AN IMPLEMENTATION STUDY: THE EFFECT OF DIGITAL GAMES IMPLEMENTATION ON CALCULUS I LEARNING PERFORMANCE FOR COLLEGE STUDENTS

A Dissertation

by

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Submitted to the Graduate and Professional School of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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August 2023

Major Subject: Educational Psychology

ABSTRACT

Digital Game-Based Learning (DGBL) demonstrated a positive impact on students' motivation, engagement, knowledge acquisition, and many other areas. However, all the benefits DGBL can offer for the classroom do not seem to be enticing enough to persuade classroom instructors to implement DGBL in their classroom. There is a disconnect between current studies in DGBL with the reality in the classroom. With a limited information available on how to implement a digital game in the classroom, a classroom instructor needs to overcome a lot of hurdles. Meanwhile, at the same time, classroom instructors feel the pressure from both parents and the school administrator if the outcome for the decision using digital games not as expected.

The first part of the study is a systematic review to seek understanding on implementation practices done so far in the DGBL. The systematic review found out that in DGBL studies there were few and fragmented information on the implementation practices. Consequently, it is very difficult to comprehend on how the study differentiate the frequency (number of sessions for the students to play the game) and the duration (how long supposed the students play the game in every session or in total) to make sure a learning transfer happening. The systematic review laid a foundation of the importance to understand how gaming frequency and gaming duration will affect the learning transfer in the DGBL classroom.

The second part of the study seeks for understanding on how the implementation plan might create a difference in students' gaming activity and how it will affect their learning performance on the Revised Calculus Concept Inventory test. This study was designed as a quasi-experimental study with one classroom as a treatment group and one other classroom as a control group. Treatment classroom has 31 students from a cohort program starting Fall 2022 and the control classroom has 25 students a non-cohort program. Both classrooms were from a college in Bryan, Texas. The result indicated a non-significant result on the student's learning performance for the treatment group and the gaming activity showed a high participation. However, this study could not make a comparison between the treatment and the control group because of unexpected circumstances between a cohort and a non-cohort classroom. This study brought an insight on how different implementation plan might impact the student's gaming activity, but still need to be confirmed through a further study with a presence of the control group.

DEDICATION

For my wife, without her I will not be here.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Susan Pedersen, and my committee members, Dr. Wen Luo, Dr. Steven Woltering, and Dr. Bugrahan Yalvac, for their guidance and support throughout the course of this research.

Thanks also goes to Dr. Jocelyn Widmer, who gave me an opportunity to start my career life early at the Office of Academic Innovation and Online Learning during my last two semesters finishing my dissertation.

To my friends, colleagues at Center for Teaching Excellence, Dr. Justin T. Dellinger as my supervisor who shows a great support during the past few months for completing my journey at Texas A&M University as a student with a wonderful experience.

I would like to praise the University Writing Center with their consultants who work hard helping graduate students on their academic writing, all the faculty members at the Educational Psychology department, and also the graduate advisor who relentlessly showing a great support to their students.

Lastly, many thanks to my wife, my mother and father, my mother-in-law and father-in-law (deceased), and my whole family for their patience, love, and encouragement to pursue of my dream.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a dissertation committee consisting of Dr. Susan Pedersen (advisor), Dr. Steven Woltering (committee member), and Dr. Wen Luo (committee member) of the Department of Educational Psychology and Dr. Bugrahan Yalvac (committee member) of the Department of Teaching, Learning, and Culture.

The result in Chapter 4 was reviewed by Dr. Wen Luo and Dr. Susan Pedersen. All other work conducted for the dissertation was completed by the student independently.

Funding Sources

This study was funded by the student independently.

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CHAPTER I

INTRODUCTION

1.1 Introduction

Digital Game-Based Learning (DGBL) has demonstrated a positive impact on students' learning experiences in various ways, such as motivation, engagement, immersive learning, knowledge acquisition, critical thinking, problem-solving, collaboration, and communication skills (Barbosa & de Ávila Rodrigues, 2020; Barr, 2017; Chang et al., 2020; Hamari et al., 2016; Marklund & Taylor, 2016; Qian & Clark, 2016; Troussas et al., 2020; Vlachopoulos & Makri, 2017).

However, all the benefits DGBL can offer for the classroom do not seem to be enticing enough to persuade teachers to implement DGBL in their classrooms. Barko and Sadler (2013) raised a concern even for teachers who are talented and highly creative, finding a justification for using digital games in their classroom is a complex decision. In addition, Molin (2017) argued most studies in DGBL mainly focused on how to empower students in the classroom, rather than addressing teachers' role as the dominant factor for DGBL implementation.

Using digital games in the classroom is not as simple as asking the students to play the game. Teachers need to be able to confirm the suitability of the games, the method, and the subject matter. Several studies identified common challenges for teachers in implementing DGBL in their classes, including time insufficiency for preparing a gaming session, limited technical competence to choose suitable digital games, tight scheduling for the semester, anxiety for facilitating classroom discourse to connect between gaming and the curricula, and anxiety for introducing DGBL (Chee et al., 2014; Jong, 2016; Molin, 2017).

The decision to implement DGBL in the classroom itself already a big hurdle for many teachers. Once they make the decision, there are many tasks awaiting for them to get ready with the implementation. Game choice, supporting resources availability, curriculum alignment, classroom activity plan, how often and how long the student should play the game, where and when the gameplay should take place, and more tasks to think and prepare for bring in the game to the classroom.

One important consideration in DGBL implementation is the time spent on gameplay, specifically on how to set the timetable for how long per session, how many sessions, and how many weeks. There were studies looking at the relationship between gaming behavior as how often or how many hours the student plays the game in daily life and academic performance; the results were mixed (Khatri et al., 2014; Wright, 2011) . However, such information did not correlate to the effect of the number of hours spent on playing digital games for learning to knowledge acquisition.

In DGBL studies the duration of study are very broad and at one point become problematic to find a pattern. How the study setup the intervention, setup the amount of gaming frequency and how long the student should play the game in a session, is hard to understand the rationale. One possible reason DGBL studies do not explain further on the study design like why 1 hour of gameplay, 5 hours of gameplay, or 1 hour gameplay for 3 gameplay sessions was driven by the game itself. The complexity of the game, the availability of the game, whether it was a completely built game or partially built game, or the number of stages of the game compared to the curricula for the topic. In addition, the classroom availability becomes another factor that defines the number of sessions of gaming.

However, in a DGBL intervention, if the digital game is considered as part of the learning material beside the formal learning material in the curriculum, the frequency and the intensity of the gaming session might make a difference in the learning and the information retention by the end of the study. Studying information across two or more sessions that are separated (i.e. spaced apart or distributed) in time often produces better learning and retention than spending the same amount of time studying the material in a mass (Arthur et al., 2010; Cepeda et al., 2009; Dail & Christina, 2004; Shea et al., 2000).

Fishman et al. (2014) did a national survey of the K-12 teachers and discovered that over 55% of teachers claimed using digital games in the classroom at least once a week. In resonance to that survey, Takeuchi and Vaala (2014) also conducted a national survey to the K-8 teachers and revealed that approximately 78% teachers claimed using digital games at least once month for engagement purpose and also as a reward. However, it was unclear how the teachers use the game, in what context, for how long, was it for all the students, or how it helps the students in term of learning.

Silseth (2012) underlined important roles of teachers in DGBL implementation: 1) as an expert guide to the students in making a connection between the game and the learning objectives; 2) as a facilitator who provides instruction, discussion, observation for enabling students' reflection and providing feedback; 3) as a connector to bring relevance beyond the course. Egenfeldt-Nielsen et al. (2015), in his book, *Understanding Video Games: The Essential Introduction* discussed the important roles of teachers in facilitating learning with video games to steer the game usage into the right direction, provide effective debriefing that catch misperceptions and different students' experiences during the gaming session.

1.2 Theoretical Framework

1.2.1 Distributed Practice Effect in Learning

The spacing effect, also known as lag effect or distributed practice effect, is an increased temporal lag between study episodes, often resulted in increased performance on memory retention (Ebbinghaus et al., 1913). Distributed practice has been shown to enhance various skills, such as playing video game (Shebilske et al., 1999; Stafford & Dewar, 2014), surgical skills (Andersen et al., 2016; Spruit et al., 2015; Verdaasdonk et al., 2007), playing piano (Simmons, 2012), and golf-putting (Dail & Christina, 2004)

Most of the distributed learning effect studies investigated between a group that completed the sessions across multiple days to one that completed within a single day. Smith and Scarf (2017) found out in longer timescales, in general for both adults and children, distributed practice enhanced the generalization of learning and the retention. Stafford and Dewar (2014) used an online game to investigate the effect of practicing (number of attempts playing the game) on game achievement. One of the findings, as the players practiced the game, their average scores improved even though not necessarily increased the highest score.

1.2.2 Classroom Discussion

Río et al. (1995) suggested a classroom with students that interact in a deep and meaningful conversation would result in better outcomes in fostering learning. In a conversation or a discussion, students made public their perspectives on issues arising from the learning material, at the same time they also processed their peers' proposed perspectives, and at the end of the discussion, they reconciled possible conflicts among themselves (Murphy et al., 2009).

Evidence suggested discussions about and around text or learning material have the potential to increase students' comprehension, meta-cognition, critical thinking, reasoning, and supporting arguments (Reznitskaya et al., 2001). In DGBL context, students' discourse in the classroom has the same potential for fostering learning. Digital games often have narration that is not directly related to the learning material, teachers will need to be part of the discourse to fill the gap.

1.3 Purpose of the Study

The purpose of this study was to investigate how a DGBL implementation plan might affect the students gaming activities, gaming behavior, and the learning performance on the Calculus I concept inventory test.

This study was designed to mimic as real as possible the normal Calculus I classroom situation with two different Calculus I instructors, one who had three years' experience using the digital game and the other one who was a first timer using the digital game.

The implementation plan was built solely by the instructor at their own convenience level without any interruption from the research team. Through the study, we wanted to see evidence in the students gaming activities like how long they spent their time to complete the game and how often they play the game. And, how these two gaming variables affect their test result that measures their conceptual knowledge in Calculus I.

1.4 Significance of the Study

This study built on previous systematic literature review which underlined the importance of an implementation plan in a DGBL study in its contribution to the learning performance.

This study was designed to seek insights on different teaching practices that affect the student's interaction with the game which resulted in the learning performance. Therefore, this study tried to answer these questions below:

1. Is there any significant difference in the learning performance between the pre-test and post-test result for each classroom?
2. Is there any significant difference in the learning performance between the treatment and the control group in the pre-test and post-test result?
3. What kind of teaching practices applied in the classroom contribute to the student's gaming behavior specifically in the number of gaming sessions and time-spent in game?
4. Is there any difference in the student's gaming behavior specifically in the number of gaming sessions and time-spent in game to accomplish the game?
5. Is there any relationship between number of sessions, time-spent in-game, and the learning performance?

The significance of this study lies in its implication for future DGBL implementation practices. DGBL implementation practices to date put less focus for both on the gaming session activities and describing what the instructors do in the implementation. This study aims to contribute to the educational field in several ways: 1) offer a new perspective for DGBL studies to use further distributed practice in gaming for fostering learning; 2) provide evidence-based practice for DGBL studies to analyze deeper on teaching practices that lead to better learning result; and 3) encourage future studies in DGBL to discuss deeper every aspect related to the implementation process to give better ideas for future implementations.

1.5 Definition of Terms

These are terms being used in this study:

DGBL – An acronym of Digital Game Based Learning, which refers to the instructional strategy that utilize digital-game(s) in the classroom. The digital game itself can be an educational game or a commercial game.

Implementation – Implementation refers to the process of planning and executing the idea of using a digital game as an instructional tool in the classroom.

Learning performance – Learning performance refers to the knowledge acquisition based on the standardized test result.

The RCCI Test – An acronym for the Revised Calculus Concept Inventory Test, a standardized test that measures the basic concept for Calculus I, designed and developed by a research team from Texas Tech University under the National Science Foundation (NSF) grant.

