to a more manageable and practicable form for analysis (Mertler, 2017; Saldana, 2021). The first step was to transcribe each interview recording into intelligent transcriptions, which included every word but excluded pauses and filler words such as “ah” and “um.” After transcription, each interview was thoroughly read multiple times to ensure accurate interpretation so that common thoughts, ideas, and responses could be identified. The first cycle of coding was performed using in-vivo and descriptive coding. In-vivo coding preserves the participants spoken words by using direct quotes from the participants (Saldana, 2021). Descriptive coding, a method that uses analytic memo writing to purposefully combine or summarize first-cycle coding methods to create a variety of codes that are numbered into a more unified scheme for understanding and analysis (Saldana, 2021). The iterative process of coding is used to distill the volume of raw data into categories and themes, providing a link between the data and its meaning (Saldana, 2021).

The second cycle of coding was performed using pattern coding. Pattern coding entails grouping similar codes from the first coding cycle into fewer, more meaningful categories to enable the emergence of major themes (Creswell & Creswell, 2018; Saldana, 2021). An Excel spreadsheet was organized containing a list of the codes generated from both coding cycles. After the data was coded, the spreadsheet data was organized to distill additional emerging themes. The spreadsheet was refined after each
cycle of coding. Connections were sought among the common themes to further refine, explain, or elaborate on the quantitative data (Mertler, 2017).

**Procedures and Timeline**

This study’s procedures were divided into three phases: preparation, intervention and data collection, and data analysis. Each phase is described below in terms of the researcher’s and participants’ roles. A timeframe for the researcher’s and participants’ roles is included for each phase. Table 3.9 summarizes these roles and timelines for this study.

Table 3.9

*Procedures and Timeline*

<table>
<thead>
<tr>
<th>Phase I: Preparation</th>
<th>Activities</th>
<th>Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Researcher’s Role</strong></td>
<td>Obtained IRB approval</td>
<td>Before the beginning of the term</td>
</tr>
<tr>
<td></td>
<td>Created the MCSA pre-test and post-test in eLearn (our Learning Management System).</td>
<td>One week before the beginning of the term</td>
</tr>
<tr>
<td></td>
<td>Created informational videos for participants</td>
<td>First day of the term</td>
</tr>
<tr>
<td></td>
<td>Entered measurement conversion standards data into StudyMate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Created the student perception survey as a Google Form survey</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Created StudyMate Research Study survey in Google Forms that served as the consent form to participate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Identified participants (i.e., chose which sections of students to use)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sent StudyMate Research Study letter</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provided informational videos to participants</td>
<td></td>
</tr>
<tr>
<td><strong>Participants’ Role</strong></td>
<td>Completed StudyMate Research Study survey in Google Forms</td>
<td>11:59 PM on the third calendar day of the course</td>
</tr>
<tr>
<td></td>
<td>Completed MCSA pre-test</td>
<td></td>
</tr>
<tr>
<td>Activities</td>
<td>Time Frame</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Researcher’s Role</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Provided informational video on the StudyMate flashcard tool</td>
<td>• Fourth day of the term (after completion of the MCSA pre-test)</td>
<td></td>
</tr>
<tr>
<td>• Provided informational video on the MCSA post-test</td>
<td>• Monday of week 5</td>
<td></td>
</tr>
<tr>
<td>• Provided informational video on the student perception survey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Collected quantitative data on:</td>
<td>• Within seven days of the completion date</td>
<td></td>
</tr>
<tr>
<td>• MCSA pre-tests and MCSA post-tests</td>
<td>• Weekly from week 1 through week 5</td>
<td></td>
</tr>
<tr>
<td>• Frequency and duration of student use data from StudyMate</td>
<td>• Week 7</td>
<td></td>
</tr>
<tr>
<td>• Collected data from student perception survey open-ended questions</td>
<td>• Weeks 8 and 9</td>
<td></td>
</tr>
<tr>
<td>• Designed interview protocol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Invited five students to participate in interviews</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Scheduled and conducted interviews</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Participants’ Role</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Used StudyMate for a minimum of 10 minutes three days a week for five weeks</td>
<td>• Weeks 1–5</td>
<td></td>
</tr>
<tr>
<td>• Completed MCSA post-test</td>
<td>• By 11:59 PM on Saturday of the fifth week of the course (open for 24 hours for completion)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• By 11:59 PM on Wednesday of the sixth week of the course (open for 48 hours for completion)</td>
<td></td>
</tr>
<tr>
<td>• Completed student perception survey</td>
<td>• Weeks 8 and 9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Participated in an interview (a total of 5 students participated in interviews)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Phase III: Data Analysis**

<table>
<thead>
<tr>
<th>Activities</th>
<th>Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Researcher’s Role</strong></td>
<td></td>
</tr>
<tr>
<td>• Collected any remaining data</td>
<td>• Weeks 10-15</td>
</tr>
<tr>
<td>• Conducted data analysis</td>
<td></td>
</tr>
</tbody>
</table>
Phase I: Preparation

Before the beginning of the term, I sought approval for my research study from the appropriate institutional review boards (National Commission, 1978) to conduct my study. I completed several organizational activities before the academic term in preparation for my research study. The first task was to craft the Measurement Conversion Standards Assessment pre-test (MCSA pre-test) and post-test (MCSA post-test) in eLearn. The Measurement Conversion Standards Assessment (MCSA) was administered twice to each student, the first time as the MCSA pre-test and the second time as the MCSA post-test. As my second task, after creating the MCSA pre-test and post-test, I created two informational videos for participants, one for each portion of the test. The third and fourth tasks were to enter the measurement conversion standards data into the StudyMate study tool and then to create an informational video and sheet describing the StudyMate tool, including what it was, where to find it, how to use it, and the minimum expected participation requirements. Next on the task list was to create the student perception survey, an adapted version of the Technology Acceptance Method (TAM) in which the language was modified to reflect the use of StudyMate. After creating the student perception survey as a Google Form, I created an informational video on the student perception survey. The final two tasks included crafting an informational video and letter describing the study and inviting participation, and creating an online survey in Google Forms that served as consent to participate.

One week before the academic term began, I identified my potential participants as students enrolled in an online section of MAT 1130 for Fall 2021. After identifying my potential participants, I sent each of them the informational video and letter describing
the study as a means of inviting them to participate. I invited students to complete an online survey in Google Forms by 11:59 PM on the course’s third calendar day. The Google Form was entitled StudyMate Research Study and included an option to not participate in the study. See Appendix J for the StudyMate Research Study letter. The online survey served as the consent letter for those who decided to participate. On the first day of the term, I provided the participants with an informational video on the MCSA pre-test.

The participants’ role in Phase I had two components. The first component was to view the study’s informational video and respond to the StudyMate Research Study online letter, consenting to participate. The second component was to view the informational video on the MCSA pre-test and then complete the MCSA pre-test. The MCSA pre-test was administered online through eLearn so that the students would receive immediate feedback. Only one attempt was permitted for the MCSA pre-test, and the assessment had a time limit of 25 minutes. The MCSA pre-test was available to students electronically for a 24-hour period. The MCSA pre-test was administered to establish a baseline for the students’ knowledge of the measurement conversion values prior to their experience using the StudyMate flashcard tool. The objective of administering the MCSA pre-test so early in the course was to see what students knew before studying the content. Taking the assessment early in the course also provided a baseline score of students’ knowledge of measurement conversion standards and provided the students with documentation of the progress they made by studying and memorizing the material (Berry, 2008). An explanation was provided to the students indicating that the MCSA pre-test’s purpose was to establish current baseline knowledge,
not necessarily to achieve a high score. The MCSA pre-test was administered using a lockdown browser with webcam monitoring to ensure that students were not cheating. Both the online survey and the MCSA pre-test had a deadline of 11:59 PM on the third calendar day of the course. The data for the MCSA pre-test was collected from the online instructor tools within seven days of completion.

**Phase II: Intervention and Data Collection**

On the fourth calendar day of the term, I provided the students with an informational video and sheet describing the StudyMate tool. Students used the StudyMate flashcard tool for a minimum of 10 minutes three times a week, from week one through week five. The StudyMate data was collected at the end of each week for the five weeks.

On Monday of the fifth week, I provided the informational video on the MCSA post-test, which was available electronically for 24 hours and was due by 11:59 PM on Saturday of week 5. Only one attempt was permitted for the MCSA post-test with a time limit of 25 minutes to complete the assessment. The MCSA post-test was administered using a lockdown browser with webcam monitoring to ensure students were not cheating. The objective of administering the MCSA post-test was to establish the impact of using the StudyMate flashcard tool for 10 minutes a day on three nonconsecutive days for five weeks on memorizing the measurement conversion standards.

Also on Monday of the fifth week, I provided an informational video on the student perception survey. The student perception survey was administered as a Google Form survey after completing the MCSA post-test. Students had 48 hours of access to complete the student perception survey, which was due by 11:59 PM on Wednesday of
week 6. At the end of week 6, I cross-checked to verify that I had collected all quantitative data from the MCSA pre-test, the MCSA post-test, and StudyMate.

In week 7, I collected the data from the student perception survey. I used the collected data from the student perception survey to design my interview protocol. I invited all students to participate in an interview. Only five students volunteered to participate in interviews. During weeks 8 and 9, I scheduled and conducted the interviews. The interviews were conducted virtually and recorded using Zoom videoconferencing software. The video files were stored digitally on a secure server for retrieval and transcription. Each interview lasted approximately 20–30 minutes and consisted of three phases: introduction, interview questions, and conclusion. The introduction consisted of introducing the interviewer and describing the purpose of the interview. It provided an explanation of the research questions’ structure and what was done with the data. Phase two consisted of asking the interview questions that were used to support the research questions. Finally, the conclusion phase consisted of closing remarks and a reminder of what would be done with the data. Table 3.10 summarizes the procedures of the intervention implementation by week.

Table 3.10

<table>
<thead>
<tr>
<th>Week</th>
<th>Researcher Activity</th>
<th>Participant Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>• Provided MCSA pre-test informational video</td>
<td>• Completed MCSA pre-test by 11:59 PM on the third calendar day of the course</td>
</tr>
<tr>
<td></td>
<td>• Collected MCSA pre-test data within seven days of the completion date</td>
<td>• Completed Google Survey as consent form by 11:59 PM on the third calendar day of the course</td>
</tr>
<tr>
<td></td>
<td>• Provided StudyMate informational video</td>
<td>• Used the StudyMate flashcard tool for a minimum of 10 minutes three times during the week</td>
</tr>
<tr>
<td></td>
<td>• Collected StudyMate data at the end of each week for week 1</td>
<td></td>
</tr>
</tbody>
</table>
2. Collected StudyMate data at the end of each week for week 2
   - Used the StudyMate flashcard tool for a minimum of 10 minutes three times during the week
3. Collected StudyMate data at the end of each week for week 3
   - Used the StudyMate flashcard tool for a minimum of 10 minutes three times during the week
4. Collected StudyMate data at the end of each week for week 4
   - Used the StudyMate flashcard tool for a minimum of 10 minutes three times during the week
5. Provided MCSA post-test informational video
   - Provided student perception survey informational video
   - Collected StudyMate data at the end of each week for week 5
   - Collected MCSA post-test data within seven days of the completion date
6. Collected any uncollected data from the MCSA pre-test, MCSA post-test, and StudyMate
   - Completed student perception survey form by 11:59 PM on Wednesday of week 6
7. Collected student perception survey data
   - Design interview protocol
8. Scheduled and conducted interviews
   - Participated in an interview
9. Scheduled and conducted interviews
   - Participated in an interview
10–15. Analyzed the data

Phase III: Data Analysis

In weeks 10–15, I collected any remaining data and began data analysis. JASP software was used to analyze the descriptive and inferential statistics for the quantitative component of the data. Descriptive statistical analysis organized, simplified, and summarized the numerical data to facilitate presentation of the study’s findings (Mertler, 2017). Descriptive statistical analysis was applied to MCSA pre-test and MCSA post-test...
data to determine central tendency measures, specifically the median. The purpose of determining the median was to establish a baseline of knowledge of the measurement conversion standards before and after the incremental, spaced repetition use of the StudyMate flashcard tool.

Inferential statistics were used with the MCSA pre-test and MCSA post-test scores for multiple regression analysis. Multiple regression analysis was used to analyze and assess the relationship between the independent variables, namely, the frequency and duration of use of the StudyMate flashcards for incremental, spaced repetitive practice, and the dependent variable, namely, the MCSA post-test scores. This analysis technique also assessed the importance of the relationship between each independent variable and the dependent variable. Inferential statistics drew conclusions beyond the immediate data and inferred broader generalizations about the data (Trochim et al., 2016).

Inductive analysis was used to analyze participants’ interview responses. I transcribed the interview responses, then authenticated the transcriptions by listening to the video files and following the transcript recordings to verify the content. Any necessary edits were made at that time. Any additional notes pertaining to non-verbal behaviors were noted and added to the interviewer’s transcription. The participants were emailed a transcript of their interview responses for reviewing with the option for editing for clarification purposes. After completing all interviewer and participant editing, the transcripts and video files were saved on a secure server.