Gaming sessions – Gaming session refers to the amount of each unique user accessing the game during the study period in order to accomplish the game.

Time-spent in-game – The total time-spent in-game refers to the total time used for each unique user to accomplish all tasks in-game.

CHAPTER II

ORGANIZING IMPLEMENTATION PRACTICES IN DIGITAL GAME BASED LEARNING RESEARCH IN STEM EDUCATION: A SYSTEMATIC REVIEW

2.1 Introduction

Digital Game-Based Learning (DGBL) has been researched for decades and draws a lot of attention in the Educational Technology field as a very promising instructional tool. Stewart et al. (2013) distinguished three types of projected primary learning outcomes in DGBL study, including knowledge transfer (cognitive learning outcomes), skill acquisition (skill-based learning outcomes), and behavioral change (affective learning outcomes). Educational game developers usually build their games to achieve knowledge transfer, such as in math, science, or any other subject matter. Meanwhile, there are ~~also~~ digital games like Flight Simulator, Tank Simulator, The Sims, Tycoon Series, etc. that aim to support skill acquisition. And there are also digital games that specifically developed to raise awareness and expect a behavioral change on certain social issues, like poverty (e.g. SPENT, Survive125, This War of Mine, etc.), hunger (freerice.com), healthy lifestyles (nutrition.gov), etc. thru the gameplay.

Recent meta-analysis confirmed the effectiveness of DGBL in the classroom (Backlund & Hendrix, 2013; Byun & Joung, 2018; Clark et al., 2016; Connolly et al., 2012). However, there were still some issues reported, such as methodological flaws, less empirical evidence that made the study less generalizable as reported by Hays (2005) since two decades ago.

Research has long shown that how technology-based innovations were implemented in the classroom affect their impact on outcomes. The implementation is the key step between the teacher and the students (Claesgens, 2013). Usually, it is better to have a duration of over a year for implementing technology-enhanced lessons to give enough time to overcome barriers with hardware and software (Gerard et al., 2011). Also, teachers' openness to change also plays a big role in technology implementation (Baylor & Ritchie, 2002). Many literatures in DGBL raised a concern about less information in the implementation practices, which makes the readers harder to comprehend if the reported results were purely because of the DGBL or there are other circumstances contributing to the results (Clark et al., 2016; O'Neil et al., 2005; Sitzmann, 2011).

Despite the benefit and positive outcomes from many studies on DGBL, there was limited research on DGBL implementation in the classroom. NMC Horizon Report (2014) predicted that Game-Based Learning time to adoption was between two or three years. There were studies that claimed over 70% K-12 teachers used digital games in their classroom from daily to weekly (Fishman et al., 2014; Takeuchi & Vaala, 2014). In contrast, (Anderson, 2019) during an interview session with Dan White, a co-founder of Filament Games, found out merely about 10% of K-12 classroom in the United States that using digital-games for learning purposes. Why there was a big gap? When we looked further into the type of game and how the teachers used the game in the classroom, that was where the big gap was. Takeuchi and Vaala (2014) found out the two highest responses were puzzle games and trivia games used as a break activity. Such findings were unsatisfactory and showed there was a very basic misconception about the game's terminology. And there were still many questionable practices that referred to using the game in the classroom that possibly mislead the overall direction of DGBL studies.

2.2 Purpose of the Study

In this study, games refer to educational games that are purposefully developed to achieve certain learning objectives and commercial-of-the-self (COTS) games for entertainment, but to some extent being used in educational context (Backlund & Hendrix, 2013; Stewart et al., 2013). And as previously stated, the fact that the presence of DGBL in the classroom was limited, finding more thorough information on DGBL implementation practices would be beneficial to support future DGBL studies and DGBL classroom integration. Therefore, this review will try to answer these questions below:

1. What implementation practices have been reported in STEM educational games research?
2. For studies that report implementation practices, what study designs have been used and what outcomes have been investigated?
3. Are there any implementation practices that are associated with positive outcomes?

2.3 Method

In this systematic review, we used six inclusion criteria, as defined below:

1. It must be digital-game based study.
2. It must be in K-12 classroom setting.
3. It must be in Science, Technology, Engineering, and Mathematic (STEM) field.
4. It must have information related to DGBL implementation practices.
5. It must be published between 2007– 2017.
6. It must be an academic paper.

We used electronic database search to find the first set of studies. The search used multiple iterations to optimize the result. The final search command was described as below:

TI ((elementary or middle or intermediate or high) n1 school*) OR AB ((elementary or middle or intermediate or high) n1 school*)

AND

TI (gaming or game*) OR AB (gaming or game*)

AND

TI implement* or AB implement* OR TI (math* or scienc* or engineer*) or AB (math* or scienc* or engineer*) OR TI stem n1 educat* OR AB stem n1 educat*

We conducted the search on ERIC and caught 479 studies as the initial pool to validate the search command. We used Rayyan from QCRI as the tool to organize the search result and made inclusion decision comparing the title and abstract of the study with the inclusion criteria. When the selection process hit 250 studies, we found 50 studies that matched the inclusion criteria based on the Title and Abstract description. We stopped the selection process to run a trial on full-text review. The purpose of this step was to validate the search command before we expanded the search to a larger set of databases. We found 10 studies that matched with the inclusion criteria based on the full-text review. Therefore, we used the search command and expanded the search process to other four digital database: (1) Education Source, (2) Academic Search Ultimate, (3) Education Full Text (H. W. Wilson), and (4) Educational Administration Abstract.

After the expanded search process, there were total 1,924 studies found (Table 1) and after cleaned the duplicates, there were 779 studies went for title and abstract screening. Most of the studies were excluded because of mainly failed to meet two criteria, they were not digital game-based learning studies and non-STEM related studies. There were 171 studies going for full-text review.

Table 1. Database Search Result

Database	Number of Papers found
ERIC	497
Education Source	590
Academic Search Ultimate	487
Education Full Text (H.W. Wilson)	302
Educational Administration Abstract	48
Total	**1,924**

After we did full-text review, we had 81 that met the inclusion criteria for this systematic review as shown in Table 2.

Table 2. PRISMA Result

Number of Papers from Database Search Result	**Number of Initial Papers after Removing Duplicates**	**Number of Identified Papers based on Abstract Review**	**Number of Selected Papers using Inclusion Criteria**
1,924	779	171	81

2.4 Result

2.4.1 Analysis of game variables

This section describes the results based on type of games used in the papers.

a. Type of games

Out of 81 studies in this review, 64 studies stated using educational games that were purposely designed for educational, 14 studies mentioned using mini games, and 3 studies using serious games or also known as commercial-of-the-shelf (COTS).

There were 10 studies missing the game titles. All the game titles and the studies listed in Appendix.

b. Subject area and age group

Our finding showed 81% of the studies in this review were in K-8 classroom. Both mathematics and science in elementary education had almost the same number of studies, though in the middle school science had more studies compare to math. Meanwhile, in the high school, there was quite a high interest in science, especially biology, compared to other branches of science education and interdisciplinary subject such as computational thinking, computer science, etc.

Table 3. Subject Area and Age Group Composition

	Elementary	*Middle School*	*High School*
Math	19	18	2
Science	11	16	8
Engineering		2	5

c. Game using context

Defining where we want to use the game during an implementation is crucial, along with how we want to use the game in the classroom. In the studies reviewed, we found out 63 studies used the game as part of their classroom activity where the students spend some time to play the game (Addy et al., 2018; Bakker et al., 2016; Epstein et al., 2016; Wilson et al., 2018). The common practices that we found in the studies, the research team or the teachers simply asked the students to play the game in the classroom. A short briefing or a classroom instruction that related to the game content prior to the game session, a pre-test for measuring prior knowledge of the students on the topic, game session, and end the study with an immediate post-test after the game session or a delayed post-test depending on the research setup (Kinnebrew et al., 2017; Sung et al., 2018).

From the 63 studies mentioned above, 9 studies showed a more comprehensive alignment process to match the game context and the learning goals for the corresponding lessons (Bell & Gresalfi, 2017; Foster & Shah, 2015; Pellas & Vosinakis, 2018; Sadler et al., 2015). The alignment process could be as simple as preparing an extra worksheet to connect the game experience and the learning material, teachers' guide, or teachers' made material to support students' learning experience.

After-school program was another way of using the game that we found in the reviewed studies. There were 8 studies used the game as an after-school program like for enrichment to increase arithmetic fluency where the participation voluntarily and membership to the program was small (Plass et al., 2013); tutorial session for a group of students who had a low performance on the exam to play the game as part of the tutoring session with graduate education students (Ke, 2013); remedial class for students who failed to achieve the desired standard to play a monopoly game (Lin et al., 2013), or as simple as a non-mandatory supplement learning material where the students could play the game at home with no minimum requirement to accomplish (Katmada et al., 2014).

Another alternative setting in this review was computer-lab setting. There were 10 out of 81 studies which took place in computer-lab setting. In this setting, the participants voluntarily joined the study, came to the computer-lab or a classroom that setup purposely to fit the research, and follow the research protocol for completing the study (Habgood & Ainsworth, 2011; Hsu et al., 2016; Kim & Ke, 2016).

Table 4. Game Use Setting by Subject Area

Game Use Setting	*Math*	*Science*	*Engineering*
In-class	27	28	8
After-school / At-home	6	1	1
Lab Setting	6	4	

d. Gameplay modes

In this review, there were several modes of gameplay for the studies. The most frequent mode of gameplay was individual gameplay, accounted for over 80% of the studies. In this individual gameplay, participants either using a shared device such as PC station in the classroom or tablet or one-to-one device (Israel et al., 2016; Kinnebrew et al., 2017; Sung et al., 2018; Wilson et al., 2018). As predicted, there were many studies using individual play as the mode of gameplay. Individual gameplay was the simplest way to find a direct impact of the game on cognitive learning outcome.

There were 16 studies using a collaborative gameplay such as students worked in pairs using a laptop to play the game (Wallon et al., 2018); work as a group to deviate a solution in a game that mimicked real-world context

(Panoutsopoulos & Sampson, 2012; Sánchez & Olivares, 2011). Plass et al. (2013) studied between individual gameplay mode, collaborative mode, and competition mode on learning performance and found out that competition increased in-game learning, collaboration decreased in-game performance, but overall, out-of-game math fluency improved in any gameplay mode. Collaborative gameplay also resulted in greater interest, enjoyment, and stronger intention to play, including invoked a stronger mastery goal orientation.

Meanwhile, with the popularity of Massive Multiplayer Online Games (MMOs), there were 4 studies using a multiplayer gameplay where several individual students play the game using each individual device in a multiplayer environment. One of MMOG game was McLarin's Adventures, designed for 8^{th} grade and 9^{th} grade students for measuring complex-problem solving ability (Eseryel et al., 2011; Eseryel et al., 2013). Another multiplayer game in this subset of studies was DimensionM, an educational game in a 3-D immersive game environment for learning Pre-Algebra and Algebra concept. Ritzhaupt et al. (2011) found out that there were positive changes in students' attitude towards Mathematic and Mathematic self-efficacy, and there were no significant changes in the Mathematic achievement through a 16-weeks long intervention of DimensionM.

Table 5. Gameplay Modes by Subject Area

	Math	*Science*	*Engineering*
Individual Play	30	27	9
Collaboration Play	11	6	1
Multiplayer Online	2	2	-

2.4.2 Analysis of the outcome variables

Many studies came up with multiple outcome variables to answer the research questions. In this review, 63 studies used factual/conceptual knowledge as one of the outcome variables. A likely explanation from the reviewed studies, the easiest way to see an immediate effect of a treatment in an experimental setting was by assessing factual or conceptual knowledge. On the contrary, a traditional well-designed course might give similar outcomes that fail to capture the advantages offered by digital games environment.