The interview transcripts, the qualitative component of the data, were analyzed using Delve software. First, I reviewed the volume of data and then, using the Delve software, organized it into themes to present the research findings (Creswell & Creswell,
Two cycles of coding were conducted, with in-vivo and descriptive coding in the first cycle and pattern coding in the second cycle of coding. The qualitative data analysis process included member checking and peer debriefing to ensure rigor and trustworthiness.

**Rigor and Trustworthiness**

For a research study to be considered high-quality, credible, and trustworthy, it must meet the criteria and standards of sound practice (Mertler, 2017). Standards of sound practice include rigor, quality, and trustworthiness, that is, the accuracy and believability of the study (Mertler, 2017). Validity and reliability are the metrics used to measure rigor and trustworthiness in quantitative studies. Validity measures an instrument’s accuracy (i.e., did it measure what it was intended to measure?), while reliability measures the consistency of the collected data (i.e., were the results consistent under the same circumstances using the same methods?) (Mertler, 2017). Common practices to ensure a data set’s credibility and trustworthiness include triangulation, member checking, peer debriefing, and an audit trail (Creswell & Creswell, 2018; Mertler, 2017; Trochim et al., 2016). Each of these practices was used in this research study to ensure rigor and trustworthiness.

**Triangulation**

Triangulation builds the rigor and the trustworthiness of a study by offsetting one method’s weakness with the strength of another method (Carter et al., 2014). There are four triangulation types: methodological, research, theoretical, and data (Carter et al., 2014). This research study used data triangulation, which integrates multiple data sources to achieve an accurate and comprehensive view of the research study (Trochim et al., 2018; Mertler, 2017).
Data triangulation involves gathering qualitative and quantitative data at various times from various sources. This study’s triangulation data included the MCSA pre-test and MCSA post-test scores, the StudyMate frequency and duration of use data, the student perception surveys, and the interview data. The convergence of multiple data sources builds a coherent picture of the research topic (Creswell & Creswell, 2018). The use of quantitative and qualitative data for methodological triangulation provided a more comprehensive picture for a better understanding of the effect of the incremental, spaced repetition of StudyMate flashcards on memorizing the measurement conversion standards.

Member Checking

Member checking was a way for me to share my data and findings with participants, providing them the opportunity to examine and validate my findings (Mertler, 2017). Maintaining transparency through member checking included sending the participants a copy of their transcribed interview for review so that participants may provide corrections, if necessary, to ensure the accurate representation of the data I had captured. Member checking also included sharing the study’s findings and offering the participants the opportunity to review my initial findings to confirm that my findings resonated with them. Member checking validated the accuracy of the data and helped me form a trusting relationship with the participants.

Peer Debriefing

Peer debriefing is a technique for verifying research processes, enhancing a research study’s accuracy, and strengthening its credibility. Peer debriefing is accomplished through active dialoguing with others who have a fresh perspective on the
research study to review and ask questions about the study (Creswell & Creswell, 2018; Mertler, 2017). This study’s peer debriefing was conducted with my research writing partner, dissertation advisor, and dissertation committee members. These conversations enabled us to review, critique, and reflect on the research process (Mertler, 2017). The goal was to ensure that my data and findings had been sufficiently explored and were valid, reliable, and credible. At every step of the research process, time was spent on peer debriefing to ask questions, seek different viewpoints, discover new possibilities, and encourage deeper thinking in my research and writing.

**Audit Trail**

An audit trail is the body of notes, memos, and journal entries collected by a researcher to document the steps followed from data collection through data analysis. The audit trail is an in-depth account tracking the thought process by which decisions were made throughout the analysis portion of the research (Carcary, 2009). This documentation process provides written evidence of the researcher’s train of thought, from the coding of data to why codes were clustered together to the final creation of the overall theme. In short, an audit trail explains what the researcher was thinking and how and why decisions were made. For the present study, I kept notes in an online journal in order to increase the study’s rigor by providing evidence of the direction of my thought process and thoughts for analysis of the data.

**Plan for Sharing and Communicating Findings**

The purpose of this action research was to evaluate the impact of the incremental, spaced repetition of StudyMate flashcard use on student memorization of measurement conversion standards in an online Mathematics in Health Sciences course. This study’s
findings provide important information on improving students’ preparedness for completing a health science degree and becoming successful in the health care field. Participant confidentiality and anonymity were preserved by removing any identifiers and using pseudonyms in the shared information. This study’s findings were shared with the participants and the stakeholders, specifically, the MAT 1130 Committee and the MAT 1130 instructors.

First and foremost, the participants received the findings of this study through email. Sharing my findings was a way for me to recognize and confirm the importance of their participation in this study. Participants may also have benefited from receiving the results by becoming more cognizant of their critical thinking abilities as they reflected on the impact and pertinence of the study’s findings on their academic and career success. Sharing the study results promoted participant trust in the research process and encouraged a respectful, collaborative relationship between the researcher and participants.

The stakeholders included the MAT 1130 committee members, who oversee the curriculum content and materials used in MAT 1130, and the full-time and adjunct MAT 1130 instructors. In a short, informal presentation, this study’s findings were conveyed to the MAT 1130 committee members and the full-time and adjunct instructors. The findings included (a) the background information leading to this study, (b) the purpose of the study, (c) the methodology used, (d) the data results, (e) my conclusions regarding the meaning of the data, and (f) a recommended course of action moving forward. Time was allotted for questions and answers.
Mertler (2017) wrote that “sharing the results – either formally or informally – is the real activity that helps bridge the divide between research and application” (p. 259). The significance of sharing my findings with my peers improved my study’s credibility by illustrating to fellow educators that my research was not an isolated event but that it has a connection to what happens in the classroom (Mertler, 2017).
 CHAPTER 4

ANALYSIS AND FINDINGS

This action research evaluated the impact of and student perception of incremental, spaced repetition of StudyMate flashcard use on memorization of measurement conversion standards for an online Mathematics in Health Sciences course. Both quantitative and qualitative data were collected to answer the following questions:

1. How and to what extent does incremental, spaced repetition of StudyMate flashcard use impact MAT 1130 online students’ memorization of measurement conversion standards?
2. What are the perceptions of MAT 1130 online students regarding the incremental, spaced repetition of StudyMate flashcard use in memorizing the measurement conversion standards?

This chapter presents an overview and analysis of the quantitative and qualitative data collected during this action research study. This chapter is divided into three main sections. The first section presents and analyzes the quantitative data, namely, the Measurement Conversions Standards Assessment (MCSA) Pre-test and Post-test scores, the StudyMate data on frequency and duration of student flashcard use, and the Student Perception Survey results. The second section presents and analyzes the qualitative data, namely, the results of five semi-structured student interviews. The final section integrates the quantitative and qualitative findings.

Quantitative Analysis and Findings

For all participants in the MAT 1130 online sections, quantitative data was collected via the MCSA Pre-test and Post-test; the StudyMate software system, which
collects information on the frequency and duration of flashcard use; and the Student Perception Survey. Descriptive and inferential statistics were analyzed using JASP Version 0.16 (https://jasp-stats.org), an open-source statistical analysis software.

The MCSA is an instructor-created assessment consisting of 56 completion-type questions to assess student memorization of measurement conversion standards. The number of correct responses out of the 56 questions is the assessment value. The MCSA Pre-test and MCSA Post-test consisted of identical content, but the question order was scrambled between the two administrations. The MCSA was created, tested, and approved by the full-time math faculty at the author’s college and is used by all faculty who teach MAT 1130. In the present study, all students took the MCSA Pre-test no later than the fourth day of the term, and the MCSA Post-test at the end of the fifth week of the term. The MCSA was used to assess student success at learning the assigned measurement conversions both overall and within each of four subscales: time measurement, weight measurement, linear measurement, and liquid measurement. Data collected by the StudyMate software on the frequency and duration of student flashcard use were reviewed to verify that each student had complied with the study requirement that they use the flashcards at least three times a week for at least ten minutes each time. The Student Perception Survey consisted of 12 questions and measured student responses using a five-point Likert scale. This instrument was used to collect student response frequencies regarding student perceptions of the incremental, spaced repetition use of StudyMate flashcards. The student perception survey data was collected from Likert scale responses as ordinal data.
MCSA Results

Internal Consistency

The internal consistency of the MCSA Pre-test and MCSA Post-test was computed using Cronbach’s alpha coefficient, which computes the correlation between responses to multiple questions (Adams & Lawrence, 2019b). In general, a Cronbach’s alpha coefficient of 0.60 or greater is considered reliable (Ahdika, 2017). The Cronbach’s alpha values for the MCSA overall and the four subscales, namely, time measurement, weight measurement, linear measurement, and liquid measurement, were calculated using JASP. The MCSA overall had a reliable internal consistency (Cronbach’s α = .70), as did the weight measurement, linear measurement, and liquid measurement subscales. Table 4.1 presents the Cronbach’s alpha data for the MCSA Pre-test and the MCSA Post-test overall and for each of the individual subscales. Concerns related to the time measurement subscale are discussed in Chapter 5.

Table 4.1
Summary Results for Cronbach’s alpha (N = 18)

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Pre-test Cronbach’s α</th>
<th>Post-test Cronbach’s α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.89</td>
<td>0.82</td>
</tr>
<tr>
<td>Time Measurement Conversions</td>
<td>–*</td>
<td>–*</td>
</tr>
<tr>
<td>Weight Measurement Conversions</td>
<td>0.68</td>
<td>0.63</td>
</tr>
<tr>
<td>Linear Measurement Conversions</td>
<td>0.73</td>
<td>0.87</td>
</tr>
<tr>
<td>Liquid Measurement Conversions</td>
<td>0.86</td>
<td>0.83</td>
</tr>
</tbody>
</table>

*Unable to calculate due to high correct response rates

Descriptive Statistics

Table 4.2 presents descriptive statistics for the MCSA Pre-test and Post-test results. Participants achieved a higher mean score on the MCSA Post-test (M = 52.28) than on the Pre-test (M = 31.22). The standard deviation decreased from the MCSA Pre-
test \((SD = 8.21)\) to the Post-test \((SD = 4.13)\), indicating that the scores on the MCSA Post-test were more tightly clustered around the mean score. For each subscale, likewise, the mean score increased from the MCSA Pre-test to the Post-test, while the standard deviation decreased from the MCSA Pre-test to the Post-test, indicating a smaller variance in Post-test scores for each subscale as for the overall score (see Table 4.2).

Table 4.2  
*Descriptive Statistics for MCSA Pre-test and Post-test (N = 18)*

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Pre-test</th>
<th></th>
<th>Post-test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Overall</td>
<td>31.22</td>
<td>8.21</td>
<td>52.28</td>
<td>4.13</td>
</tr>
<tr>
<td>Time Measurement Conversions</td>
<td>11.61</td>
<td>0.50</td>
<td>11.89</td>
<td>0.32</td>
</tr>
<tr>
<td>Weight Measurement Conversions</td>
<td>2.33</td>
<td>1.61</td>
<td>5.17</td>
<td>1.15</td>
</tr>
<tr>
<td>Linear Measurement Conversions</td>
<td>5.00</td>
<td>2.06</td>
<td>7.67</td>
<td>1.19</td>
</tr>
<tr>
<td>Liquid Measurement Conversions</td>
<td>12.28</td>
<td>5.71</td>
<td>27.56</td>
<td>3.37</td>
</tr>
</tbody>
</table>

*Note.* The maximum score on the MCSA Pre-test or Post-test is 56.

Inferential Statistics

The Shapiro-Wilk test was applied to confirm whether the mean difference between MCSA Pre-test and Post-test scores met the normality assumption. The result (see Table 4.3) indicated a deviation from normal distribution \((p < .05)\) for the MCSA overall, the time measurement conversions, the linear measurement conversions, and the liquid measurement conversions. The weight measurement conversions had a normal distribution \((p \geq .05)\).
Table 4.3
*Shapiro-Wilk Test of Normality* (N = 18)

<table>
<thead>
<tr>
<th>Subscale</th>
<th>W</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.88</td>
<td>0.03</td>
</tr>
<tr>
<td>Time Measurement Conversions</td>
<td>0.57</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Weight Measurement Conversions</td>
<td>0.91</td>
<td>0.08</td>
</tr>
<tr>
<td>Linear Measurement Conversions</td>
<td>0.89</td>
<td>0.04</td>
</tr>
<tr>
<td>Liquid Measurement Conversions</td>
<td>0.95</td>
<td>0.48</td>
</tr>
</tbody>
</table>

*Note.* Significant results suggest a deviation from normality.

This deviation from normality reflected dependence between the data sets and required a nonparametric test that does not assume that the sampled populations have normal distribution (Adams & Lawrence, 2019a). To investigate whether there was a statistically significant difference between the MCSA Pre-test and Post-test scores, I used the Wilcoxon signed-rank test (Adams & Lawrence, 2019b). The results of the Wilcoxon signed-rank test analysis, presented in Table 4.4, indicated a statistically significant difference in the median overall scores between the MCSA Pre-test ($Mdn = 32.00, SD = 8.21$) and the Post-test ($Mdn = 54.50, SD = 4.13$), $W = 171.00, p < .001$. The $r$ value, used to gauge the effect size of the analysis (Adams & Lawrence, 2019b), indicated a large effect size on the overall scores ($r = 0.62$). The median score on each subscale was likewise higher on the Post-test than on the Pre-test, but this difference was only significant for the linear and liquid measurement conversions, though it was borderline significant for the weight measurement conversions. The $r$ values for the subscales indicated a large effect size for the weight, linear, and liquid measurement conversions and a moderate effect size for the time measurement conversions (see Table 4.4) (Adams & Lawrence, 2019b).
Table 4.4  
*Summary Results of Wilcoxon Signed-Rank Test (N = 18)*

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Pre-test Mdn</th>
<th>Post-test Mdn</th>
<th>W</th>
<th>p</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>32.00</td>
<td>54.50</td>
<td>171.00</td>
<td>&lt; .001</td>
<td>0.62</td>
</tr>
<tr>
<td>Time Measurement Conversions</td>
<td>11.61</td>
<td>11.89</td>
<td>15.00</td>
<td>0.04</td>
<td>0.34</td>
</tr>
<tr>
<td>Weight Measurement Conversions</td>
<td>2.33</td>
<td>5.17</td>
<td>105.00</td>
<td>0.001</td>
<td>0.55</td>
</tr>
<tr>
<td>Linear Measurement Conversions</td>
<td>5.00</td>
<td>7.67</td>
<td>149.50</td>
<td>&lt; .001</td>
<td>0.58</td>
</tr>
<tr>
<td>Liquid Measurement Conversions</td>
<td>12.28</td>
<td>27.56</td>
<td>171.00</td>
<td>&lt; .001</td>
<td>0.62</td>
</tr>
</tbody>
</table>

**StudyMate Use Data**

Data on the frequency and duration of each student’s use of the StudyMate flashcards were collected to assist with interpreting the findings. All students were required to access the StudyMate flashcards three times a week and use them for ten minutes each time. All eighteen participants met this minimum requirement during each of the five weeks of the study. The collection of this StudyMate data provided support for the validation and triangulation of the findings.

**Student Perception Survey**

Student response data regarding the students’ perceptions of the incremental, spaced repetition use of the StudyMate flashcards was collected. The Student Perception Survey questionnaire was modified to a 5-point Likert-type questionnaire. The participants were asked to state their level of agreement with each of several statements using the following choices: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, and (5) strongly agree.

**Internal Consistency**

The internal consistency of the Student Perception Survey was computed using Cronbach’s alpha (Adams & Lawrence, 2019d) and shown to have a very reliable internal
consistency overall (α = .82). Internal consistency was also calculated for each of three subscales: Perceived Usefulness (α = .90) had a very reliable internal consistency, while Perceived Ease of Use (α = .64) and Attitude Toward Using Flashcards (α = .73) had reliable internal consistencies. Table 4.5 presents the Cronbach’s alpha data for the Student Perception Survey overall and for the individual subscales within the Student Perception Survey.

Table 4.5
Summary Results for Cronbach’s alpha (N = 18)

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Cronbach’s α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Perception Survey</td>
<td>0.82</td>
</tr>
<tr>
<td>Perceived Usefulness</td>
<td>0.90</td>
</tr>
<tr>
<td>Perceived Ease of Use</td>
<td>0.64</td>
</tr>
<tr>
<td>Attitude Toward Using Flashcards</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Descriptive Statistics

The Student Perception Survey was divided into three subscales: Perceived Usefulness, Perceived Ease of Use, and Attitude Toward Using the Flashcards. All responses in all subscales were either (4) agree or (5) strongly agree. The Perceived Usefulness subscale (M = 4.63, SD = 0.62) indicated that students found the flashcards useful. The Perceived Ease of Use subscale (M = 4.83, SD = 0.44) indicated that students found the flashcards easy to use. The Attitude Toward Using the Flashcards subscale (M = 4.51, SD = 0.69) indicated that students were likely to use similar flashcards in the future. Table 4.6 presents the descriptive statistics for these three subscales.
Table 4.6
*Descriptive Statistics for Student Perception Survey Subscales (N = 18)*

<table>
<thead>
<tr>
<th>Subscale</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Usefulness</td>
<td>4.63</td>
<td>0.54</td>
</tr>
<tr>
<td>Perceived Ease of Use</td>
<td>4.83</td>
<td>0.31</td>
</tr>
<tr>
<td>Attitude Toward Using Flashcards</td>
<td>4.51</td>
<td>0.48</td>
</tr>
</tbody>
</table>

**Qualitative Analysis and Findings**

Qualitative data were collected from semi-structured individual interviews conducted with five purposively selected participants at the end of the intervention. The interviews were conducted via Zoom due to COVID-19-related restrictions on in-person contact. All five interviews were recorded in Zoom and then digitally transcribed in Microsoft Word using the transcribe feature. I printed and then read through each transcript multiple times while listening to the corresponding audio file to ensure accuracy. Member checking was also conducted: each interview participant was given a copy of his or her interview transcript and invited to verify the content, make corrections, and provide additional comments. Two software applications, Delve and Excel, were used to analyze the data. Once the accuracy of the transcripts was verified, the files were imported into Delve and coded. After coding in Delve, the data was exported to Excel for descriptive coding. Inductive analysis was used to code, categorize, and classify the data to develop themes and assertions. The inductive analysis process involves a series of steps that reduces the amount of data by “grouping data that provide similar types of information” (Mertler, 2017, p. 173). Through inductive analysis, data were first coded, then refined into categories and emergent themes (Creswell & Creswell, 2018; Mertler, 2017). I used two cycles of coding with two rounds of analysis for each coding cycle. The
process of coding the data helped me reflect on the connections among the data in order to develop themes. In the sections below, I will describe the qualitative analysis process for (a) first-cycle coding of qualitative data, (b) second-cycle coding of qualitative data, and (c) developing themes and assertions. I will then provide a comprehensive presentation of the qualitative findings and themes.

**First-Cycle Coding of Qualitative Data**

My first coding cycle consisted of two rounds of analysis, including in-vivo and descriptive coding.

**In-Vivo Coding**

The first round of analysis consisted of in-vivo coding, a first-cycle coding method in which the participants’ actual words are used in the coding process (Saldana, 2021). The phrases were mined from the participant interviews. In-vivo coding preserves the language of the participants to ensure the inclusion of their voices as part of the analytical process (Saldana, 2021). An example of in-vivo coding would be the use of the phrase “surprised and excited at how much I remembered”, a direct quotation from an interview participant, as a code. In-vivo coding captures the participants’ insights and experiences related to using the flashcards to memorize the measurement conversion values. My in-vivo coding focused on the most meaningful language within each sentence rather than using the entire sentence as a code. A total of 168 in-vivo codes were generated in the first round of coding. Figure 4.1 is a screenshot from the in-vivo coding process in Delve.
Next, I used descriptive coding as a transitional technique (Saldana, 2021). Descriptive coding uses a word or short phrase to summarize the topic of the qualitative data (Saldana, 2021). An example of descriptive coding would be the use of the phrase “liked repetition for continuous review”, which is not a direct quotation but rather a summary of a participant’s intended meaning, as a code. Descriptive coding sparked reflections through using analytic memo writing to explore the depth and complexity of meaning conveyed through the in-vivo codes. The descriptive coding was conducted in a three-column Excel spreadsheet, as this made it easier to look at more items simultaneously, and was performed after Delve had been used for in-vivo coding. The first column provided a space for analytic memos, the interviewer’s thoughts, and notes.
taken during the interview. The second column was the actual transcript, and the third column provided a space for coding. The transcript phrase was highlighted and numbered in the second column. The corresponding code in the third column was numbered with the same number as the phrase in the second column to indicate which code went with which transcript phrase. I read each transcript line by line, highlighting and numbering the phrases in column two that conveyed meaning. In column three, a brief code phrase was assigned to each highlighted transcript sentence and given the same number as the transcript sentence. Two hundred and three codes were generated through descriptive coding. Sample descriptive codes included: “a ten-minute time frame is doable”, “like flexible study time because of work schedule”, and “huge benefits from minimal practice time”. Figure 4.2 displays the layout, highlighting, and numbering of the transcript in the second column of the Excel document, and the corresponding codes in the third column.

Figure 4.2
An Example of the Excel Document Layout Used for Descriptive Coding
Transition from First-Cycle to Second-Cycle Coding

The initial codes were reviewed for additional meaning. The audio files were checked numerous times to ensure that the essence of the meaning of each participant’s comments was captured. The transition from first- to second-cycle coding involved taking the third-column codes from each interview and combining them into a single document to be organized and refined. In addition to a column containing each set of interview comments, each row was assigned a letter and a number as a cell identifier, so that it was easier to identify where comments were located when the codes were subsequently refined. The codes were refined through merging and organizing all of the codes generated through in-vivo coding in Delve and descriptive coding in Excel. These cell identifiers enabled me to cross-check individual comment placement within the refined code column. Columns were also created for the refined codes and for the cell locations where each code occurred to enhance tracking and placement of the interview comment codes. A color-coding process was used to group similar ideas to distill the codes into refined codes. Figure 4.3 provides a sample view of the Excel spreadsheet showing the letters and numbers assigned to each row, the five columns for the comment codes from the five individual interviews, and the column for the refined codes, and depicting how the cell codes have been color-coded and collapsed into refined codes.
The final list of refined codes was reviewed to verify that the codes captured the essence of the participants’ comments. This verification included a thorough review and cross-checking of all audio files, transcripts, and coding documents. Peer debriefing included several conversations with my dissertation chair and writing partner regarding the process and results from the first cycle of coding. Forty-three refined codes were derived from the in-vivo and descriptive coding. Sample refined codes included “study time flexibility”, “efficient use of time”, and “successful memorization using flashcards was motivating”.

**Second-Cycle Coding of Qualitative Data**

My second coding cycle consisted of two rounds of pattern coding.

**Pattern Coding – Round One**

Pattern coding is a method for identifying data that has been similarly coded and organized into a smaller number of groupings, categories, or themes (Saldana, 2021). This coding cycle was a reflective process wherein a deeper understanding of the data
was achieved by reorganizing, renaming, and merging similar codes (Creswell & Creswell, 2018; Saldana, 2021). The refined codes were gathered for review and then organized and grouped based on how the information best fit together as concepts. These groupings included convenience, course design, emotional connection, external factors, flexibility, indirect impact, instructor control, practicality, reduced cognitive load, student control, use of time benefit, and usefulness.

I began by determining the different types of relationships among the refined codes, and then sorted the refined codes according to relationship type. These relationships informed the categories into which the codes were placed. For example, comments associated with the convenience of using the flashcards, such as “flashcards could be used anywhere”, were placed in the convenience category. Codes that pertained to the course layout or the design of the flashcards, such as “the materials were easy to find”, were grouped in the course design category. Codes that specified an emotional impact, such as “being pleased with success in memorizing using the flashcards”, were grouped in the emotional connection category. Codes that included factors or experiences that were not a direct result of this course, such as “the impact of COVID-19 on a career change”, were grouped in the external factors category. Codes that referred to flexibility in using the flashcards, such as “flexible practice schedules”, were grouped in the flexibility category. Codes that were not a direct result of actions taken within this course, such as “college course experiences”, were grouped in the indirect impact category. Codes related to aspects within the instructor’s control, such as “clear course expectations”, went into the instructor control category. Codes that indicated applicability, such as “the repetition provided continuous review”, were grouped in the
practicality category. Codes that indicated an impact on cognitive load, such as “the amount of content memorized”, were grouped in the reduced cognitive load category. Codes that pertained to aspects within the participants’ control, such as “ability to study efficiently”, were placed in the student control category. Codes that indicated efficient use of time, such as “use was effective for time management”, were grouped in the use of time benefit category. Codes that reflected the usefulness of the flashcards, such as “flashcard card practice was beneficial”, were placed in the usefulness category. Figure 4.4 shows an example of the categories and associated codes generated through the first round of pattern coding.

<table>
<thead>
<tr>
<th>Refined Codes</th>
<th>Categories</th>
<th>Conveniencia</th>
<th>Course Design</th>
<th>Emotional Connection</th>
<th>External Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 College course experiences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 career change justification</td>
<td>Cell Number</td>
<td>7, 14, 19, 21, 29, 33, 35, 39</td>
<td>3, 5, 8, 9, 10, 24, 30, 37, 43</td>
<td>16, 17, 21, 22, 26, 27, 32, 33, 36</td>
<td>1, 2, 4, 6, 40, 41, 42</td>
</tr>
<tr>
<td>3 appreciate opinion sought</td>
<td>Refined Codes</td>
<td>online modality</td>
<td>appreciate opinion sought</td>
<td>successful use of flashcards was motivating</td>
<td>College course experiences</td>
</tr>
<tr>
<td>4 covid impact on career</td>
<td></td>
<td>electronic format</td>
<td>course easy to navigate</td>
<td>appreciate flashcard usefulness</td>
<td>career change justification</td>
</tr>
</tbody>
</table>

Figure 4.4
A Sample of the Results of First-Round Pattern Coding.

Pattern Coding – Round Two

The second round of pattern coding involved the review of the twelve categories generated in the first round of pattern coding. Figure 4.5 presents an overview of the
categories and codes that emerged from the first round of pattern coding, along with example comments that were grouped into these categories and codes.