Meanwhile, 9 studies out of 63 mentioned above measured higher order level of thinking like scientific argumentation (Gould & Parekh, 2017; Wallon et al., 2018; Wilson et al., 2018); problem-solving skill (Chang et al., 2012; Eseryel et al., 2011; Eseryel et al., 2013; Sánchez & Olivares, 2011; Spires et al., 2011), mathematical reasoning (Houssart & Sams, 2011), and scientific inquiry (Schifter et al., 2012). Wilson et al. (2018) used Geniverse, an immersive, game-like learning environment for 3 to 6 weeks period with 48 high school teachers and about 2000 students, found out that students' abilities to engage in scientific explanation and argumentation were greater in the experimental group, though not statistically significant because of various teachers' instructional decisions that might have influenced the outcomes.

We also identified 43 studies measured affective learning outcomes, such as learning motivation (10), attitude and/or efficacy toward subject matters (21), learning engagement (7), or flow experience (2). The impact of DGBL on learning motivation was mostly consistent between studies concluded as significantly increases students' learning motivation (Chu & Chang, 2013; Plass et al., 2013; Wang et al., 2018). It was also consistent findings that used of games increased in studies that measured students' attitude toward subject matter, self-efficacy toward subject matter, learning engagement, and flow experience were statistically significant. Therefore, there was pretty much solid empirical evidence on how DGBL impact affective learning outcome effectively.

Meanwhile, there were only 3 studies that measured 21st century skills, such as collaboration, creativity, and communication. Annetta et al. (2010) used a simple build 3D game called MEGA to reinforce classroom instruction on Genetics unit, found out the students consistently use their digital age literacy and information literacy skills during the activity, showed ability and willingness to take risks using their inventive thinking, exercised a high productivity through planning, prioritizing, and managing information, and communicate effectively between students using in-game chat features. DGBL also became an effective learning tool for cultivating students' creativity that resulted in a positive effect on increasing their performance (Hsiao et al., 2014). Smith (2014), with Quest

Atlantis, a virtual science game, shared a similar finding that using game environment fostered practices of 21st century skill competencies.

2.4.3 Study design

Study design is one section that often getting a lot of attention in DGBL studies. All et al. (2014) argued with the diversity in study designs, some of which were suboptimal, created a difficulty for making of generalization on DGBL effectiveness. Cook et al. (2002) explored between experimental study design as a gold standard for determining causality but at the same time also offered a quasi-experimental design could offer the same degree under certain assumption. In this study, twenty-one studies claimed using experimental study design. The experimental design was comparing different game versions or different gameplay modes rather than simply comparing between a game and a non-game environment.

The result in the experimental studies comparing between a game and a non-game environment, gaming environment gave a better result in the measured outcome. Meanwhile, the findings in comparing different gameplay mode in game environment experiment showed a mix result. Epstein et al. (2016) using Bacon Brains as comparison with National Institute on Drug Abuse (NIDA) game series on similar topics found out that competitive mode worked better for males, in contrast collaborative mode worked better for female. Plass et al. (2013) found out that competition play mode increased significantly in-game learning performance, whereas collaboration decreased the performance, even though both game play mode increased the interest, enjoyment and invoke a stronger mastery goal orientation. Several studies found out there was no difference between solitary mode and collaborative mode on science content knowledge, self-efficacy toward science learning, science learning motivation, but from the qualitative study, they found out that collaborative play enrich the students learning experience and improve their collective problem solving (Chen & Hwang, 2014; Meluso et al., 2012).

A quasi-experimental design is a similar to experimental design, but with a non-randomized sample became more preferable in the reviewed studies, with 31 studies using it. Instead of using a traditional instructional method as comparison, 10 out of 31 studies comparing two different gaming environments that incorporate additional instructional strategy. It was an interesting fact in the studies that comparing a plain use of game and using an additional instructional strategy with the game such as worked example (Chen et al., 2013), teachable tutoring agent (Pareto, 2014), and embedded concept map (Hwang, Yang, et al., 2013) resulted in a higher significance on the outcome whenever the game usage reinforced by the additional instructional strategy. Marino et al. (2013) found out no significant difference in students with learning disabilities who used UDL-aligned units supplemented with video games compared to those taught using traditional curricular. However, the students with learning disabilities showed an appreciation of the options available, not just typical learning aid included in traditional science instruction and textbook.

Although there was an urge in the field to have more and more rigorous study, we found out 16 studies using a pre-post study design with no control group as a comparison. These studies were usually a small-scale study to seek better understanding of specific game feature or certain effect on using the game. An interesting finding, Martin et al. (2015) began with 4,000 students in his study, though at the end of the study ended up with 1,103 students who completed the pre-test and post-test, built the study based on smaller study to seek further understanding how splitting method helped students learn fraction in a larger setting. Even though such studies gave a significant result with a high sample size, it became less meaningful without the presence of any comparison group (Klisch, Miller, Wang, et al., 2012; Martin et al., 2015; Ritzhaupt et al., 2011).

In this set of literatures, we identified 10 studies that discussed certain part of a new game development. There were 4 out of 10 studies were design study of new game development for mathematics (Katmada et al., 2014; Panagiotakopoulos, 2011), physics (Clark et al., 2011), and engineering (Cohen et al., 2017). Shelton and Parlin (2016) designed a mobile GPS games named GeePerS*Math, found out GeePerS*Math helped the children with DHH to improve their ability on doing estimation, rounding skills, and also observed unintended outcome like peer tutoring and the students read out loud the text of the game as they played.

As mentioned in this section, there were 2 studies that related to student with disabilities. It could be an indicator of growing interest in the field for finding out how DGBL could also affect students with disabilities.

2.4.4 Duration of study

Organizing the duration of study was one of the trickiest parts of this review. There was little consensus about how to report how long or how often the game play. A limited, fragmented, and non-standardized information between studies to describe how long the study was ongoing and how often the game play ongoing. It was hard to figure out how many minutes or hours spent on playing the games during the study. Therefore, it was even harder to seek a pattern whether the frequency (how often) within a certain period, the intensity (time spent on the game), or the duration (how long the study ongoing) that counted from the beginning of the study to the end of the study had any effect on the result of the study.

Regarding the frequency or intensity of gameplay during the study, we organized this review based on the how long the study using the games and how often the gameplay session during the study. As defined, one-time study simply a one visit and spent some minutes or hours for the study. A short term will refer to within a week to a month with a single or multiple sessions in each week, a medium term will refer to more than a month up to three months with a single or multiple sessions in each week, and a long term will refer to over three months period with a single or multiple sessions in each week. Also, several studies that did not report a clear information on the frequency nor the intensity of the study. Table 6 summarized all the studies in this systematic review, including the significance of the study.

It was interesting to observe the significance of the study in this systematic review. Less than 50% of one-time study in mathematics showed statistically significant, meanwhile in Science and Engineering, split into half and half between the statistically significant and the statistically insignificant. Thus, we could expect that by increasing the frequency and the intensity might give a better result.

As shown in Table 6, for studies in mathematics and engineering, studies with multiple times and a longer gameplay showed over 70% of statistically significant result compared to the non-significant result. Meanwhile, for studies in science with multiple sessions and a longer gameplay, showed only 35% of them were statistically significant.

A technology implementation usually starts with a small-scale study and then put a suggestion for scaling up into larger study for measuring effectiveness. Therefore, a solid and crystal clear how the small-scale study in DGBL study being implemented will help to replicate the study in a larger scale that might lead into a better generalization for the field.

Table 6. Significance of the Study by Duration of Study and Subject Area

	Math		*Science*		*Engineering*	
	S	N	S	N	S	N
One Time Study	3	6	5	5	1	1
Multiple Time – Short Term	11	3	5	12	4	0
Multiple Time – Medium Term	5	2	1	2	1	0
Multiple Time – Long Term	3	2	1	0	1	0
No Information	2	2	1	1	0	1
Total	24	15	13	20	7	2

2.4.5 Research practices and instructional practices during classroom implementation

Besides discrepancy and lack of detail for reporting in duration of study for DGBL classroom implementation, there are other issues in describing research practices and instructional practices during the implementation process. A lot of studies did not describe clearly what the researchers do in preparing the classroom implementation, what the teachers or instructors do or prepare, or other important information that possibly affect the significance of the study. All et al. (2014) raised a concern for replication issues in DGBL studies because of missing information on multiple areas, such as implementation of the intervention, sampling, similarity of the different interventions, and information on the tests implemented. This review specifically extracts such information from each study and categorizes them as shown in the Table 7 below.

There were a lot of studies focusing on the research practices, which was expected and explained how mostly studies being done. Normally, a research briefing would be the first step to start the study, set up several meetings with the teachers or administrators to discuss the study, threw a professional development for the teachers, and built some material as a guideline for the study. During the study, there were several common practices from the studies, such as giving the students tutorial or trial session in the first day of the study, classroom observation, and providing technical support to the teachers during the study. And at the end of the study, it was very typical to see a closing survey for the participants and/or the teachers, a debriefing session to explain how the gameplay connected to the learning, an interview with the teachers or the participants, and a focus group discussion. However, none of the study explained the reasoning behind for doing such practices in relation to their study protocol and if any relationship with the expected result from the study.

Meanwhile, in the instructional practices, there were 54 studies that embedded the game into the classroom activity together with lectures for the related topics. And there were 8 studies that the teachers used the game as a supplement material for after school activity. However, there were neither any further details on the reasoning why the teachers used the game for after school activity nor what did the teachers expect to get by doing that.

There were studies that described the study protocol through a flowchart with the time allocated for each stage, which gave a better idea for the field on figuring out the study protocol (Hwang, Hung, et al., 2013; Hwang, Sung, et al., 2012; Panoutsopoulos & Sampson, 2012; Sung et al., 2018).

Table 7. Research and Instructional Practices Mentioned

Type	*Practices*	*Number of Papers*
Research	Research Procedure Briefing	62
	Collaboration between Teachers and Researchers such as curriculum alignment, supporting material development,	47
	Teachers' Professional Development	27
	Teachers' Guidance Material	31
	Tutorial or Trial Session	30
	Technical Support	56
	Classroom Observation	48
	Closing Survey	48
	Research Team Lead Debriefing Session	13
	Interview Session for teachers / instructors	9
	Interview Session for participants	14
	Focus Group	1
Instructional	Embedding gameplay into classroom activity	54
	Game-based lesson plan	9
	After-School supplement material	8

2.5 Discussion

The current review covers 10 years of studies on the use of digital games in K-12 science education. There were 81 articles included in the review, which all of them discussed digital games usage in the classroom, though none of them gave a proper description of how the implementation being done. All the studies reviewed here were focusing either looking at how the game feature affect certain learning outcome or looking at students' performance comparison. There was less explanation on the instructor and the instructions during the study, which affected the overall result.

Another tendency in this review was most of the studies still focus measuring lower order of thinking skills rather than higher order of thinking skills. Digital games offer advantages such as contextualization of real-world setting, highly immersive environment with sophisticated audio experience along with stunning visualization, and a risk-free environment that allows room for mistakes. Therefore, to use all the gaming environment advantages, it is more appealing to find out whether gaming environment is effective in fostering higher order of thinking skills compare to the traditional learning method.

Also, digital games offer so many opportunities to enhance student learning experience through embedding collaborative works, discussion, competitive environment, and other interactivity rather than just simply ask the student to play the game and conduct an assessment focusing on factual or conceptual knowledge. In this review, we found out there was a huge gap between what a game environment could provide for learning and what the researcher did to use the advantages of the game environment.

In a K-12 classroom, we know that teacher has an important role in technology adoption into the classroom. McCrory (2008), in Handbook of Technological Pedagogical Content Knowledge for Educators described teachers' knowledge of technology, science, and pedagogy comes together in knowing where (in the curriculum) to use technology, what technology to use, and how to teach with the technology. With such an expectation, any kind of technology related implementation will put teacher directly in a hot spot whether it will work as expected or not at all. Unfortunately, in DGBL studies, there was not much information reported that explained the role of the teachers, what they did, what kind of complication arose, how the teachers handled it, etc. Therefore, it was hard for the reader to comprehend whether the game itself contributed to the study result; the teacher did an extraordinary effort to get the study done, or the sample population fit precisely for the study. It also might explain the reason why there is not much DGBL adoption in the classroom as of today.

In this review, there were evidence that connect teacher as a potential variable that could make a difference in the study result. For example, teachers' experience held an important role to connect the game and the learning (Bell & Gresalfi, 2017); teachers' professional development (Annetta et al., 2010; Ault et al., 2015; Sadler et al., 2015) teachers held a key role in the successful implementation (Habgood & Ainsworth, 2011; Israel et al., 2016; O'Rourke et al., 2012; Wilson et al., 2018); instructional strategy contributed to the result (Bakker et al., 2016; Chen & Hwang, 2014; Hsu & Tsai, 2013; Ke, 2008b; Kinnebrew et al., 2017; Klisch et al., 2013; Pellas & Vosinakis, 2018; St Clair-Thompson et al., 2010; Wallon et al., 2018; Wang et al., 2018) and Brom et al. (2015) indicated the disparity in teacher's instructional practices might affect the overall result of the study.

However, all of them only wrote a very brief information with no further explanation how it will affect the study result. With such limited information, it is less likely to understand the whole process of DGBL implementation and to what extent teachers will contribute to the successful DGBL implementation in the classroom.

It will be more interesting if there are more studies in DGBL that describe more details on what is happening during the implementation such as what is the initial planning, if any disruption what they change in between, any highlight on the instructional practices, anything specific with the teachers during the implementation, etc. Those missing details will help the field making a solid interpretation of the result and help the field with a better guideline for replication in similar study and/or classroom adoption.

Another two related items in method of research that become a mystery are sample size and study period. Any technology-based study will have concern with the sample size that will affect the cost if it requires volume licensing or device availability and the longer the study period will increase the overall cost of the study, too. Therefore, it is very common for DGBL study that use a small sample size and a short study period. Regardless of the significance of the result, the recommendations for future study will consider a larger sample size and a longer term of study. On the other hand, DGBL studies that include a large sample size with either 16 weeks or a full school year did not consistently statistically significant in higher learning outcome as expected. Because of this, it will leave us with a doubtful question whether the DGBL intervention work as we thought.

Obviously, there is a need for further information that describes the implementation process of DGBL involving the game itself, the teachers, the instructions, and the students as the target for the intervention. It is about time that DGBL intervention should consider applying the fidelity of implementation framework as an integral part of future studies. The fidelity of implementation will ensure the study implemented the intervention as intended by the researchers. Wilder, Atwell, & Wine (2006) argued that lack of implementation fidelity might cause study with a less effective, less efficient, or less predictable responses. Meanwhile, when comparing a study implemented with a fidelity and without fidelity, there is a profound difference in the effectiveness up to two or three times higher in yield average effect sizes for study implemented with fidelity (Durlak & Dupre, 2008).

2.6 Conclusion

With nowadays game engine advancement, there are more possibilities for educational games getting more immersive and more engaging without jeopardizing the game design to achieve the learning goals. However, with a better quality and availability in educational game alone, not enticing enough for teachers to adopt DGBL into their classroom. Research to date on the DGBL has built a set of evidence of its potential for bringing learning into the classroom. However, this review finds out fragmented information in how DGBL being implemented in the classroom. There is still a huge gap in information to understand completely the complexity of the implementation process. None of the reviewed studies have been able to describe clearly on the implementation process to unveil further on what they do in the classroom, what they plan, what they change if any, what instructional practices they apply, etc.

There is so much burden on the teacher for implementing new intervention in their classroom, especially with digital games. Teachers will need a very thorough thinking process to search, evaluate, and even experience the game itself before they come into decision to implement the game. Barko and Sadler (2013) argued that even a very talented and creative teacher would be hard pressed to find a justification for using games in their classroom.

Therefore, this study convinces us the need for a well-documented implementation section in any future DGBL study. This is also a good reminder to apply the fidelity of implementation framework in any future study, which will give assurance for the readers that the whole intervention process following certain protocols that consider every aspect to bring the intended result.

CHAPTER III

METHOD

This chapter describes the participants, the designs and procedures, the data resources, the data collection, and the data analyses implemented in this study. The design and procedures include a brief overview of the Calculus digital game, the standardized test instrument, the syllabus for each group, and the general description of each group.

3.1 Participants

This study was conducted in a college in a metropolitan area in Brazos Valley, Texas. The study used 2 classrooms of Calculus I in the Spring 2023, one classroom was a Spring Cohort 2023, and the other classroom was a non-cohort Calculus I for the Spring 2023. Both classrooms had 32 students, 1 student from the cohort classroom did not return the signed consent form and 4 students from the regular classroom did not return the signed consent form.

Both instructors have over 10 years teaching experience in Calculus. The instructor for the treatment group has 3 years of experience using the Calculus digital game. On the other hand, the instructor for the control group a first timer in using the Calculus digital game to mimic the common context for instructors who want to give a try using a digital game in the classroom.

Prior to the study, the researcher met with both instructors to explain and discuss the purpose of the study, the Calculus digital game, the procedure of the study and the expectation for the instructor during the study. In the meeting, the researcher made a consensus with both instructors that the cohort classroom would act as the treatment group and the regular classroom would serve as the control group.

Each instructor has their own respected syllabus for the classroom with a similar structure such as attendance, quizzes, homework, and exams. Both instructors used the same electronic textbook for the course, same workbook and exam questions bank that were developed by a team of Calculus instructors in the college. As an incentive for the participants, both instructors agreed to give extra bonus points for those who play the game and complete up to the last stage of the game.

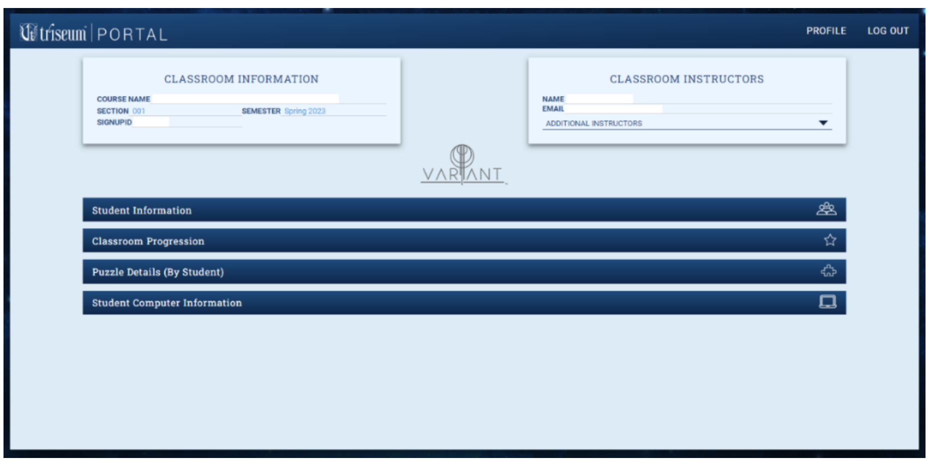
3.2 Variant: Limit

Variant: Limit (Thomas et al., 2017), an educational game, was specifically designed for mastery learning in abstract concepts about limits, limit laws, asymptotes, and concepts of infinity. During the study, the game was used as a supplement to the regular curricula for the Calculus I. The game was built in a 3D environment to give an immersive experience while the players solve a series of challenging calculus problems to end a geomagnetic storm threatening the planet's survival.

The game used narratives that allowed the players exploring each stage to maintain a balance between play and learning. The game does not rely on the repetitive drills, though the players are allowed to revisit any stages they have passed.

There are four zones in the game that discuss: (1) the nature of points; (2) functions and its relationship to limits and limit laws; (3) relating continuity to limits; and (4) asymptotes. The game gives a flexibility to the instructor to monitor each students' progress and track students' engagement through the instructor's portal (Figure 1).

Figure 1. Game Portal for Instructor



In the portal, the instructor can monitor total time spent in the game, number of login sessions, and last login sessions as shown in Student Information Section (Figure 2).

Figure 2. Student Information Section

Student Information

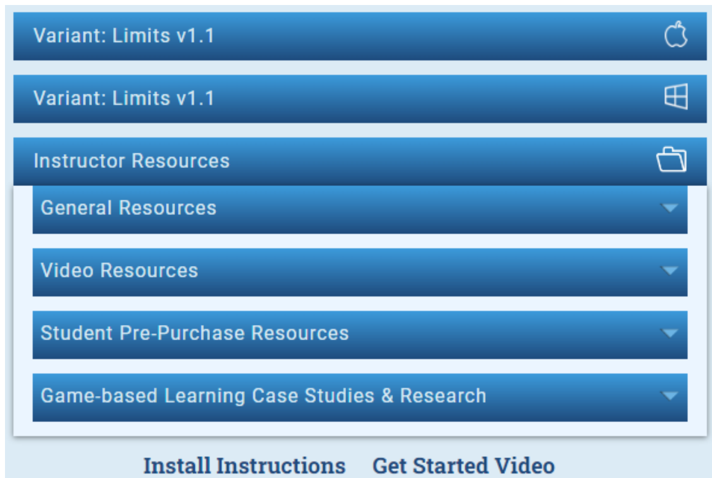
FIRST NAME	LAST NAME	USERNAME	EMAIL	TIME PLAYED (HH:MM:SS)	SESSIONS	CURRENT ZONE	FIRST ACTIVITY (UTC)	LATEST ACTIVITY (UTC)
				6:37:02	4	4	01/18/23 19:46	01/30/23 01:18
				4:42:31	10	4	01/19/23 01:51	02/07/23 00:33
				8:23:55	20	4	01/19/23 02:21	02/04/23 08:59
				7:26:00	15	4	01/19/23 04:26	02/01/23 07:07
				5:15:30	13	3	01/22/23 21:38	02/05/23 05:36
				3:58:14	2	4	01/22/23 22:00	02/05/23 06:54
				5:57:38	8	4	01/23/23 01:17	02/07/23 05:56
				4:42:53	7	4	01/23/23 03:29	02/04/23 04:53
				7:01:58	9	4	01/23/23 18:16	02/06/23 23:22
				16:13:26	23	4	01/24/23 02:28	02/08/23 20:39
				7:05:24	14	4	01/25/23 21:34	02/06/23 00:34

If the instructors need to go deeper with the students' interaction in the game with the puzzles in every zone, they can track them including the number of attempts; how long to solve the puzzle; whether it is completed or not; and whether the student use hint button or not using Classroom Progression or Puzzle Detail section (Figure 3).

Figure 3. Classroom Progression and Puzzle Detail Section

The game also provides resources for instructors to enrich their implementation planning, instructional strategy, and delivery in the classroom. The instructors have access to numerous documents through the general resources like the learning objectives for every section in the game, textbook mapping resources, guides for every zone, puzzle keys, etc. (as shown in Figure 4).

Figure 4. Resources Page for Instructor



3.3 Instrument

The Revised Calculus Concept Inventory (RCCI) is an improved set of questions, from the Calculus Concept Inventory (Epstein, 2007) and the Calculus 1 Concept Inventory (Thompson et al., 2018), for measuring student knowledge of calculus concepts. The RCCI aims to serve the national interest by providing calculus instructors an accurate measurement of students' knowledge of calculus concepts.

The RCCI building started with a national survey, numbers of expert reviews from the Mathematical Association of America's Research in Undergraduate Mathematics Education (MAA-RUME) committee, think aloud with college ready students, pilot testing at 11 schools with 38 instructors and 509 students during the Fall 2021. Moskal et al. (2022) reported there were 20 multiple-choice questions as a result from pilot testing, and the research team kept refining these questions through a rigorous psychometric analysis.

The RCCI reliability report showed Cronbach's $\alpha = 0.73$ (Moskal et al., 2022), which indicates the RCCI has a good internal consistency and is within an acceptable range to use the instrument.

3.4 Treatment Conditions

In this study, the game was provided at no cost to the students. Both instructors agreed to let the students access and play the game outside the classroom time up until the first exam that covered Limits as part of the Calculus I course for the Spring 2023.