*Table 4.7*
Categories and Codes from the First Round of Pattern Coding

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenience</td>
<td>Appreciation for convenience</td>
<td>Flashcards used anywhere</td>
</tr>
<tr>
<td></td>
<td>Pertained to course layout</td>
<td>Materials easy to find</td>
</tr>
<tr>
<td>Emotional Connection</td>
<td>Success in memorizing using the flashcards</td>
<td>Successful memorization was motivating</td>
</tr>
<tr>
<td>External factors</td>
<td>Experiences outside this course influenced</td>
<td>Covid impact on a career change</td>
</tr>
<tr>
<td></td>
<td>choices</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>Flexibility of study time</td>
<td>Spaced time between practicing</td>
</tr>
<tr>
<td>Indirect Impact</td>
<td>Factors outside this course impacting</td>
<td>Previous college course experience</td>
</tr>
<tr>
<td></td>
<td>experiences</td>
<td></td>
</tr>
<tr>
<td>Instructor Control</td>
<td>Aspects of the course within the Instructor’s control</td>
<td>Clear course expectations</td>
</tr>
<tr>
<td>Practicality</td>
<td>Flashcards are a great tool for memorizing</td>
<td>Applicability within this course and to other content areas</td>
</tr>
<tr>
<td>Reduced cognitive load</td>
<td>10-minute time increments for studying</td>
<td>Repetition provided a continuous review</td>
</tr>
<tr>
<td>Student Control</td>
<td>Factors within student control</td>
<td>Study time flexibility</td>
</tr>
<tr>
<td>Use of time benefit</td>
<td>Efficient use of time</td>
<td>Time management for a busy schedule</td>
</tr>
<tr>
<td>Usefulness</td>
<td>Effectiveness of flashcard usage</td>
<td>Practice was beneficial for memorization</td>
</tr>
</tbody>
</table>

I edited my list of categories several times, with each version providing a better understanding of the categories and the emerging themes. This process allowed me to connect categories and subcategories to determine their relationship to the developing themes. Peer debriefing was conducted with my dissertation chair and writing partner to discuss the process and results from the second cycle of coding. My dissertation chair provided feedback regarding the best means of representing the categories and data and of developing themes and assertions.
Developing Themes and Assertations

Using the refined codes and several rounds of peer debriefing with my dissertation chair, I began to formulate the wording of the themes that were emerging from the data while also ensuring alignment of the categories and codes. Three main themes emerged from the qualitative data: (1) certain factors increased the efficiency of studying with flashcards, (2) certain factors increased the effectiveness of studying with flashcards, and (3) certain factors encouraged students to develop positive attitudes towards using flashcards. I created three flow charts that helped me clarify and visualize the relationships among the codes, categories, and themes.

Each theme was supported with thick, rich descriptions (Mertler, 2017). Specifically, the themes, categories, and codes were supported using participant quotes taken verbatim from the interview responses. Pseudonyms are used for the participants who provided the quotes to ensure confidentiality. Three themes and assertions emerged from the qualitative data (see Table 4.8).

Table 4.8
Themes, Assertions, and Categories from Qualitative Data

<table>
<thead>
<tr>
<th>Theme</th>
<th>Assertion</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors impacting the efficiency of studying with flashcards</td>
<td>Students indicated that efficient use of their time was a high priority when studying and memorizing content.</td>
<td>Convenience Flexible study time Use of time benefit</td>
</tr>
<tr>
<td>Factors impacting the effectiveness of studying with flashcards</td>
<td>Students indicated that a study tool that effectively helped them memorize the measurement conversion standards was a high priority for studying and memorizing the content.</td>
<td>Usefulness Practicality Cognitive load reduced</td>
</tr>
</tbody>
</table>
Factors impacting development of positive attitudes towards using flashcards

Students indicated that using the flashcards created a positive attitude towards studying and memorizing the content.

Recommendations for learning tool use
Emotional connection

**Theme 1: Factors Impacting the Efficiency of Studying with Flashcards**

Efficient use of time consists of performing or functioning in the best possible manner while wasting the least amount of time and effort. Students who participated in the interviews indicated that their time was valuable. Using their study time most productively, that is, as efficiently as possible, was a high priority. The interviews were conducted on an individual basis, but the consensus among the participants was that there were three main factors or inherent characteristics of this study method that increased the efficiency of studying with flashcards: (a) convenience, (b) flexibility, and (c) observing a benefit in exchange for their expenditure of time and effort. These three categories support the theme of factors impacting efficiency of studying with flashcards since they all revolve around how the use of student time is impacted. Figure 4.5 shows a flow chart illustrating the flow from code to category to theme for Theme 1.
Convenience. Students lead very hectic lives; thus, being able to complete required tasks within the limited time permitted by their busy schedules is a top priority. Students consider any activity that meets their needs while causing no impediment to their schedule a convenience. The electronic format of the flashcards meant that they were easily accessible, easy to use, and could be used anywhere. For instance, Tanya spoke positively about the electronic format and the resulting ease of use, while
Josephine likewise championed the electronic format because it made the flashcards easy to use anywhere.

Kiara: I liked that the flashcards are electronic, so I didn’t lose them. I’m not a technology person, so I was so proud that I was able to use the flashcards in just a few minutes. Using the flashcards was just a click of the mouse.

Tanya: I liked that the flashcards were electronic and at my fingertips whenever I wanted to study. I thought they were super easy to use. The technology was so easy to use that anyone can figure out how to use them. All you had to do was open the flashcards and start clicking, and boom, you were doing it.

Josephine: I really liked that they were electronic, so I could use them on any device at any time, no matter where I was. They were simple and easy to use.

The students’ comments also suggested that the convenience of electronic flashcard use impacted the efficiency with which the students could study the material:

Anastasia: I could use them anywhere simply by pulling them up on my phone. It only took a few minutes to figure out how to use them, and I was off and running.

The online, electronic format of the StudyMate flashcards made them easily accessible, easy to use, and useable anywhere, and thus played a significant role in the impact of the flashcards’ convenience on studying efficiency.
Flexibility. Most college students, especially community college students, juggle family, work, and school responsibilities (Bourdeaux & Schoenack, 2016), meaning that sometimes life gets in the way and a student’s day does not go as planned. Having the ability to easily change or modify their actions in response to a schedule that goes awry provides the flexibility needed to accomplish their tasks. Student interview responses indicated that flexible study time, that is, the ability to choose which days and times of the week they would study with the flashcards, was another priority related to efficient use of time. Flexible study times impacted studying efficiency in that they allowed students to choose when, how often, and how long to use flashcards for studying, thus allowing for the adjustment of study time, frequency, and duration to fit into any schedule. In our interviews, Anastacia, Burton, Kiara, and Tanya all indicated the value of flexible study time.

Anastacia: The flexible study time allows me to juggle work and school. I felt like the 10-minute time frame three days a week was ideal. I think that it would have been too hard with my work schedule to do them every day. I would recommend students use them when it is convenient for them in their busy schedule.

Burton: It’s good to have the flexibility to be able to adjust your study time around other things you need to do. Ten minutes of practice every other day was really not much time in the big picture, and it worked well with my other commitments.

Kiara: I liked the flexibility of studying when it fits into my schedule, especially when my schedule changed. I think it was easier to
practice one day than not practice again the next day. It was almost as if I had time to let the information settle before I tried them again. I’m glad they [the flashcards] were not required to be done every day because I have a very hectic schedule. I think having them available for those who want to use them according to their schedule is better than requiring students to do them at specific times.

Tanya: Being on-call, my schedule is constantly changing, so being able to use them [the flashcards] at different times worked well for me.

Flexible study time for flashcard use benefited students because it contributed to the efficiency with which they could study.

**Use of time benefit.** Given the limited number of hours in a day, students are more likely to study efficiently and to use their time well when they can observe a direct benefit resulting from their expenditure of time and effort. Using the flashcards for a predetermined duration that has been shown to result in a return on investment of time, such as 10 minutes each time, helped students stay organized and remain accountable with regard to their practice, and alleviated the stress of juggling tasks of indeterminate length. This benefit was significant because it allowed students to manage their time on task and study what needed to be studied before moving on to the next task. Example comments supporting the beneficial use of time were made by Anastacia, Kiara, and Josephine.
Anastacia: I felt like the 10-minute time frame for studying was ideal and fit into my schedule easily. I felt I could stay on task memorizing the material by committing to doing the flashcards three times a week.

Kiara: School, in general, is hectic, so anything to use my time well, such as the 10-minute study time, is a great help. I liked how I could do my 10 minutes of practice anytime, so I was using my time efficiently.

Josephine: Time management is huge for me since I block off parts of my day to study specific subjects in addition to my other activities, and I have found that the 10 minute study time is a great transition activity for being organized. I am very structured, and I found that 10 minutes wherever it fit used my time well so that no subject was overlooked.

Burton also mentioned that accountability was a significant factor in his experience with the flashcards: “Being a part of this study kept me accountable to myself to get my memorizing done. I don’t know if I would have practiced as much to memorize the standards if I wasn’t using the flashcards.”

**Theme 2: Factors Impacting the Effectiveness of Studying with Flashcards**

Theme 1 focused on how the present study method enabled efficient use of time. Theme 2 focuses on the effectiveness of the present study method and the factors or characteristics that make it effective. Effectiveness in the context of a study method or tool means that it allows for maximal learning with minimal effort. For a study tool to be effective at helping students memorize measurement conversions standards, it must (a) be useful, (b) be practical, and (c) minimize cognitive load to allow maximum memorization to occur. These three categories support the theme of factors impacting the effectiveness
of studying with flashcards since they all revolve around the idea that the incremental, spaced approach to using flashcards produced the desired result of memorizing the measurement conversion standards; therefore, the incremental, spaced approach to using flashcards was effective for memorization. Figure 4.6 shows a flow chart illustrating the flow from code to category to theme for Theme 2.

*Figure 4.6*
Code to Category to Theme Flow Chart for Theme 2
Usefulness. Practicing with flashcards is known to be useful for memorization. Students indicated that the flashcard practice was useful because of its practical impact on their success at practicing for the purpose of memorizing the conversion standards. The flashcards’ usefulness consisted primarily of the perceived benefit that resulted from their use, but also incorporated their incremental learning component, which reduced the cognitive load associated with studying and thus prevented overload of the working memory and promoted the transference of concepts into the long-term memory so that memorization occurred. Incremental learning is the introduction of new concepts among and alongside previously memorized concepts. In this case, specifically, the measurement conversion standards were introduced in groups of fourteen items. When a new group of conversion standards was introduced each week, the new items were mixed in with the previously learned items until all 56 standards had been introduced. In our interviews, Burton, Kiara, Josephine, and Tanya all spoke of the usefulness of and benefit from studying with flashcards.

Burton: The usefulness and benefits of 10 minutes of practice are amazing because you get lots of practice in a short amount of time.

Kiara: When my daughter asked why the memorization was so easy, I told her about the benefits and the ease of memorizing using the flashcards. I would memorize 14 items then add new ones to what I had already gotten memorized.

Josephine: I think flashcards can work for and be beneficial for anyone for anything you need to memorize.
Tanya: I thought they [the flashcards] were a very useful, beneficial, and easy way to practice and memorize the conversions.

Students found that incremental learning reduced the pressure to memorize all new information at once, and increased the amount of information memorized. Examples of comments supporting incremental learning come from Anastacia and Tanya.

Anastacia: I liked learning 14 items in the first grouping, then the second grouping added 14 new items to the first grouping that I had already memorized.

Tanya: The second week was added to what I already learned from the first week. There were twice as many standards the second week, but I already knew half of them from the first week, which boosted my confidence.

**Practicality.** Recall that practical value or applicability is an important component of usefulness. Students indicated that any activity that is adaptable or has been designed for actual use in a variety of settings is considered practical. Practice with the flashcards was demonstrably useful given that it was effective for memorizing the conversion standards; it was also practical in that similar flashcards could be applied to memorizing other material in other settings as well. Any study method must be practical if it is to be effective; if it is not practical, students will not use it. Burton and Josephine mentioned the practicality of the flashcard technique in general, while Kiara and Anastacia spoke to the practicality of flashcards specifically for the non-traditional, older student.
Burton: I do feel like it’s such a huge value to use the flashcards, so you recognize your ability to memorize and remember things better. They [the flashcards] are versatile enough to use with other things in other classes. I’m probably going to use flashcards to get the terminology memorized in other classes since it worked so well in this class.

Josephine: Finally, I found something practical [the flashcards] that works to help make memorizing easy. The flashcards aren’t some weird thing you only use once.

Kiara: I figured it had been so long since I was in school; maybe flashcards were a good place to start. They [the flashcards] have made memorizing the measurement conversions so easy. I will use flashcards in the future, especially with the classes I’ve got to take. I’ve actually made some to use with my Intro to Health Class.

Anastacia: Since I’m an older student, I will use whatever tools I can to help me be successful, and the flashcards did that for me. They are easy to use, something practical, and I can use them with other things I need to memorize.