The control group used the game at their own pace, with minimum intervention from the instructor. The instructor sent a regular announcement to remind the students that the game was available for them to play, and the game would benefit them in their learning. Beside the game, the instructor used the electronic textbook and the workbook that the college already prepared for the class.

The experimental group had the same electronic textbook and workbook for the course. The students had the same time frame to play the game. However, the instructor played an active role to promote and to encourage the students to use and to play the game. The instructor used the announcements, the quizzes, or the classroom discussion to incorporate the game. The instructor also used the puzzle keys to help the students moving forward between stages in the game.

Both classrooms shared the same syllabus structure where the students had homework; participation components through attendance, quizzes, and projects; chapter exams; and final exam. Both instructors agreed for five extra points for the game completion to be added to the final grade.

3.5 Procedure

The first day of the class started with a quick introduction about the course, the instructor, the students, the course syllabus, and what were the expectations. The instructor gave a short introduction about the study and then let the researcher explain further details on the study, distribute the consent form, and collect the signed consent form. The instructor also emphasized the extra credit that the students could get from completing the game during the study period.

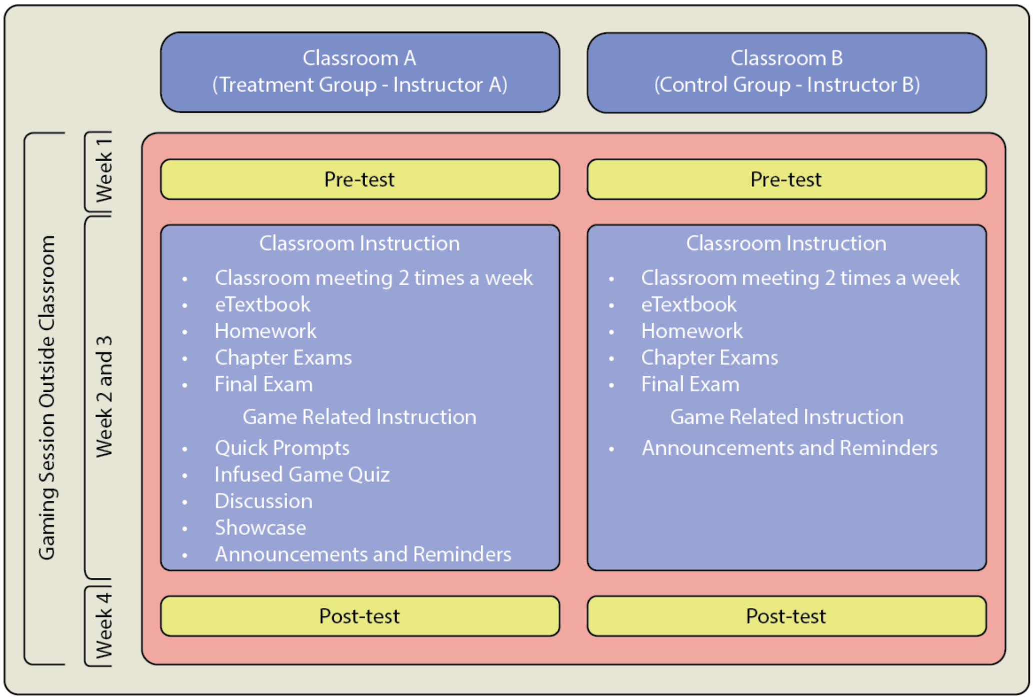
The pre-test using the RCCI opened immediately after the first day of class for a week. Each instructor sent an announcement through the learning management system and reminded the student at the end of the class for the week to complete the pre-test. The students had access to the Qualtrics system that hosts the questions. As agreed by both instructors, the pre-test and the post-test were only for the study and did not affect any score for the class. And the message was clearly relayed to the students to treat the pre-test and post-test as a practice for them on preparing the real exam for the course.

The students in the control classroom played the game on their own pace with minimum intervention from the instructor. They played the game outside the classroom and treated the game as a supplement to the course. The students also knew that if they completed the game, they would be included in a raffle to win $20 Amazon gift card.

The students in the treatment classroom played the game on their own pace, but the instructor was actively involved to promote the game and encouraged the students in many ways. The instructor regularly sent a reminder to the students to play the game, used some game artifact for the quizzes (as shown in Figure x), and facilitated discussion in the classroom whenever the students raised a question or had some difficulties within the game. The students got the same information as the control group that they got an extra credit for completing the game up to the final stage and their eligibility for a raffle to win $20 Amazon gift card.

At the fourth week, the students got their first exam for the semester that covered Limits. At the same period, the immediate post-test using the RCCI also open for the student through the Qualtrics system for a week. Figure 5 shows a complete summary of the study.

Figure 5. Implementation Steps



3.6 Data Analysis

In this study, we used descriptive statistics to find each group mean, median, modes, standard deviation, and checked the distribution before further analysis for learning gains and its significance using ANOVA.

The data analysis utilized gaming indicators from the instructor dashboard to get insights on the student's gaming behavior during the study. The total time spent, number of sessions, and when the student started to play the game for the first time to seek insights between difference gaming intensity and gaming strategy to the learning experience and learning performance.

This study also investigated the relationship between the instructor's instructional strategies, the student's gaming behavior, and the learning performance result.

CHAPTER IV

RESULTS

Instructor as a key factor in DGBL studies often overlooked in determining the outcomes of the study. DGBL studies usually measure of its effectiveness straightforward based on the outcome resulted from using or playing the game. In this study, the report comprises three sections: 1) quantitative result, 2) implementation activity, and 3) students' gaming activity.

4.1 Quantitative Results

This section shared the result of the study to answer these research questions below:

1. Is there any significant difference in the learning performance between the pre-test and post-test result for each classroom?
2. Is there any significant difference in the learning performance between the treatment and the control group in the pre-test and post-test result?
3. Is there any relationship between number of sessions, time-spent in-game, and the learning performance?

This study was designed to compare between an experimental classroom and a control classroom. However, the study ended with only one experimental classroom that had enough data for doing a quantitative analysis. Therefore, instead of using ANOVA, this study used a paired t-test to check the significance of the standardized test result from the pre-test to the post-test.

There were 31 students enrolled and signed the consent document for the study. During the semester, 2 students did not participate completely in the study, 9 students either did the pre-test or post-test. Total 29 students played the game during the study period. Therefore, after cleaning the data, there were 20 students who completed the pre-test, post-test, and played the game.

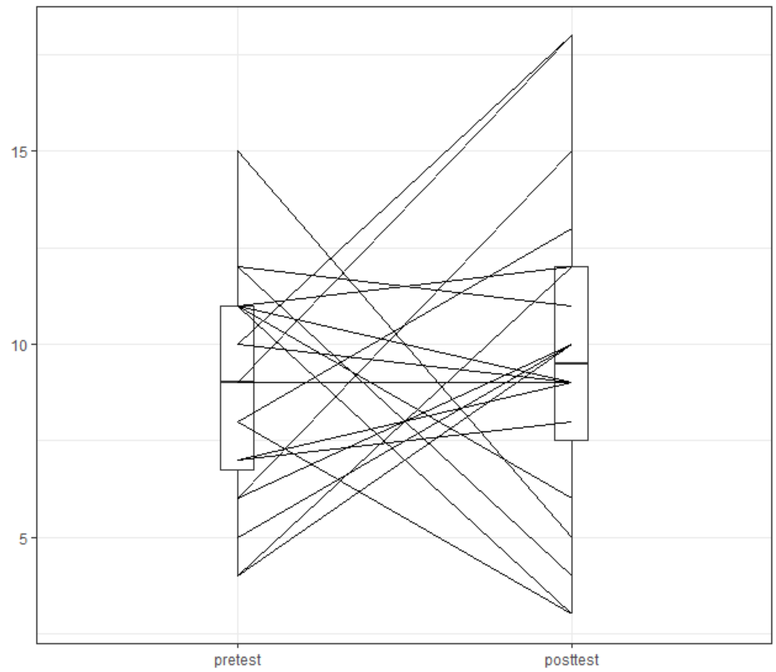
Table 8 below reported the mean for the pre-test as 8.65 with standard deviation 3.27 and the post-test as 9.85 with standard deviation 4.03.

Table 8. Treatment Classroom Sample Mean and Standard Deviation

Group	Count	Mean	Standard Deviation
Post-Test	20	9.85	4.03
Pre-Test	20	8.65	3.27

Figure 6 provided a box plot to visualize the test score result for both pre-test and post-test, including how each data paired with each other.

Figure 6. Box Plot with Paired Data Visualization



With the data set less than 30, the next step was to check whether the differences in the pairs follow a normal distribution. In this situation, a Shapiro-Wilk test was performed to check whether the differences in the pairs show any evidence of non-normality. Figure 7 shared the Shapiro-Wilk test result which did not show evidence of non-normality (W = 0.95, p-value = 0.44).

Figure 7. Shapiro-Wilk Test Result

```
        Shapiro-Wilk normality test

data:  difference
W = 0.95449, p-value = 0.4405
```

Figure 8 showed a histogram for the difference of the pairs and Figure 9 showed the QQ plot for the difference of the pairs. Both graphs served as a visual examination for the difference in the pairs and did not show any evidence of non-normality.

Figure 8. Histogram of The Test Score Difference

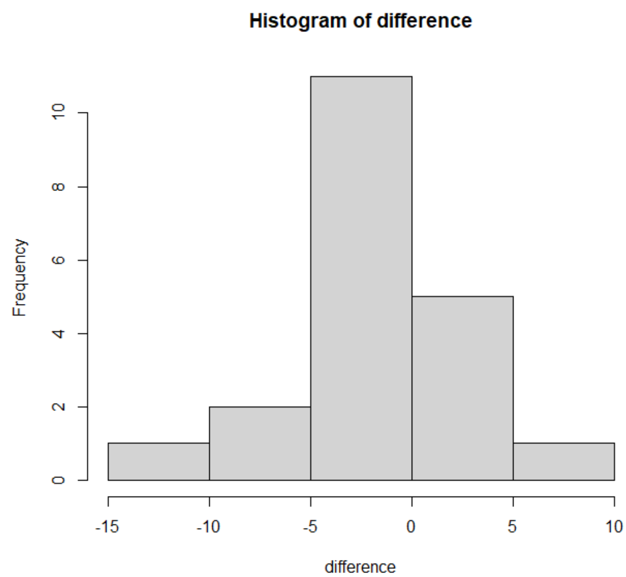
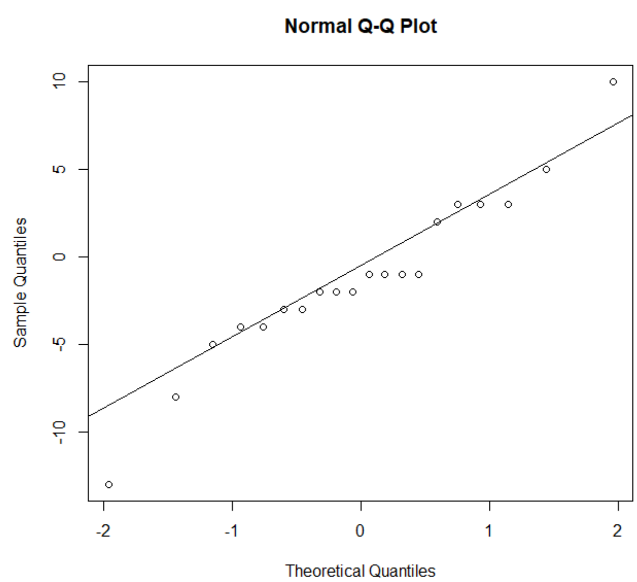


Figure 9. QQ Plot of the Test Score Difference



Paired t-test was used to compare the difference on the pre-test and the post-test result for the treatment classroom. As presented in Figure 11 below, p-value = 0.5048, which is greater than the significance level alpha = 0.05. Therefore, we could not reject the null hypothesis and concluded that the average score of the post-test result in the treatment classroom was not significantly different from the average score of the pre-test.