Reducing Learning Load. A successful study method must be more than just useful and practical, however: for memorization to take place, the study method must require an appropriate learning load. Learning load is the term that students use for cognitive load. Cognitive load, as described above in greater detail, is related to the amount of information that the working memory can hold and process at one time.
(Mergel, 1998). When the working memory is overloaded with information, cognitive overload prevents the transference of concepts to the long-term memory, which prevents learning and memorization (de Araujo Guerra Grangeia et al., 2016). Reduction and management of the cognitive load leads to more efficient use of the working memory (Sweller, 2016). Reducing the learning or cognitive load through incremental introduction of content and continual repetition for review prevented the students from feeling overwhelmed by the amount of content. This approach prevented cognitive overload and thus effectively increased the return on investment for the time spent studying with flashcards. For example, Anastacia, Kiara, and Tanya indicated no feeling of being overwhelmed and praised the repetitiveness as an effective component of the method.

Anastacia: I really want to do well since I’m an older student, and the flashcards helped me quickly memorize the standards. I really feel like using the flashcards was essential to memorizing the conversion standards. I was able to keep going over the stuff I had already learned, which made it easier to remember, and that was very encouraging. Each week I did better and better. I was surprised and excited at how much I remembered each time I went through the flashcards. I never felt overwhelmed by the amount of information I was trying to memorize. I was very excited when I was able to go through all 56 several times without missing any!

Kiara: I want to do well, and I am, thanks to using the flashcards to help with my memorization of the material. I’m very happy with my
success using the flashcards so much, so I kept coming back to them. I never felt like there were too many conversions to memorize at one time.

Tanya: I liked the repetitiveness of the flashcards because I felt more and more success each time which encouraged me to continue using them [the flashcards]. I never realized how much more I could get memorized doing a little at a time versus trying to memorize all the information all at once.

**Theme 3: Factors Impacting Development of Positive Attitudes Towards Using Flashcards**

The first two themes, Factors impacting the efficiency of studying with flashcards and Factors impacting the effectiveness of studying with flashcards, addressed the second research question regarding student perceptions of the incremental, spaced repetition of StudyMate flashcard use in memorizing the measurement conversion standards. The third theme centers around the development of positive attitudes towards using the flashcards to memorize the measurement conversion values. Positive attitudes towards using the flashcards stemmed from (a) recommendations for learning tool use and (b) an emotional connection. These two categories touched students on an emotional level, which had an impact on their attitudes, encouraging the development of positive attitudes towards using flashcards. Figure 4.7 shows a flow chart illustrating the flow from code to category to theme for Theme 3.
Figure 4.7
Code to Category to Theme Flow Chart for Theme 3

**Recommendations for Learning Tool Use.** College students struggle with memorization for many reasons, including the use of less productive learning strategies or the failure to embrace any learning strategy at all. Struggles with memorization can result when a student selects a preferred strategy that does not support long-term retention (Lyle et al., 2020), when a student overestimates his or her own knowledge level and thus underestimates the need for further studying, or when a student does not choose or use any study strategy at all (Hoque, 2018). Thus telling students how helpful flashcards can be for memorization provides them with an effective learning tool. Burton, Kiara, and Tanya all expressed appreciation for the suggestion that they use flashcards.

**Burton:** This is my first class back in 25 years. I’m only taking one class at a time since I’ve forgotten how to study. I appreciated the flashcard suggestion to memorize the measurement conversion standards. Flashcards never entered my mind as a way to study.
Kiara: I had not thought about using flashcards to get the measurement conversion standards memorized until I read your letter about your research study.

Tanya: I don’t know if I would have thought to use flashcards if it weren’t for your letter about the study. I would definitely recommend using them [the flashcards].

One student, Josephine, had previous experience using flashcards in other settings and had seen positive results. Thus this student reported feeling grateful that flashcards were available as a study tool for this class.

Josephine: I have used flashcards in the past and I was glad that was an option for this class. I would have used flashcards anyway. The study interested me and since the flashcards were already there, I figured I would use them.

**Emotional Connection.** When students have a positive emotional connection to what they are doing, such as a feeling of excitement linked with the experience of learning new material, it makes a difference in the amount of effort they will put forth in the future. Students indicated that they felt an emotional connection between their positive experience and a feeling of accomplishment. Many participants developed an emotional connection with using the flashcards to memorize the measurement conversion standards. Comments from Josephine, Kiara, and Tanya pointed to a positive emotional connection with flashcard use.

Josephine: I was glad that using flashcards was an option for this class. The flashcards were definitely useful in helping me memorize the
measurement conversion standards. I found that I wanted to study them [the flashcards] more often than three times a week because of how much I was able to remember each time.

Kiara: The flashcards are awesome! I’m glad I used the flashcards to get the standards memorized. I really enjoyed using the flashcards and found that I wanted to study them more often than three times a week. I looked forward to seeing how many I could remember from practice to practice. It was almost as if I was competing with myself to see how many I could remember from practice to practice.

Tanya: It became a game to see how fast I could memorize the new ones [the measurement conversion standards]. I kept getting faster and faster and doing better each time I practiced.

The participants also demonstrated an emotional connection with the experience of being asked their opinion about using the flashcards. They realized that their opinion mattered, and that someone was listening to them. This emotional connection can be seen in Josephine and Tanya’s comments.

Josephine: I think it is great that you want to hear what I have to say since being asked my opinion doesn’t happen much.

Tanya: I will say I appreciate you wanting to hear from us students.

**Chapter Summary**

Quantitative and qualitative data were collected and analyzed to answer this study’s research questions. The quantitative data included the MCSA Pre-test scores,
the MCSA Post-test scores, and the Student Perception Survey responses. Descriptive statistical analysis of the MCSA Pre-test and Post-test results indicated a higher mean score and lower standard deviation on the MCSA Post-test than on the Pre-test. The Shapiro-Wilk test indicated deviation from a normal distribution \( p < .05 \) for the MCSA overall. The Wilcoxon signed-rank test indicated a significant statistical difference in the medians between the MCSA Pre-test and MCSA Post-test. Cronbach’s alpha showed reliable internal consistency for the Student Perception Survey overall and for each of its subscales. Descriptive statistical analysis of the Student Perception Survey results indicated that students found the flashcards useful and easy to use, and that they were likely to use flashcards in the future.

Qualitative data was gathered through five semi-structured student interviews. Inductive analysis of this data led to the assertions that (a) students indicated that efficient use of their time was a high priority when studying and memorizing material, (b) students indicated that a study tool that effectively helped them memorize the measurement conversion standards was a high priority when studying and memorizing material, and (c) students indicated that using the flashcards had led them to develop a positive attitude towards studying and memorizing the content. The three themes supporting these assertions include (a) some factors impacted the efficiency of studying with flashcards, (b) some factors impacted the effectiveness of studying with flashcards, and (c) some factors led students to develop positive attitudes towards using flashcards. Direct quotes from participants support these assertions and themes.
CHAPTER 5
DISCUSSION, IMPLICATIONS, AND LIMITATIONS

This chapter positions the findings of the present study in relation to the existing literature on memorization of measurement conversion standards. The purpose of this study was to evaluate incremental, spaced repetition of flashcard use for the memorization of measurement conversion standards in an online Mathematics in Health Sciences course at a midwestern community college. Data from both quantitative (i.e., pre-test and post-test scores and student perception surveys) and qualitative (i.e., student interviews) were collected and analyzed. Quantitative findings indicated a higher mean score and lower standard deviation on the MCSA post-test as compared to the pre-test, as well as a statistically significant difference between the median pre-test and post-test scores. Qualitative data revealed three themes: (1) certain characteristics of the flashcards impacted the efficiency of studying with flashcards, (2) certain characteristics of the flashcards impacted the effectiveness of studying with flashcards, and (3) certain characteristics of the flashcards led participants to develop positive attitudes towards using flashcards. Integration of the findings of this study points to the conclusion that incremental, spaced repetition of flashcard use can have a beneficial impact on memorization. This chapter presents the (a) discussion, (b) implications, and (c) limitations of this action research.
Discussion

It is important to situate this study’s findings within the larger body of literature, particularly the literature associated with memorization. The quantitative and qualitative research findings were integrated to directly address this study’s research questions: (1) How and to what extent does incremental, spaced repetition of StudyMate flashcard use impact MAT 1130 online students’ memorization of the measurement conversion standards? And (2) What are the perceptions of MAT 1130 online students regarding the incremental, spaced repetition of StudyMate flashcard use as a means of memorizing the measurement conversion standards? The discussion of findings is organized according to these two research questions.

Research Question 1: How and to what extent does incremental, spaced repetition of StudyMate flashcard use impact MAT 1130 online students’ memorization of the measurement conversion standards?

Proficiency is achieved when students progress from the acquisition level (i.e., perfecting a skill with exactness) to the mastery level (i.e., performing a skill with accuracy and fluency) (Hasselbring et al., 1988). Memorization of content leads to proficiency. The purpose of this research question was to determine the impact of the incremental, spaced repetition of flashcard use as a means of memorizing the measurement conversion standards. This intervention represents a combination of two memorization strategies: the incremental addition of new content was coupled with spaced repetition of practice. This section will focus on the impact of incremental, spaced repetition of flashcard use on improving memorization of the measurement conversion standards.
**Incremental, Spaced Repetition**

The findings from this study indicate that incremental, spaced repetition for the purpose of memorizing measurement conversion standards had a positive impact on the memorization of the measurement conversion standards. Because college students are constantly learning new material, memorization plays a significant role in college success because it reduces cognitive load, thus freeing brain energy for more complex tasks (Hoque, 2018). The repetitive nature of using flashcards provides opportunities for engagement with the content, which improves information retrieval and strengthens memory (Murray et al., 2018; Schmidmaier et al., 2011). By using the flashcards three times a week for ten minutes each time, students engaged with the measurement conversion standards through repetition. The incremental addition of 14 new standards to the previously memorized standards each week reduced the cognitive load associated with learning the new standards, which helped prevent working memory overload. Memorization and repeated retrieval of information reduces the amount of brainpower that is needed to recall the information subsequently, thereby reducing cognitive load (Allen-Lyall, 2018). Reduction of cognitive load in turn alleviates student feelings of disappointment and frustration and increases persistence and success (Hopkins et al., 2016; Terenyi et al., 2019).

In this study, the end goal for students was to memorize 56 measurement conversion standards within five weeks. The 56 standards were presented in four groups of 14, with one new group presented at the beginning of each of the first four weeks. There were no new standards introduced during the fifth week as the fifth week was set aside for a review of all 56 standards. Thus the number of items to be recalled each week
was increased incrementally, as opposed to delivering all 56 standards during the first week. Students were directed to practice three times a week for ten minutes each time, but were free to choose their own practice days and times during each week. All students chose an every-other-day study schedule, meaning that they opted for one day of non-practice between every two days of practice. The impact of this incremental, spaced repetition of flashcard use is evident in the higher mean score on the MCSA post-test ($M = 52.28, \text{SD} = 4.13$) as compared to the MCSA pre-test ($M = 31.22, \text{SD} = 8.21$). The lower standard deviation for the MCSA post-test scores indicates a lower variance among the MCSA post-test scores. The positive impact of the incremental, spaced repetition of flashcard use is also supported by the significantly higher median score on the MCSA post-test ($Mdn = 54.5$) as compared to the MCSA pre-test ($Mdn = 32.00$). An increase in the median score on the post-test indicates a greater midpoint around which the data is distributed, indicating an improvement in student knowledge. The increased mean and median scores coupled with the decreased standard deviation indicate that incremental, spaced repetition of flashcard use was effective for memorizing the measurement conversion standards.

This finding is consistent with the results of previous research on incremental, spaced repetition. Other studies have shown that incremental practice, an evidence-based practice strategy, increases fact fluency (Burns et al., 2019). The practice of interspersing known items with unknown items, where there is a high ratio of known to unknown items, enhances the acquisition and retention of the new items (Swehla et al., 2016). Previous studies have also shown that repeated practice may facilitate recall of facts with accuracy and speed while increasing long-term retention (Fuchs et al., 2008; Mulligan &
Spacing of the practice sessions has likewise been shown to have a powerful impact on long-term retention (Mulligan & Peterson, 2014). The insertion of intervals of time between practice sessions enhances transference from short-term to long-term memory, thus promoting better retention of items (Lyle et al., 2020; Nist & Joseph, 2008). I feel that the incremental increase in the number of standards students were given to memorize was sufficient to prevent a feeling of being overwhelmed by the total number of standards to be memorized. I speculate that the incremental increase in the number of new standards each week ensured that students had a manageable quantity of new information to process in the working memory and move to the long-term memory, thus preventing cognitive overload.

Research Question 2: What are the perceptions of MAT 1130 online students regarding the incremental, spaced repetition of StudyMate flashcard use in memorizing the measurement conversion standards?

To gain insight on student experiences, I created and administered the Student Perception Survey. The Student Perception Survey gathered information on participants’ perceptions regarding the perceived usefulness and perceived ease of use of the flashcards, and participants’ overall attitudes towards using flashcards for memorization of the measurement conversion standards. All responses were based on a 5-point Likert scale. The student responses in all categories ranged between the answer choices of (4) agree and (5) strongly agree. Student interviews were also conducted to dig deeper into student perceptions. Qualitative data from five semi-structured interviews and inductive analysis were used to develop themes. Analysis of the quantitative data from the Student Perception Survey and the qualitative data from the student interviews revealed three
major findings, or themes, regarding student perceptions: (a) certain characteristics of this study method made flashcard use efficient, (b) certain characteristics of this study method made flashcard use effective, and (c) participants developed positive attitudes towards using flashcards.

**Efficiency of Studying with Flashcards**

Actively engaging in this incremental, spaced repetition method of studying enhanced the students’ control over their learning and enabled them to optimize their use of their time. Self-direction and control over how study time is used engages students in more meaningful learning (Senzaki et al., 2017). The perceived usefulness subscale score on the Student Perception Survey ($M = 4.63$, where a score of 4 indicates satisfaction with the method and 5 indicates strong satisfaction) shows that students found the flashcards useful. Interview data collected in the present study also shows that students value an approach to studying that makes efficient use of their time: students expressed in the interviews that they were willing to invest time in the incremental, spaced repetition method as they indicated that they found this method to be useful. Students used words like “convenience”, “flexibility” and “ability to study efficiently” to describe characteristics of the flashcards that impacted the efficiency of studying with the flashcards. My interpretation is that, when students have control over the use of their limited study time, they prefer to make choices for studying that they perceive are more efficient, so they are managing their studying in the most timesaving and beneficial manner.
Effectiveness of Studying with Flashcards

The ease of actively engaging in the incremental, spaced repetition method of studying is linked not only to maximizing the return on time investment but also to maximizing the return on energy investment, that is, to getting as much benefit as possible in exchange for as little effort as possible. When students actively retrieve information that has been memorized, they are not engaging in rote memorization that will preserve the information in the memory only transiently; rather, they are engaging in meaningful learning that will preserve the information in the memory for the long term (Karpicke, 2012). The perceived ease of use subscale score on the Student Perception Survey ($M = 4.83$, where a score of 4 indicates satisfaction with the method and 5 indicates strong satisfaction) indicates that students found the flashcards easy to use and effective for memorization. Interview data collected in the present study likewise shows that students value approaches to studying that require minimal effort while yielding maximal results. Students were willing to devote time to the incremental, spaced repetition of flashcard use as they indicated that they found them to be easy to use. They used words like “usefulness” and “practicality” to describe characteristics of the flashcards that impacted the effectiveness of studying with the flashcards. My conclusion from these findings is that students felt that the incremental, spaced repetition of flashcard use for memorizing the measurement conversion standards required minimal effort while yielding maximal results, and therefore was optimally effective.

Development of Positive Attitudes Towards Using Flashcards

The participants’ successful experience with and positive outcomes from the incremental, spaced repetition of flashcard use for memorizing the measurement
conversion standards led them to develop positive attitudes towards using flashcards. Student engagement is necessary as it connects students to the material, enabling cognitive learning and motivating students to persist (Schroeder-Moreno, 2010; Zientek et al., 2017). The attitude toward using flashcards subscale score on the Student Perception Survey ($M = 4.51$, where a score of 4 indicates a positive attitude and 5 indicates a strongly positive attitude) indicates that the present participants are likely to use flashcards in the future. Students were willing to expend the effort required to implement the incremental, spaced repetition of flashcard use because the number of new items to memorize was limited to 14 each week, preventing the method from feeling overwhelming, and also because the method worked, enabling them to memorize the content successfully. In the interviews, students used phrases like “successful use of the flashcards was exciting” and “such a positive experience using the flashcards” to describe their development of positive attitudes towards using flashcards. I speculate that these students will consider an incremental, spaced repetition approach to using flashcards to learn other content in the future.

**Implications**

As the goal of action research is continuous improvement, the findings from this research naturally have practical implications for the author, for other instructors, and for learning and memory researchers. This discussion of implications is divided into the following sections: (a) personal implications, (b) implications for instructors integrating incremental, spaced repetition for memorization into their curricula, and (c) implications for future research.
Personal Implications

As a result of this study, I have learned several personal lessons that will enable my continued growth and effectiveness as an educator, coordinator, and mentor. These lessons will help me make better informed decisions regarding curriculum design, instructional approaches, and the use of educational technology. These include (a) changed perceptions of teaching and learning, (b) insights into being a scholarly practitioner, and (c) reflections on implementing an incremental, spaced repetitive learning strategy.

Changed Perceptions of Teaching and Learning

Sweller (2019) explains how the amount of information to be processed, otherwise known as the information processing load, can impact a student’s ability to process new information in a way that cements the information as new knowledge in the long-term memory. Through conducting this study, I have learned that maintaining a manageable cognitive load is a very important consideration for any teacher designing a curriculum and selecting instructional approaches. As an instructor, I previously tended to base the pace of my courses exclusively on what I needed to present within the given timeframe. After completing this study, I now understand that, while getting through the required content is important, it is actually more important to do so in a way that does not overwhelm the students. There is, in fact, little point in racing through the course content if the students are so cognitively overburdened that they will not retain the content in the long-term memory.
Insights Into Being a Scholarly Practitioner

Conducting a review of literature related to cognitive load, memorization, and technology integration helped me to understand how students organize information in the working memory and then move it to the long-term memory and how that process directly impacts learning and memorization. Prior to this study, I had some knowledge about how learning occurred, but reviewing the literature was eye-opening for me. I now have a deeper understanding of how important it is for instructors and students alike to monitor students’ cognitive load. If the quantity of new content overloads the working memory, learning does not occur. This knowledge has helped me step back and reevaluate the way I present content in class. My future decisions about curriculum and instructional design will be based not solely on getting through the content but rather on getting through the content in a way that is conducive to student learning. Being knowledgeable about curriculum and instructional design includes understanding what the research shows about the learning process. Through this research, I learned that, while it is important to collect and analyze data, there is so much more to be learned when you look beyond pre-test and post-test scores. To date, I have relied on numbers to tell me how my students were doing, but in this study, I found value in talking with my students and hearing what they had to say.

Reflections on Implementing a Meaningful Study Strategy

One insight I gained from this study is the importance of teaching students about meaningful and purposeful study strategies, and even assigning proven strategies as coursework, to help students memorize the measurement conversion standards. The feedback I received from my students revealed that many students are not aware of which
study strategies work well, and it is partly my responsibility to provide that information. Prior to this study, I presumed that my students had learned about effective study strategies in their “Introduction to College” class; that presumption was incorrect. As I built my intervention consisting of incremental, spaced repetition with flashcards, I needed to be sure that the content presented each week and the weekly increases in content were manageable with respect to cognitive load, time, and student commitment. In practice, once the students had learned the first week’s 14 standards successfully, they were excited about and committed to the flashcard method as each of the subsequent weeks began. Experiencing successful memorization through their effort became its own reward and inspiration to continue studying with that strategy. The success that the students experienced in the present study has encouraged me to propose permanently incorporating this study strategy into the Mathematics in the Health Sciences curriculum.

Implications for Instructors Integrating Incremental, Spaced Repetition for Memorization

An incremental, spaced repetition study method for memorization of the measurement conversion standards should be integrated into the MAT 1130 course and used by all of this course’s instructors. Student engagement with new content is necessary for persistence, which in turn is required for students to maximize their learning experiences and to become economically and professionally self-sufficient (Kuh, 2016). Students often skip learning activities that are presented as optional, but they are more likely to try learning activities that do not require a large commit of time or energy. The student interviews provided evidence that busy college students want tools that are both useful and easy to use. The present flashcard method offers the additional bonus of
incremental, spaced repetition, which requires short periods of time each day and minimal student effort besides being enjoyable and fostering a positive attitude towards studying.

Incremental, spaced repetition with flashcards can be used for memorization of other content in other courses. It needs to be noted that the incremental, spaced repetition approach using flashcards in other domains have a boundary in that it would be appropriate for memorization of terminology and formulas but would not be appropriate for problem-solving applications. An example of appropriate usage of incremental, spaced repetition in a Chemistry class would be for memorizing the elements and their symbols. Inappropriate use of incremental, spaced repetition in that same Chemistry class would be conducting an experiment using the scientific process. Yet when an instructor assigns incremental, spaced repetition with flashcards, it is essential that the content presented within each designated timeframe (i.e., week, month, or unit), is of a manageable quantity with respect to cognitive load, time required to learn the material, and student commitment to studying. This is true whether it is the instructor assigning the quantity of content each week or the student making his or her own flashcard schedule. Students value efficiency, when maximal results are achieved through minimal expenditure of effort, and effectiveness, when the study method leads to the desired outcome. A successful experience with incremental, spaced repetition using flashcards leads to a positive attitude toward flashcards, which provides students with a study strategy tool that they can take with them on their academic and professional journey to successfully memorize other information.

Implications for Future Research
This was my first action research study; as such, it taught me the action research technique and helped me to understand the potential impact of such research. I now have a more comprehensive understanding of research design, design implementation, data collection, data analysis and interpretation, and thinking about where research can lead. This study was conducted among online students taking a Mathematics in the Health Sciences course at the collegiate level. Administrators and instructors who are considering the implementation of incremental, spaced repetition as a study strategy may be interested in future research related to these topics.

If I were to replicate this study, I would make several changes and adjustments. I would increase the sample size to include online sections of the Mathematics in the Health Sciences course that are taught by other instructors. Increasing the number of participants would increase the validity and reliability of the results in the study. Increasing the sample size and including students in sections not taught by me would allow for generalization of the findings to all online Mathematics in the Health Sciences students. I would also extend this study over multiple years to compare data across multiple fall semesters, spring semesters, and summer semesters to search for correlations between time of year and success rates. For those who are considering implementing incremental, spaced repetition as part of a research study, I suggest incorporating a component that includes investigating the impact of incremental, spaced repetition on cognitive load and persistence.

**Limitations**

As with any research study, this study is not without limitations. The action research study approach is one limitation: action research is centered around one’s own
teaching practices; it is done by teachers for themselves within their own specific context (Mertler, 2017). Since action research is centered around one’s own unique situation and setting, the findings are not always generalizable to other contexts.

A second limitation concerns the possibility of bias. My multiple roles in this study as the researcher, the instructor, and the interviewer may have introduced subjectivity and potential bias which could shape the interpretation of my findings based on my background and experience (Creswell & Creswell, 2018). Specifically, students may have had difficulty separating my role as the interviewer from my role as the instructor. The fact I was both the instructor and the interviewer may have influenced the students’ responses: participants may have given answers that they perceived as helpful but that were not necessarily their true thoughts (Creswell & Creswell, 2018).

A third limitation of this study is the relatively small sample size and the participant selection method. The study included 18 participants who were purposefully selected from four online sections of the course taught by the researcher. This study was conducted during the COVID-19 pandemic and, as a result of adherence to social distancing safety measures, many students were juggling their own online schooling while also assisting their children with online schooling. The resulting additional demands on many students’ time may have been a factor in the low proportion of students participating in the study, contributing to the small sample size. The small sample may not be representative of all students in the online Mathematics in the Health Sciences course. In action research, a small and purposefully selected sample does not allow for generalization of the findings beyond the study (Creswell & Creswell, 2018).
larger sample size that included students in online sections taught by other instructors would provide additional data that might yield further insight.

A fourth limitation of this study is the calculation of the Cronbach’s Alpha for the time subscale. The Cronbach’s Alpha cannot be calculated for the time subscale due to high correct response rates to the test items.

A fifth limitation of this study is technical frustrations for students. The technology issue was not with the flashcards themselves; it was with internet access. With the Covid pandemic forcing schools to close, parents became their children’s teacher at home through virtual classrooms and online work, many students struggled with inadequate bandwidth at home to handle the internet needs of all household members at the same time. Many students indicated they resorted to getting in the car and parking in the parking lot of any establishment that had free Wi-Fi so they had internet access.

Recognizing the limitations of this study, I took the following measures to increase the study’s validity. I acknowledged my potential biases and subjectivities at the beginning of the study. I reduced the potential for bias in the data analysis phase by removing participant names and identifying information before assigning pseudonyms so as not to associate data with any specific individual. For the student interviews, I intentionally created an environment that fostered open and honest sharing of thoughts and feelings.

**Conclusion**

Memorization of measurement conversion standards is a task well suited to incremental, spaced repetition with flashcards. In order for memorization to occur, new
information must be sufficiently processed in the working memory before being moved to the long-term memory (Chen et al., 2018). Incremental, spaced repetition using flashcards is one way to achieve sufficient processing in the working memory, which enables successful transference and memorization of information. Quantitative pre- and post-test data showing an increase in memorization of the measurement conversion standards support the conclusion that memorization was positively impacted by incremental, spaced repetition with flashcards. The Student Perception Survey and student interviews support the conclusion that incremental introduction of information over time had a positive impact on memorization of the measurement conversion standards. Student responses also support the conclusion that incremental, spaced repetition with flashcards was an efficient and effective study method and that it encouraged a positive attitude towards using flashcards.