Figure 10. Paired t-test Result

```
        Paired t-test

data:  pretest and posttest
t = -0.67993, df = 19, p-value = 0.5048
alternative hypothesis: true mean difference is not equal to 0
95 percent confidence interval:
 -3.670476  1.870476
sample estimates:
mean difference
           -0.9
```

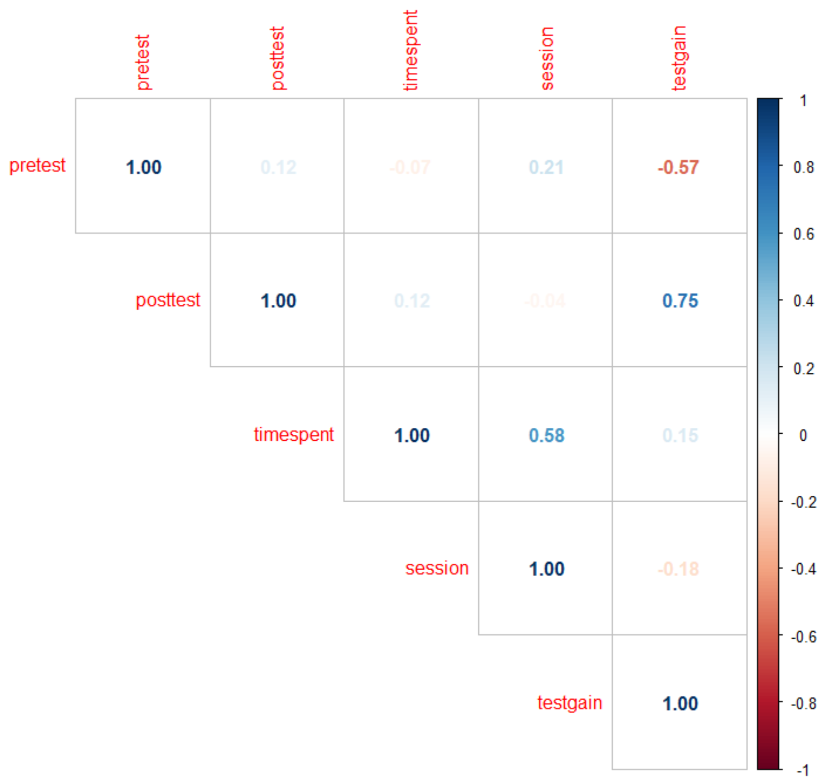
This result partially answered the first research question that sought the significant difference between the pre-test and the post-test result in each classroom because of the absence of the control classroom. The control classroom, which had 25 students who signed the consent form, ended up none of them participated in the study as expected, which caused no valuable data point gathered during the study period.

Without the presence of the control classroom, this study could not answer the second research question that sought the significant difference in the test result between the treatment classroom and the control classroom.

As part of seeking a better understanding of how an implementation plan affects the students' gaming activity and how it relates to the learning gain, this study utilizes the game background data. There are two variables monitored in the game background data. Those are total time spent in the game and the number of sessions attempted to complete the game.

Therefore, to seek an understanding of how those two variables related to the pre-test, post-test result and test gain result, we used correlational analysis. As shown in Figure 11 below, the correlational value for each variable.

Figure 11. Correlational Matrix



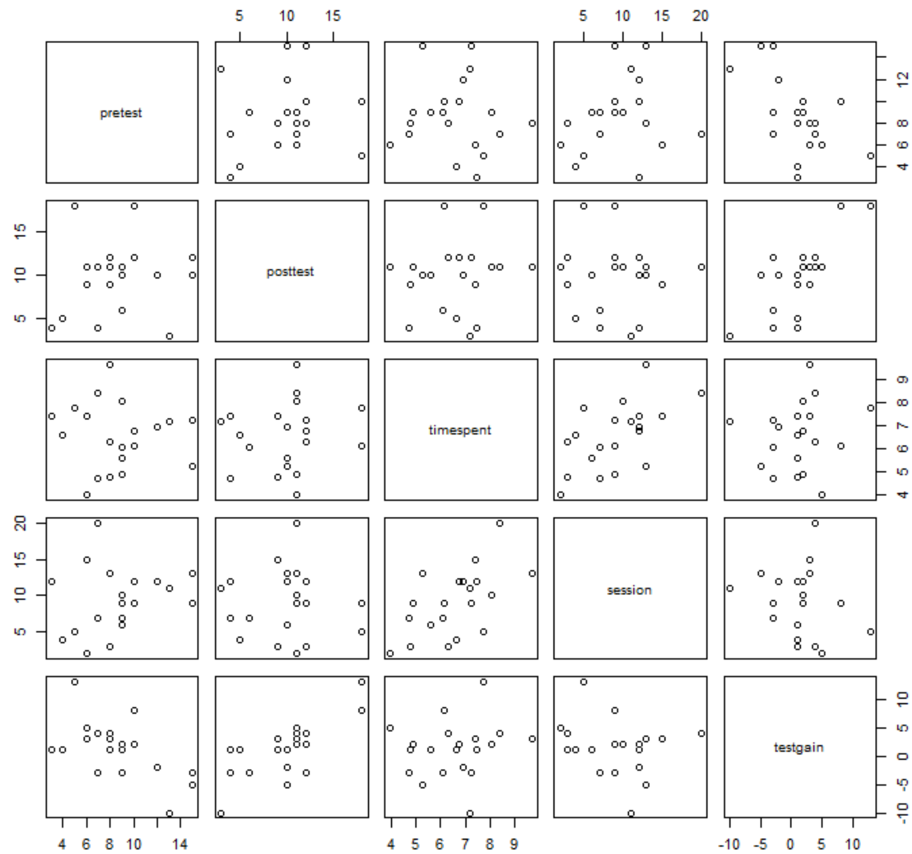
The correlation coefficient Pearson *r* for the total time spent in the game and the post-test result shows a very weak positive relationship (*r* = 0.12, p-value = 0.6015). Also, the total number of sessions in the game and the post-test result demonstrate a very weak negative relationship (*r* = -0.04, p-value = 0.8516). However, the correlation coefficient Pearson *r* between the total time spent in the game and the total number of sessions has a positive medium relationship (*r* = 0.58, p-value = 0.0068).

If we looked at the test scores gain, the correlation matrix shows that pre-test score has a medium negative correlation with the test gain (*r* = -0.57, p-value =

0.0086). In contrast, the post-test score indicates a strong positive correlation with the test gain (*r* = 0.75, p-value = 0.0002). These two results are consistent with higher pre-test score the students will have smaller test gain, and with higher post-test score, the students will have larger test gain.

Both the total time spent in game and number of sessions in game showed a very weak relationship with the test gain in a different direction. The total time spent in game and the test gain showed a very weak positive relationship (*r* = 0.15, p-value = 0.4479), meanwhile the total number of sessions in game and the test gain showed a very weak negative relationship (*r* = -0.18, p-value = 0.5250). Figure 13 below visualizes multiple scatterplots for each variable in this study

Figure 12. Scatterplot for All Variables



To check the significance of the relationship between variables, using the RStudio, we conducted the significance test and the results, as shown in Table 9 below.

Table 9. P-value Matrix for Correlation between Variables

	Pre-Test	Post-Test	Time Spent	Session	Test Gain
Pre-Test	-	0.6149	0.7630	0.3665	0.0086
Post-Test		-	0.6015	0.8516	0.0002
Time Spent			-	0.0068	0.5250
Session				-	0.4479
Test Gain					-

4.2 Implementation Activity

Instructional practices during the implementation are one of key piece information in this study. This section describes the instructional practices during the implementation for both treatment classroom and control classroom to seek understanding whether the differences in the instructional practices affect the student's gaming activity that lead into a better learning performance.

4.2.1 Common activities

Prior to the study, both instructors met together with the research team to discuss and to make an implementation plan for their individual classroom. These activities below were agreed by both instructors for them to do during the study period:

a. Regular classroom announcements.

   During the study period, the instructor sent a series of announcements to keep the awareness about the game. They sent the announcement at the beginning of the study period to let the students know that the game was ready and available for installation. During the week, there were two classroom meetings for Calculus I, and at the end of the second classroom meeting, the instructor sent a reminder for the students to keep playing the game over the weekend.

b. Extra credit for completing the game and the standardized tests.

   Both instructors agreed that giving extra credit for students who complete the game and did the standardized tests would serve as an extrinsic reward to the students. Based on their experience, extra credit worked in most cases to motivate the students in Calculus I classroom. In this study, both instructors gave 5 points to the final grade for students who complete the game, the pre-test, and the post-test.

c. A raffle ticket to win 10 Amazon Gift Card

As another incentive to increase the participation rate and give a monetary reward, the research team prepared $20 Amazon gift card for 10 students who managed to complete the game during the study period. And, both instructors also found this incentive would motivate the students further to do their works in this study.

4.2.2 Treatment classroom activities

Treatment classroom had additional activities as part of the implementation plan set by the instructor. These were the additional activities:

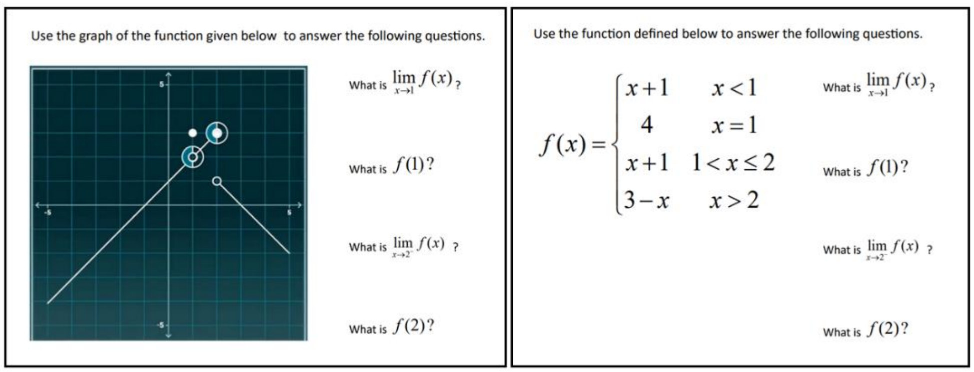
a. Game progress discussion

The instructor occasionally used this activity to trigger the students' curiosity about the game. In this study, the instructor had his Calculus I class scheduled with 20 minutes break with the prior class schedule. This break time gave a chance for the instructor to start early and had about 5 – 10 minutes of informal discourse about how the students progressed in their game. In a normal situation, if he did not have the extra time, he did a quick prompt to ask the students at the beginning of the class session. If any of the students had problems or difficulties with the game, he answered them at the end of the class session or after class.

b. Game infused quizzes

The instructor infused some game puzzles into the regular course quizzes to bridge the learning points between the game and the textbook. Figure x below showed some examples how the instructor did the quizzes.

Figure 13. Game Infused Quiz Example



These two questions are addressing the same concept which the left panel using the game puzzle and the right panel using a textbook formula.

c. Question & Answer session

The treatment classroom offered Q&A session for students who had problems with the game during the study period. The students could reach the instructor through email or ask directly during the class session. However, with the time limitation on a regular class session, the instructor had little flexibility to cover all questions. In this study, the instructor only discussed a major roadblock in solving the puzzles for most students based on his experience using the game in the classroom. He used the pre-shared instructor's guide (as shown in Figure 16) available in the instructor resources to explain how to solve the problem.

Figure 14. Puzzle Key Example

4.2.3 Control classroom activities

In the control classroom, there were no additional activities from the instructor besides the two activities agreed on the implementation plan meeting. The control classroom was purposely setup to mimic a regular classroom setting where a digital game was available as a supplement to the curricula with a minimum intervention from the instructor.

4.3 Student's Gaming Activity

This section explores further the game data from both classroom, to find out the pattern of the student's gaming activity such as the total time they spent in game and the number of session they have during the study.

Through the game data, the instructor for each classroom could review each student's progress in the game. The control classroom showed only 1 student attempted to play the game even though the game was provided at 0 cost to them to play, continuous announcement from the instructor to play the game, and possibility to earn extra credit to their final grade for the course.