This study began with my own questions about the value of progressively adding content over time to see if that approach was more beneficial for memorization than simply giving the students a list and a deadline by which to have the content memorized. With all the upheaval that the past two years have brought to education – a global pandemic, widespread school closings, role changes as college students became their children’s teachers at home, and other shifts in responsibilities – my hope was that providing my students with a new study strategy would calm some of the chaos and anxiety now associated with being in college. My questions centered around determining an appropriate quantity of content to add each week and spacing out the practice sessions as an approach to help students use their study time as effectively and efficiently as possible. This study has expanded my perspective beyond that of a teacher and given me
more empathy for the perspective of the learner. I am struck by the anonymous quote, “Learning is like building a sandcastle. Once you have the right tools, you can build anything. You can be anything you want to be.” The incremental, spaced repetition study strategy is a tool that we teachers can give to every student and that every student can use to carve their own path to success.
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APPENDIX A:
IRB Approval from University of South Carolina

INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH
APPROVAL LETTER for EXEMPT REVIEW

Patricia Bromer
957 Lawnwood Ave
Kettering, OH 45429

Re: Pro00109243

Dear Patricia Bromer:

This is to certify that the research study Incremental, Spaced Repetition and StudyMate Flashcards: The Impact on College Student Memorization of Measurement Conversion Standards was reviewed in accordance with 45 CFR 46.104(d)(1), the study received an exemption from Human Research Subject Regulations on 3/31/2021. No further action or Institutional Review Board (IRB) oversight is required, as long as the study remains the same. However, the Principal Investigator must inform the Office of Research Compliance of any changes in procedures involving human subjects. Changes to the current research study could result in a reclassification of the study and further review by the IRB.

Because this study was determined to be exempt from further IRB oversight, consent document(s), if applicable, are not stamped with an expiration date.

All research related records are to be retained for at least three (3) years after termination of the study.

The Office of Research Compliance is an administrative office that supports the University of South Carolina Institutional Review Board (USC IRB). If you have questions, contact Lisa Johnson at lisaj@mailbox.sc.edu or (803) 777-6670.

Sincerely,

Lisa M. Johnson
ORC Assistant Director and IRB Manager
APPENDIX B:

IRB Approval from Sinclair Community College

April 22, 2021

Patricia A. Bromer
Professor, Department of Mathematics
Sinclair Community College

RE: Spaced Repetition and Conversion Standards

Dear Patti:

As chair of the Sinclair Institutional Review Board for the Protection of Human Subjects (IRBOOO05624), I am writing to inform you that I have reviewed your proposal and approved the protocol as it meets the criteria for exempt status as established by the U.S. Department of Health and Human Services under category three. Please note that exempt proposals need not be reviewed by the full IRB (see Section 101, subsection b.1). Your planned research is fully compliant with Sinclair protocols. Please note, that to preserve anonymity, any grouping of respondents that numbers less than ten should not be reported (e.g. if there are only two Hispanic female subjects aged twenty-one to twenty-five at Sinclair, reporting disaggregated outcomes with so few respondents could permit their identification).

Any serious adverse events or issues relating from this study must be reported immediately to the IRB. Additionally, any changes to protocols or informed consent documents must have IRB approval before implementation.

If you have any questions or concerns, please feel free to contact me. Good luck with your research.

Sincerely,

Chad Atkinson, Ph.D.
Manager of Research
Sinclair Community College, Research, Analytics, and Reporting
Chair, Sinclair Institutional Review Board
Phone: 937-512-4118
chad.atkinson4026@sinclair.edu
## APPENDIX C:

Table C.1

*Comparison of Face-to-Face and Online Test Scores and Overall Passage Percentages*

<table>
<thead>
<tr>
<th>Term</th>
<th>Fall 2018</th>
<th>Spring 2019</th>
<th>Summer 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modality</td>
<td>F2F</td>
<td>OL</td>
<td>F2F</td>
</tr>
<tr>
<td>Number of Sections Taught</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total Number of Students</td>
<td>113</td>
<td>33</td>
<td>15</td>
</tr>
<tr>
<td>Number of Students Passing Test 1</td>
<td>92</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td>(70% or higher)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 1 Passage Percentage</td>
<td>81</td>
<td>64</td>
<td>73</td>
</tr>
<tr>
<td>Number of Students Passing Test 2</td>
<td>83</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>(70% or higher)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 2 Passage Percentage</td>
<td>74</td>
<td>58</td>
<td>73</td>
</tr>
<tr>
<td>Number of Students Passing Final Exam (70% or higher)</td>
<td>89</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>Final Exam Passage Percentage</td>
<td>79</td>
<td>58</td>
<td>80</td>
</tr>
<tr>
<td>Number of Students Passing with a C or better (70% or higher)</td>
<td>88</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>C or better Passage Percentage</td>
<td>78</td>
<td>61</td>
<td>73</td>
</tr>
</tbody>
</table>
APPENDIX D:

Table D.1
*Measurement Conversion Activity Scores and Percentages*

<table>
<thead>
<tr>
<th></th>
<th>Fall 2018</th>
<th>Spring 2019</th>
<th>Summer 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measurement Activity 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of Activity Participants</td>
<td>100</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td># Students Scoring Below 70%</td>
<td>17</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Failing Percentage (Below 70%)</td>
<td>17</td>
<td>27</td>
<td>44</td>
</tr>
<tr>
<td># Students Scoring 70% or better</td>
<td>83</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Passage Percentage (Above 70%)</td>
<td>83</td>
<td>73</td>
<td>56</td>
</tr>
<tr>
<td><strong>Measurement Activity 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of Activity Participants</td>
<td>105</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td># Students Scoring Below 70%</td>
<td>14</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Failing Percentage (Below 70%)</td>
<td>13</td>
<td>15</td>
<td>33</td>
</tr>
<tr>
<td># Students Scoring 70% or better</td>
<td>91</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Passage Percentage (Above 70%)</td>
<td>87</td>
<td>85</td>
<td>67</td>
</tr>
<tr>
<td><strong>Measurement Activity 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of Activity Participants</td>
<td>99</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td># Students Scoring Below 70%</td>
<td>10</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Failing Percentage (Below 70%)</td>
<td>10</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td># Students Scoring 70% or better</td>
<td>89</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Passage Percentage (Above 70%)</td>
<td>90</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td><strong>Overall Measurement Activity Averages</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of Activity Participants</td>
<td>101</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td># Students Scoring Below 70%</td>
<td>14</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Failing Percentage (Below 70%)</td>
<td>14</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td># Students Scoring 70% or better</td>
<td>87</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Passage Percentage (Above 70%)</td>
<td>86</td>
<td>79</td>
<td>78</td>
</tr>
<tr>
<td><strong>Overall Course Grade</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of Activity Participants</td>
<td>113</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td># Students Scoring Below 70%</td>
<td>21</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Failing Percentage (Below 70%)</td>
<td>19</td>
<td>27</td>
<td>11</td>
</tr>
<tr>
<td># Students Scoring 70% or better</td>
<td>88</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Passage Percentage (Above 70%)</td>
<td>81</td>
<td>73</td>
<td>89</td>
</tr>
</tbody>
</table>
APPENDIX E:

Table E.1
MAT 1130 Measurement Conversion Standards

<table>
<thead>
<tr>
<th>Time</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 minute (min)</td>
<td>= 60 seconds (sec.)</td>
</tr>
<tr>
<td>1 hour (hr.)</td>
<td>= 60 minutes (min.)</td>
</tr>
<tr>
<td>1 day (d)</td>
<td>= 24 hours (hr.)</td>
</tr>
<tr>
<td>1 week (wk.)</td>
<td>= 7 days (d)</td>
</tr>
<tr>
<td>1 year (yr.)</td>
<td>= 52 weeks (wk.)</td>
</tr>
<tr>
<td>1 year (yr.)</td>
<td>= 12 months (mo.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weight</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ounce (oz.)</td>
<td>= 28.35 grams (g)</td>
</tr>
<tr>
<td>1 pound (lb.)</td>
<td>= 16 ounces (oz.)</td>
</tr>
<tr>
<td>1 kilogram (kg)</td>
<td>= 2.2 pounds (lbs.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Linear Measure</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch (in.)</td>
<td>= 2.54 centimeters (cm)</td>
</tr>
<tr>
<td>1 foot (ft.)</td>
<td>= 12 inches (in.)</td>
</tr>
<tr>
<td>1 yard (yd.)</td>
<td>= 3 feet (ft.)</td>
</tr>
<tr>
<td>1 yard (yd.)</td>
<td>= 36 inches (in.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Liquid Measure</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 teaspoon (tsp)</td>
<td>= 5 milliliters (mL)</td>
</tr>
<tr>
<td>1 tablespoon (TBSP)</td>
<td>= 15 milliliters (mL)</td>
</tr>
<tr>
<td>1 tablespoon (TBSP)</td>
<td>= 3 teaspoons (tsp)</td>
</tr>
<tr>
<td>1 fluid ounce (fl. oz.)</td>
<td>= 2 tablespoons (TBSP)</td>
</tr>
<tr>
<td>1 fluid ounce (fl. oz.)</td>
<td>= 30 milliliters (mL)</td>
</tr>
<tr>
<td>1 cup (c)</td>
<td>= 8 ounces (oz.)</td>
</tr>
<tr>
<td>1 cup (c)</td>
<td>= 16 tablespoons (TBSP)</td>
</tr>
<tr>
<td>1 cup (c)</td>
<td>= 240 milliliters (mL)</td>
</tr>
<tr>
<td>1 pint (pt.)</td>
<td>= 2 cups (c)</td>
</tr>
<tr>
<td>1 pint (pt.)</td>
<td>= 480 milliliters (mL)</td>
</tr>
<tr>
<td>1 pint (pt.)</td>
<td>= 16 fluid ounces (fl. oz.)</td>
</tr>
<tr>
<td>1 quart (qt.)</td>
<td>= 2 pints (pt.)</td>
</tr>
<tr>
<td>1 quart (qt.)</td>
<td>= 32 fluid ounces (fl. oz.)</td>
</tr>
<tr>
<td>1 quart (qt.)</td>
<td>= 960 milliliters (mL)</td>
</tr>
<tr>
<td>1 gallon (gal)</td>
<td>= 4 quarts (qt.)</td>
</tr>
</tbody>
</table>
APPENDIX F:

MAT 1130 Measurement Conversion Standards Assessment

Directions: You have 25 minutes to complete each conversion. Type your answer into the space provided. Use the **appropriate abbreviated label** in your answer. You will not have the ability to go back to skipped questions. Good luck!

1) 1 minute = ___ second(s)
2) 1 hour = ___ minute(s)
3) 1 day = ___ hour(s)
4) 1 week = ___ day(s)
5) 1 year = ___ week(s)
6) 1 year = ___ month(s)
7) 60 seconds = ___ minute(s)
8) 60 minutes = ___ hour(s)
9) 24 hours = ___ day(s)
10) 7 days = ___ week(s)
11) 52 weeks = ___ year(s)
12) 12 months = ___ year(s)
13) 1 ounce = ___ gram(s)
14) 1 pound = ___ ounce(s)
15) 1 kilogram = ___ pound(s)
16) 28.35 grams = ___ ounce(s)
17) 16 ounces = ___ pound(s)
18) 2.2 pounds = ___ kilogram(s)
19) 1 inch = ___ centimeter(s)
20) 1 foot = ___ inch(es)
21) 1 yard = ___ foot/feet
22) 1 yard = ___ inch(es)
23) 2.54 centimeters = ___ inch(es)
24) 12 inches = ___ feet/foot
25) 3 feet = ___ yard(s)
26) 36 inches = ___ yard(s)
27) 1 teaspoon = ___ milliliter(s)
28) 1 tablespoon = ___ milliliter(s)
29) 1 tablespoon = ___ teaspoon(s)
30) 1 fluid ounce = ___ tablespoon(s)
31) 1 fluid ounce = ___ milliliter(s)
32) 1 cup = ___ ounce(s)
33) 1 cup = ___ tablespoon(s)
34) 1 cup = ___ milliliter(s)
35) 1 pint = ___ cup(s)
36) 1 pint = ___ milliliter(s)
37) 1 pint = ___ fluid ounce(s)
38) 1 quart = ___ pint(s)
39) 1 quart = ___ fluid ounce(s)
40) 1 quart = ___ milliliter(s)
41) 1 gallon = ___ quart(s)
42) 5 milliliters = ___ teaspoon(s)
43) 15 milliliters = ___ tablespoon(s)
44) 3 teaspoons = ___ tablespoon(s)
45) 2 tablespoons = ___ fluid ounce(s)
46) 30 milliliters = ___ fluid ounce(s)
47) 8 ounces = ___ cup(s)
48) 16 tablespoons = ___ cup(s)
49) 240 milliliters = ___ cup(s)
50) 2 cups = ___ pint(s)
51) 480 milliliters = ___ pint(s)
52) 16 fluid ounces = ___ pint(s)
53) 2 pints = ___ quart(s)
54) 32 fluid ounces = ___ quart(s)
55) 960 milliliters = ___ quart(s)
56) 4 quarts = ___ gallon(s)

* This assessment will be given on the computer using a LockDown Browser and webcam for security.
MAT 1130 Measurement Conversion Standards Assessment Answer Key

Directions: You have 25 minutes to complete each conversion. Type your answer into the space provided. Use the appropriate abbreviated label in your answer. You will not have the ability to go back to skipped questions. Good luck!