The instructor was not surprised with the phenomenon, which not only the game that the students did not play but also the regular homework and other assignments they had, they did not complete them as required. According to the instructor, the control classroom was started with 32 students enrolled, 3 students dropped the course, and almost half of the class barely met the minimum requirement to pass the class.

There were several attempts from the instructor to reach out to the students, including opened the office for them to meet and discuss how they could pass the course. However, few of them were interested in that opportunity. The instructor confirmed this phenomenon was not new and more like a norm for the post-pandemic, where a lot more students who expected to pass the course with a very minimum effort.

In contrast, the treatment classroom, which was part of a new cohort program classroom from the Fall 2022, showed a completely different phenomenon compared to the control classroom. The class had 32 students enrolled, 31 students signed the consent form, 29 students played the game, 20 students who did a complete pre-test, post-test, and played the game.

The statistic for total time spent and the total number of sessions for every student who played the game from the treatment classroom could be found from the instructor dashboard from the game (Figure 17). The students played the game as early as the first day of the class meeting and as the data showed above, there were also a group of students who started late regardless of a continuous announcement from the instructor about the game. The instructor observed the students had a discourse about the game before the class started and, as a typical cohort classroom; they reminded each other about the game and how far they progressed in the game. The instructor noticed that the late starter simply as a typical procrastination behavior from the students with the goal in mind just to complete the game and get the extra credit reward to the final grade.

Figure 15. Game Activity Dashboard

TIME PLAYED (HH:MM:SS)	SESSIONS	CURRENT ZONE	FIRST ACTIVITY (UTC)	LATEST ACTIVITY (UTC)
3:58:14	2	4	01/22/23 22:00	02/05/23 06:54
6:18:46	3	4	01/30/23 16:25	02/05/23 05:57
4:45:42	3	4	01/31/23 01:11	02/04/23 01:39
6:37:02	4	4	01/18/23 19:46	01/30/23 01:18
4:09:21	5	4	01/26/23 02:33	02/07/23 07:18
7:44:57	5	4	02/01/23 00:24	02/04/23 22:02
5:36:24	6	4	02/01/23 17:33	02/04/23 06:23
4:42:53	7	4	01/23/23 03:29	02/04/23 04:53
6:05:04	7	4	02/02/23 04:32	02/05/23 09:45
5:57:38	8	4	01/23/23 01:17	02/07/23 05:56
7:01:58	9	4	01/23/23 18:16	02/06/23 23:22
4:54:00	9	4	01/26/23 04:13	02/07/23 00:24
6:08:21	9	4	01/31/23 22:05	02/04/23 01:10
7:15:44	9	4	02/01/23 03:31	02/04/23 03:54
4:42:31	10	4	01/19/23 01:51	02/07/23 00:33
8:04:26	10	4	02/02/23 08:48	02/06/23 08:44
8:04:36	11	4	02/01/23 23:55	02/06/23 22:37
7:11:42	11	4	02/02/23 05:33	02/07/23 05:32
6:44:36	12	4	01/29/23 23:38	02/03/23 21:57
6:55:44	12	4	01/30/23 17:13	02/03/23 02:34
13:26:26	12	4	02/03/23 07:40	02/06/23 01:26
7:25:41	12	4	02/03/23 21:45	02/06/23 04:51
5:15:30	13	3	01/22/23 21:38	02/05/23 05:36
9:41:08	13	4	01/29/23 17:43	02/02/23 04:48
7:05:24	14	4	01/25/23 21:34	02/06/23 00:34
7:26:00	15	4	01/19/23 04:26	02/01/23 07:07
7:10:34	16	4	01/31/23 00:54	02/06/23 06:13
8:23:55	20	4	01/19/23 02:21	02/04/23 08:59
16:13:26	23	4	01/24/23 02:28	02/08/23 20:39

The duration of the total time spent in the game ranging from 4 hours to over 16 hours with the least 2 attempts and up to 23 attempts. On average, the students could complete the game within 6.5 hours. However, the quantitative analysis result on the pre-test and post-test comparison showed no significant difference even though the average of the post-test score was higher than the average of the pre-test score.

Another insight from the gaming activity, the students whoever reached the final stage of the game and accomplished all the tasks did not revisit the game for practice purpose. The game data showed the end point of the gaming activity varies but mostly ended early prior to the end of the study period. The gaming period was set to end by February 11, 2023 which the students were not allowed to access the game further. The game was built with a classic ending storyline that accommodate a close ending. Therefore, it was expected to see a get it done behavior from gaming perspective. Between stages, the player would have the tendency to see what would be the next, but once all the challenges accomplished, less likely for the player to re-play the game unless they find it challenging to make up the time and try to score higher.

This study used two different implementation plans for two classrooms with an expectation to see any difference in students' gaming activity patterns resulted from the treatment and the control classroom. The basic assumption was the cohort classroom that started from the Fall 2022 had not reached the bonding levels that made a big difference with a non-cohort classroom. The cohort and non-cohort condition in this study potentially became a cofounding variable that affected the students gaming activity.

This study partially answered the research question whether any difference in student's gaming activity because of different implementation plan. Even in the treatment classroom, the gaming activity showed a different level between students. However, without any gaming activity from the control group, the gaming activity from the students in the treatment classroom could not get inferred solely as a result of the difference in the implementation plan done by the instructor.

CHAPTER V

CONCLUSIONS

5.1 Discussion

In early 2000, cohort programs in higher education gained traction because of a major decline in student retention and graduation rate in the United Kingdom and the United States that gave a rational to the idea for improving student completion rates through forming learning groups (Jarzabrowski & Wilson, 2002; Unzueta et al., 2008). Students in cohort programs function as a supporting group on the journey sharing mutual success and individual achievement, collaborate on tasks and assignments, have a positive peer relationship, share a sense of accomplishment of completing the class assignments, and have chances to explore their talents through collaboration with different peers (Maher, 2005; Mandzuk et al., 2005; Opacich, 2019; Seed, 2008).

The most disturbing finding in this study was the fact that none of the students in the control group who signed the consent form fulfilled their requirement for the study. There are two possible explanations for why the treatment classroom played the game and the control classroom did not play the game as explained below.

First, the game integration into the class activities as explained in the result section that done by the instructor in the treatment classroom did affect the students' gaming activity. Although, in this study we cannot confirm the relationship with a very definitive answer because of the missing gaming activity from all students in the control classroom.

Second, the cohort grouping led to a greater student involvement than the non-cohort group experienced. The control classroom was a non-cohort program classroom, which meant the students were not part of the same class from the beginning, but they were required to pass Calculus I for their degree requirement. The treatment classroom, which a cohort program that started in the Fall 2022, showed a higher rate of participation, which was consistent with a characteristic of a cohort classroom.

During the planning stage of this study, it was expected on the control classroom to see fewer students' participation or engagement in the gaming activity. The rationale behind was using a digital game without a sufficient instruction other than just asked them to play the game made the students felt frustration rather than excitement (Jääskä & Aaltonen, 2022). However, in this study, we found an extreme situation where not a single student who signed the consent document in the control classroom participated in the study and even half of the classroom barely met the requirement for passing the course.

Daniels et al. (2021) pointed the significant decrease in the students' perceptions of success during the pandemic while their perceptions of cheating increased, which aligns with what the instructor experienced in the control classroom. The instructor reported this phenomenon became a new trend after the decision to set the classroom back to the face-to-face classroom.

Grade inflation also becomes another issue during pandemic and post-pandemic in education. Grade inflation is a global phenomenon where students are awarded higher marks without demonstrating that they have a higher level of mastery (Finefter-Rosenbluh & Levinson, 2015), and unfortunately become more apparent during the pandemic (Karadag, 2021; Sanchez & Moore, 2022). The instructor emphasized multiple times to the students that they were required to do all necessary assignments as outlined in the syllabus to pass the course. However, not every student took it seriously, and the instructor suspected they experienced a grade inflation during the pandemic and still expecting to have such leniency applied.

A possible explanation from the student's perspective that still need to be confirmed through a further interview or a focus group discussion, the students treat the game as an assignment that needs to be completed and submitted, which might jeopardize the goal of fostering learning. The cohort classroom itself creates a safe environment for the students to play the game and help each other accomplish the game until to the end stage. They collaborated to find answers to the puzzles, but not to seek the meaning as long as the task completed. Basic assumption on playing an educational game is there should be learning transfer through the gameplay. However, there are several potential problems with that assumption, for example rather than explore and learn what if the students choose to seek the “correct answer” (Myers, 2010), dishonesty problem where the students seek solutions from others to win it (Consalvo, 2007), and not everyone interested in gaming and consider them worthy as learning tools (Whitton, 2010).

Hanghøj and Brund (2010) argued that game-based teaching is a complex phenomenon involving teacher roles, game design, and pedagogical approaches. In the control classroom, practically it was her first-time experience using the game in her course. Therefore, the control classroom, we defined the minimum pedagogical approach to integrate the game in the course through informing the game availability and asked the student to play by themselves.

In the treatment classroom, the instructor had approximately 3 years' experiences with the game and was familiar with the resources available for the game. As suggested in some literatures, instructor holds a central role in facilitating learning in the game-based teaching by connecting to the curriculum and translating the game world to the real-world context (Li et al., 2021; Meyer & Sørensen, 2011; William et al., 2011). The instructor aligned the game context to his course activities, like quizzes, classroom discussion, and provide a chance for the students to ask questions related to the game. At the same time, the instructor raised an issue about time constraint in his class session pretty much just enough to deliver the course material. In this study, the instructor had approximately 10 minutes extra time to bring discourse about the game by coming early to the classroom with some of the students who came early because of the recess 20 minutes they had prior to the Calculus I. However, it was just too short for a fruitful discussion for building a connection between the game and the course. Time constraint is a common barrier in game-based setting (Sánchez-Mena & Martí-Parreño, 2017).

Despite all the efforts that the instructor did to integrate the game into the classroom activities, the study suggested no significant difference in the pre-test and the post-test result. This result might indicate that the game itself is not effective. Although, in a different study with the same game, Thomas and Rugh (2021) demonstrate a significant odds ratio that indicate for the students who play the game have 1.52 times higher for a favorable outcome to pass the Calculus I with a minimum C than the students who are not using the game. However, the odds ratio itself does not relate directly to the game effectiveness and how the game implementation affects the result.

As an educational game, Variant: Limits (Thomas et al., 2017) has various supporting elements for instructor who want to use the game in the classroom. The instructor's resources provide an alignment matrix for each section in the game to the textbook, there is an instructor's guide to each puzzle in the game, and the dashboard allows the instructor to monitor how far the students progressing in the game. With all available resources, there is a high expectation that the students able to learn through the gameplay. However, William et al. (2011) revealed even though the students were more likely learning from the game through their engagement, but as students still differed in their understanding of the topic, the game itself did not guarantee that learning would occur.

Educational content usually is the main component in the game design for most of educational games, but the game genre can be another influential factor for students to get engaged in the game. Game genre has the potential to develop quality learning experience and supporting students' learning style (Khenissi et al., 2016; Rapeepisarn et al., 2008). In this study, the game has a classical ending storyline, which implies a complete resolution of events. In the game, the player explores the virtual world to solve mathematical puzzle that led to the next stage of the game. During the gaming session, while the player moves between stages, works on the puzzles, the learning transfer occurs naturally within the process. However, in gaming perspective, solving puzzles to continue to the next stage is not necessarily positively correlate with learning transfer process. Therefore, even there are multiple attempts to play the game until the final stage, the attitude for completing the game as simple as winning the game without concerning for learning transfer is very high (Consalvo, 2007; Myers, 2010).

The variety of total time spent in the game and the numbers of session for the students to play the game are two variables that become an interest for further investigation. This study did not able to make a comparison how these two variables made any difference in supporting learning transfer. However, this study gave an insight how gaming activity had relationship to the test gain even with a very low relationship. Replicating the study with a better control and treatment classroom setup might give further idea how these two variables will affect the result in learning transfer.