1) 1 minute = 60 sec
2) 1 hour = 60 min
3) 1 day = 24 hr.
4) 1 week = 7 d
5) 1 year = 52 wk.
6) 1 year = 12 mo.
7) 60 seconds = 1 min
8) 60 minutes = 1 hr.
9) 24 hours = 1 d
10) 7 days = 1 wk.
11) 52 weeks = 1 yr.
12) 12 months = 1 yr.
13) 1 ounce = 28.35 g
14) 1 pound = 16 oz.
15) 1 kilogram = 2.2 lbs.
16) 28.35 grams = 1 oz.
17) 16 ounces = 1 lbs.
18) 2.2 pounds = 1 kg
19) 1 inch = 2.54 cm
20) 1 foot = 12 in.
21) 1 yard = 3 ft.
22) 1 yard = 36 in.
23) 2.54 centimeters = 1 in.
24) 12 inches = 1 ft
25) 3 feet = 1 yd
26) 36 inches = 1 yd
27) 1 teaspoon = 5 mL
28) 1 tablespoon = 15 mL
29) 1 tablespoon = 3 tsp
30) 1 fluid ounce = 2 tbsp
31) 1 fluid ounce = 30 mL
32) 1 cup = 8 oz.
33) 1 cup = 16 tbsp
34) 1 cup = 240 mL
35) 1 pint = 2 c
36) 1 pint = 480 mL
37) 1 pint = 16 fl. oz.
38) 1 quart = 2 pt.
39) 1 quart = 16 fl. oz.
40) 1 quart = 960 mL
41) 1 gallon = 4 qt.
42) 5 milliliters = 1 tsp.
43) 15 milliliters = 1 tbsp
44) 3 teaspoons = 1 tbsp
45) 2 tablespoons = 1 fl. oz.
46) 30 milliliters = 1 fl. oz.
47) 8 ounces = 1 c
48) 16 tablespoons = 1 c
49) 240 milliliters = 1 c
50) 2 cups = 1 pt.
51) 480 milliliters = 1 pt.
52) 16 fluid ounces = 1 pt.
53) 2 pints = 1 qt.
54) 32 fluid ounces = 1 qt.
55) 960 milliliters = 1 qt.
56) 4 quarts = 1 gal
**APPENDIX G:**

Table G.1
*Technology Acceptance Method Questions*

<table>
<thead>
<tr>
<th>Perceived Usefulness</th>
<th>Student Perception Survey Adapted Wording</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wording Recommended by Gao (2005)</strong></td>
<td><strong>Wording</strong></td>
</tr>
<tr>
<td>1) Using this site would enhance my effectiveness in learning.</td>
<td>1) Using the StudyMate flashcards enhanced my effectiveness in memorizing the measurement conversion standards.</td>
</tr>
<tr>
<td>2) Using the site would improve my course performance.</td>
<td>2) Using the StudyMate flashcards improved my course performance.</td>
</tr>
<tr>
<td>3) Using this site would increase my productivity in my coursework.</td>
<td>3) Using the StudyMate flashcards increased my productivity in my coursework.</td>
</tr>
<tr>
<td>4) I found the course website helpful.</td>
<td>4) I found the StudyMate flashcards helpful in memorizing the measurement conversion standards.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Perceived Ease of Use</th>
<th><strong>Wording</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>5) I found this site easy to use.</td>
<td>5) I found the StudyMate flashcards easy to use.</td>
</tr>
<tr>
<td>6) Learning to use this site would be easy for me.</td>
<td>6) Learning to use the StudyMate flashcards was easy for me.</td>
</tr>
<tr>
<td>7) My interaction with the site was clear and understandable.</td>
<td>7) My interaction with the StudyMate flashcards was clear and understandable.</td>
</tr>
<tr>
<td>8) It would be easy for me to find information at the site.</td>
<td>8) It was easy for me to find the answers using the StudyMate flashcards.</td>
</tr>
<tr>
<td>9) I dislike the idea of using this course website.</td>
<td>Not Using – Attitude Question</td>
</tr>
<tr>
<td>10) I have a generally favorable attitude toward using this site.</td>
<td>Not Using – Attitude Question</td>
</tr>
<tr>
<td>11) I believe it is (would be) a good idea to use this site for my coursework.</td>
<td>Not Using – Attitude Question</td>
</tr>
<tr>
<td></td>
<td>Attitude Toward Using</td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>12</td>
<td>Using this course website is a foolish idea.</td>
</tr>
<tr>
<td>13</td>
<td>I intend to use this course website during the semester (or when I take this course).</td>
</tr>
<tr>
<td>14</td>
<td>I will (would when I take this course) return to this site often.</td>
</tr>
<tr>
<td>15</td>
<td>I intend to visit this site frequently for my coursework.</td>
</tr>
</tbody>
</table>

(Gao, 2005)
APPENDIX H:

Student Perception Survey

Thank you for participating in this research study. This survey seeks information on your perceptions of the StudyMate flashcards. There are 18 questions, and it should take you less than 10 minutes to complete the survey. For questions 1-12, please read each statement, then rate your response according to the following scale: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, (5) strongly agree. For questions 13-18, please read each statement and select the most appropriate response.

<table>
<thead>
<tr>
<th>Perceived Usefulness</th>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Using the StudyMate flashcards enhanced my effectiveness in memorizing the measurement conversion standards.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>2. Using the StudyMate flashcards improved my course performance.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>3. Using the StudyMate flashcards increased my productivity in my coursework.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>4. I found the StudyMate flashcards helpful in memorizing the measurement conversion standards.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Perceived Ease of Use</th>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. I found the StudyMate flashcards easy to use.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>6. Learning to use the StudyMate flashcards was easy for me.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>7. My interaction with the StudyMate flashcards was clear and understandable.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>8. It was easy for me to find the answers using the StudyMate flashcards.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attitude Toward Using</th>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. I believe it was a good idea to use the StudyMate flashcards for memorizing the measurement conversion standards.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>
10. I intend to continue to use the StudyMate flashcards during the remainder of the course.
   1 2 3 4 5

11. I am very likely to continue to use the StudyMate flashcards for reviewing the measurement conversion standards.
   1 2 3 4 5

12. I found using the StudyMate flashcards for memorizing the measurement conversion standards to be beneficial.
   1 2 3 4 5

Questions 1–12 adapted from the Technology Acceptance Method (Gao, 2005)

Demographic Information

Please select the most appropriate response.


14. Gender: M F

15. Ethnicity:
   African American
   Asian
   Hispanic
   White
   Other

16. Number of Credit Hours Taken in the current term:
   0-5 hours 6-11 hours 12-15 hours 16+ hours

17. Total Number of College Credit Hours Taken:
   0-18 hours 19-36 hours 37-52 hours 53+ hours

18. Major/Field of Study:
   Biology
   Nursing
Pharmacology

Radiology

Therapy (Physical, Occupational, Assistant)

Veterinarian Technology

Other _________
APPENDIX I:
Interview Protocol

Date and Time of Interview:

Interviewer: Patti Bromer

Interviewee:

Thank you for agreeing to participate in this research study. The purpose of this action research will be to evaluate the impact of and student perception of the StudyMate flashcard tool on memorization of measurement conversion standards for an online Mathematics in Health Sciences course.

Thank you for agreeing to participate in this interview. This interview will last 20 to 30 minutes. I will remind you that your participation in this action research study is voluntary, and there are no risks or rewards associated with your participation. You are free to withdraw from the study or interview at any time without fear of negative repercussions.

Ethical research practices dictate that the interview participants understand how the data gathered will be used. Therefore, the information obtained in this interview will be used for research purposes only. Your confidential participation in this study will be preserved using a pseudonym.

It is important that you understand the purpose and conditions of your involvement and the conditions of your participation. Therefore, please read through the remainder of this form to confirm your understanding of the purpose and conditions of your involvement and participation in this study.

- The interview will be conducted via Zoom and will be recorded.
- Any interview content available through academic publications or other academic outlets will be anonymized with a pseudonym to preserve your confidentiality, and care will be taken to ensure that any other information from the interview will not reveal your identity.
- The interview transcript will be sent to you to review and correct any factual errors.
- Patti Bromer, the researcher, will analyze the transcript of the interview.
- The interview transcript will only be accessible by Patti Bromer and university advisors with whom she might collaborate as part of the research process.
- The video recording and transcript will be stored on a password-protected computer for the research study duration. The recording and transcript will be permanently deleted upon the conclusion of the research project.
- All or part of your interview content may be used in academic papers or an archive of the project.
- Any variation of the above conditions will only occur with your explicit approval.
- I, the student, recognize that my participation in this interview is entirely voluntary, and I can withdraw or stop the interview at any time.
- I, the student, understand that I will not receive any benefit of payment for my participation.
- The student will receive a copy of the interview transcript and make any edits necessary to ensure factual accuracy.
- I, the student, understand the steps taken to preserve confidentiality and anonymity.
- I, the student, have been able to ask questions and understand that I am free to contact the researcher with any questions I may have in the future.

* This document will be built in Google forms.
Thank you for agreeing to participate in this interview. I will remind you that your participation in this action research study is voluntary. You are free to withdraw from the study or interview at any time without fear of negative repercussions. There are no risks or rewards associated with your participation.

This interview will last 20 to 30 minutes and will be recorded using Zoom teleconferencing software. In addition to recording our interview, I will be taking some brief notes throughout our interview to ensure the data’s accuracy.

After the interview has been transcribed, you will have the opportunity to review it for accuracy and clarify if needed. You will receive a copy of the final report once all editing is completed.

Before we begin, do you have any questions or concerns? (Clarify as needed for the participant.) Ok, let us begin.

**Introduction**

Our first set of questions will provide a little bit of background and your experience with college courses in general.

1) How long have you been taking college courses?

2) Can you briefly describe your experiences taking college courses?

**Student Perceptions**

The second set of questions is specifically about your perceptions about using spaced and repeated practice of the StudyMate flashcards.

3) Please describe your perceptions on the usefulness of the spaced and repeated practice of using the StudyMate flashcards to memorize the measurement conversion standards. (RQ2)

4) Please describe your perceptions on the ease of using the spaced and repeated practice of the StudyMate flashcards to memorize the measurement conversion standards. (RQ2)

5) Please describe your overall thoughts and attitude regarding the spaced and repeated use of the StudyMate flashcard tool to memorize the measurement conversion standards? (RQ2)

That concludes the questions I have for this interview.
To provide some closure, let me describe the next steps in this process. Today, I have recorded and taken brief notes on our discussion of the impact of and student perception of the spaced and repeated practice using the StudyMate flashcards to memorize the measurement conversion standards. This video file will be stored digitally on a secure server for retrieval and transcription later. The information obtained in this interview will be used for research purposes only. After I have transcribed our interview, I will send you a copy to review for accuracy and any editing or clarification changes that need to be made. After completing any editing or clarification changes, the transcript will be saved with the audio file on a secure server. When the final report has been finished, you will receive a copy of that final report.

Do you have any questions or concerns that you feel were not addressed in this interview?

Thank you for your time sitting down with me for this interview and for participating in this research study.
APPENDIX J:

Consent to be a Research Subject

Incremental, Spaced Repetition and StudyMate Flashcards: The Impact on College Student Memorization of Measurement Conversion Standards Research Study Letter

Dear MAT 1130 Students,

My name is Patti Bromer. I will be your instructor for MAT 1130 for this term. I am also a doctoral candidate in the Education Department at the University of South Carolina. In addition, I am conducting a research study as part of the requirements of my degree in Curriculum and Instruction with a concentration in Instructional Technology, and I would like to invite you to participate.

The purpose of my action research will be to evaluate the impact of and student perception of incremental, spaced repetition and StudyMate flashcard use on memorization of measurement conversion standards for MAT 1130. If you decide to participate, you will be asked to commit 30 minutes per week for the first five weeks of the term to use the StudyMate flashcard tool in eLearn and 15 minutes to complete the student perception survey at the beginning of the sixth week of the course. Your commitment to participate will require you to

1. log into your eLearn account
2. open the StudyMate flashcard tool
3. use the flashcard tool for 10 minutes three times per week for five weeks (August 26 – October 2)
4. complete the student perception survey at the beginning of the sixth week of the course (October 5)

You may be invited to participate in a 20–30-minute interview during the eighth or ninth week of the course (The week of October 11). The interview will consist of asking you questions about your perceptions of the StudyMate flashcard tool. You do not have to answer any questions that you do not wish to answer or that may make you feel uncomfortable. The interview will be conducted via Zoom and will be recorded for accurate transcription of what is discussed. You will have an opportunity to review the transcript of the interview. The video recording and transcription will only be reviewed by the research team members and destroyed upon the completion of the study.
Participation is confidential. Study information will be kept on a secure server at the University of South Carolina. The study results may be published or presented at professional meetings, but your identity will not be revealed. You will not receive any benefit of payment or incentive for participating in the study. You will not be penalized for not participating in the study. Your participation in this study is entirely voluntary, and you can withdraw at any time without fear of penalty.

We will be happy to answer any questions you have about the study. You may contact me at 937.512.2786 and patti.bromer@sinclair.edu or my faculty advisor Dr. Alison Moore at AM160@mailbox.sc.edu.

Thank you for your consideration. If you would like to participate, please check the “Yes, I am at least 18 years old, and I will participate” button below and enter your name on the line provided. If you do not want to participate or you are not at least 18 years old, please check the “No, I will not participate” button below and enter your name on the line provided.

☐ Yes, I am at least 18 years old, and I will participate in this research study
☐ No, I will NOT participate in this research study

Respectfully,

Patti Bromer

Patti Bromer
444 W. Third Street
Dayton, Ohio 43402
937.512.2786
Patti.bromer@Sinclair.edu