5.2 Conclusions

Game-based teaching is not the same as using a digital game in the classroom. It is not only a simple modification of the course to embed some game components. And it is not also a method for giving an external motivation to the students through playing a game. A deeper and broader pedagogical approach needed to have a more holistic approach to get the most learning experience in a game-based learning environment. Therefore, instructor involvement in game-based pedagogy study is very essential, not just as a subject of a study, but as a collaborative researcher as suggested by Barab and Squire (2004).

Therefore, it is important to work closely with the instructor in any future DGBL studies. There are sets of activity that need to be done together between the research team and the instructor to build the pedagogical framework for the study. The instructor needs to be equipped with game-based pedagogical skill that allow them to create a pedagogical framework for the classroom, bridge the learning process, and connect the students to the topic (Kangas et al., 2016; Li et al., 2021).

The roles for the instructor for the study need to be defined as it hold a key factor during a game implementation. Any instructor who decides to use a digital game in the classroom will need to understand each possible roles for a game-based classroom. The roles will guide further detail on their implementation plan and sync the plan with the classroom activity. Hanghøj and Brund (2010) identified four roles of instructor during in a game-based classroom implementation: instructor, playmaker, guide, and evaluator. Shah and Foster (2015) emphasized the importance for instructor to use the game as pedagogical partner and as an anchor for facilitating a social, affective, motivational, and cognitive learning experience.

The instructor's experience with the game that supposed to give an advantage in game-based implementation not sufficient to nail a significant result in fostering learning to the students. The pedagogical approach not just simply custom tailors the course activity to include game activity like what the instructor in the treatment classroom did in this study. A game-based teaching will need more than just using the game as a supplement for outside the classroom activity. There should be more risk-taking decisions to use the classroom regular time to play the game with the students as a substitute to the regular curricula despite the limited amount of time as a classic barrier in game-based classroom setting. And it is worth to pursue further study for looking best practices how to use the game as a supplement to the curricula or infused to the curricula, how long and how often the students should play the game, and how to assess the learning transfer for a better implementation practice.

5.3 Limitations

The results in this study might be not a significant result and based on a very small sample size with an extra ordinary condition where the control group did not function as expected. However, this study might reflect the real classroom situation where without a lot of intervention from the research team, there are plenty rooms of deviation from the instructor, the students, and the game itself.

Therefore, the need for a game-based pedagogy is very important for having a better insight in measuring the effectiveness of DGBL in the classroom, not merely about the effectiveness of the game itself, but also the effectiveness of an implementation plan in contributing a significant result.

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APPENDIX

LISTS OF THE STUDY

Author(s)	Types of Study	Game Title	Gaming Context	Gaming Activity
Pellas and Vosinakis (2018)	Mixed-Method	Robot Vacuum Cleaner	In-class learning activity (Game-based lesson plan), Individual Play, Collaboration (several students play together using 1 device), Multi-player (several students play individually and collaborate virtually)	6 sessions, 4 weeks, 240 minutes
Wang et al. (2018)	Quantitative Study	Speedy World	In-class learning activity, Individual Play	80 minutes
Addy et al. (2018)	Mixed-Method	Operation: Ebola!	In-class learning activity, Individual Play	1 - 10 sessions, 90 minutes
Wilson et al. (2018)	Quantitative Study	Geniverse	In-class learning activity, Individual Play	40 - 110 minutes, several days, 3 weeks or more
Sung et al. (2018)	Mixed-Method		In-class learning activity, Multi-player (several students play individually and collaborate virtually)	100 minutes
Wallon et al. (2018)	Mixed-Method	The Golden Hour	In-class learning activity, Collaboration (several students play together using 1 device)	
Bell and Gresalfi (2017)	Mixed-Method	Boone's Meadow	In-class learning activity (Game-based lesson plan), Collaboration (several students play together using 1 device)	4 days, 10 minutes or more
Garneli et al. (2017)	Quantitative Study	Gem Game	In-class learning activity, Individual Play	60 minutes
Gould and Parekh (2017)	Mixed-Method	Mystery of Taiga River	In-class learning activity (Game-based lesson plan), Individual Play, Collaboration	18 sessions, 1 hour

Author(s)	Types of Study	Game Title	Gaming Context	Gaming Activity
Kinnebrew et al. (2017)	Quantitative Study	Surge	In-class learning activity, Individual Play	1 week, 180 minutes
Chizary and Farhangi (2017)	Qualitative Study		In-class learning activity, Collaboration (several students play together using 1 device)	
Cohen et al. (2017)	Quantitative Study	Griddle	In-class learning activity, Individual Play	4 sessions, once a month and two at the third month
Kim and Ke (2016)	Quantitative Study	OpenSim	Lab-setting, Individual Play, Collaboration (several students play together using 1 device)	30 minutes
Bakker et al. (2016)	Quantitative Study		In-class learning activity, Individual Play	20 weeks
Israel et al. (2016)	Quantitative Study	Cell Command, Crazy Plant Shop, and You Make Me Sick!	In-class learning activity, Individual Play	180 minutes, 6 weeks
Hsu et al. (2016)	Quantitative Study	Saving The Princess	Lab-setting, Individual Play	35 minutes
Shelton and Parlin (2016)	Mixed-Method	GeePeerS Math	In-class learning activity, Individual Play	
Epstein et al. (2016)	Quantitative Study	Bacon Brains	In-class learning activity, Individual Play	6 sessions, 240 minutes
Ault et al. (2015)	Mixed-Method	Reason Racer	In-class learning activity, Individual Play	10 sessions over 6 weeks
Brom et al. (2015)	Quantitative Study	Orbis Pictus Bestialis and Bird Breeder	In-class learning activity, Individual Play	30 minutes
Sadler et al. (2015)	Quantitative Study	Mission Biotechnology	In-class learning activity (Game-based lesson plan), Individual Play	10 sessions, 2 weeks
Chang et al. (2015)	Quantitative Study	The Math App	In-class learning activity, Individual Play	18 sessions, 20 mins, 9 weeks
Martin et al. (2015)	Quantitative Study	Refraction	In-class learning activity, Individual Play	7 weeks, 140 minutes

Author(s)	Types of Study	Game Title	Gaming Context	Gaming Activity
Foster and Shah (2015)	Mixed-Method	Dimension M	In-class learning activity (Game-based lesson plan), Individual Play	1 session, 16 weeks, 1600 minutes
Hung et al. (2015)	Mixed-Method	Motion Math: Hungry Fish	In-class learning activity, Individual Play	40 minutes
Mohd Syah et al. (2015)	Quantitative Study	Math ACE	In-class learning activity, Individual Play, Small group activity	5 days, 5 hours
Marino et al. (2013)	Mixed-Method	Filament Games	In-class learning activity (Game-based lesson plan), Individual Play, Collaboration (several students play together using 1 device)	
Pareto (2014)	Quantitative Study	Find Pair, Pack Many, Remove All, and Divide	In-class learning activity, Individual Play, Collaboration (several students play together using 1 device)	1 session a week, 12 weeks.
Hsiao et al. (2014)	Quantitative Study	ToES	In-class learning activity, Individual Play	4 sessions, 4 weeks, 160 minutes
Chu and Chang (2013)	Quantitative Study		In-class learning activity, Individual Play	60 minutes
Chen et al. (2013)	Qualitative Study	The Alchemist's Fort	In-class learning activity, Individual Play	3 sessions, 135 minutes, 3 weeks
Smith (2014)	Mixed-Method	Quest Atlantis	In-class learning activity, Individual Play	5 days, 120 minutes or more
Katmada et al. (2014)	Mixed-Method		After School / At Home, Collaboration (several students play together using 1 device)	14 weeks
Chen et al. (2015)	Mixed-Method	Carrot Land	In-class learning activity, Collaboration (several students play together using 1 device)	20 minutes
Barko and Sadler (2013)	Quantitative Study	Mission Biotech	In-class learning activity (Game-based lesson plan), Individual Play	2 - 3 weeks total 5 - 7 hours

Author(s)	Types of Study	Game Title	Gaming Context	Gaming Activity
Nejem and Muhanna (2013)	Quantitative Study		In-class learning activity, Individual Play, Collaboration (several students play together using 1 device)	
Marino et al. (2012)	Mixed-Method	You made me sick and Prisoner of Echo	In-class learning activity, Individual Play	60 minutes
Hsu and Tsai (2013)	Quantitative Study		In-class learning activity, Individual Play	30 minutes
Klisch et al. (2013)	Quantitative Study	CSI: Web Adventures	In-class learning activity, Individual Play	2 sessions, 90 minutes, 1 week
Anderson and Barnett (2013)	Mixed-Method	Supercharged	In-class learning activity, Individual Play	3 days
Hwang, Hung, et al. (2013)	Quantitative Study	Butterfly Ecology	In-class learning activity, Individual Play	120 minutes
Kolovou et al. (2013)	Qualitative Study	Hit The Target	After School / At Home, Individual Play	3 weeks
Lin et al. (2013)	Quantitative Study	Monopoly	After School / At Home, Individual Play	40 minutes
Eseryel et al. (2013)	Mixed-Method	McLarin's Adventure	In-class learning activity, Individual Play	2 sessions, 16 weeks, 1600 minutes
Plass et al. (2013)	Quantitative Study	Factor Reactor	After School / At Home, Multi-player (several students play individually and collaborate virtually)	30 minutes
Hwang, Wu, et al. (2012)	Quantitative Study	Jigsaw Puzzle, Matching Game, and Shooting Game	In-class learning activity, Individual Play, Multi-player (several students play individually and collaborate virtually)	150 minutes
Panoutsopoulos and Sampson (2012)	Quantitative Study	Sims 2: Open for Business	In-class learning activity, Multi-player (several students play individually and collaborate virtually)	
Hwang, Sung, et al. (2012)	Quantitative Study		In-class learning activity, Individual Play	1 session, 60 minutes

Author(s)	Types of Study	Game Title	Gaming Context	Gaming Activity
Ke and Abras (2013)	Mixed-Method	Lure of The Labyrinth, Ker-Splash, and The Sim Lemonade Stand	Lab-setting, Individual Play	15 sessions, 1 hour, 3 weeks
Schifter et al. (2012)	Qualitative Study	Sheep Trouble and Weather Trouble	In-class learning activity, Individual Play	
Ernst and Clark (2012)	Mixed-Method	YoYo Game, Catch the Clown, Bug Catcher, and Falling Fruit	In-class learning activity, Individual Play	
Bai et al. (2012)	Mixed-Method	Dimension M	In-class learning activity, Individual Play	18 weeks
Shin et al. (2012)	Quantitative Study	Game Boy: Skills Arena	In-class learning activity, Individual Play	3 sessions, 5 weeks, 225 minutes and 2 sessions, 13 weeks, 390 mins
Ke (2013)	Mixed-Method	Decention, Factor Dazzle, Fantasy Stock Exchange, Sim Lemonade Strand, Ker-Splash, Late Delivery, Square Off, Bathroom Tiles, Turtle Pond, and Lure of the Labyrinth	After School / At Home, Individual Play	2 sessions, 10 hours, 5 weeks
Chen et al. (2012)	Quantitative Study	Cross number puzzle	In-class learning activity, Individual Play	2 sessions, 2 weeks, 80 minutes
O’Rourke et al. (2012)	Qualitative Study		In-class learning activity, Collaboration (several students play together using 1 device)	10 weeks, 100 - 200 minutes
Sánchez and Olivares (2011)	Quantitative Study	Evolution, BuinZoo and Museum	In-class learning activity, Individual Play	5 sessions, 450 minutes, 5 weeks
Habgood and Ainsworth (2011)	Mixed-Method	Zombie Division	Lab-setting, Individual Play, Collaboration (several students play together using 1 device)	4 hours, 34 days

Author(s)	Types of Study	Game Title	Gaming Context	Gaming Activity
Ritzhaupt et al. (2011)	Mixed-Method	DimensionM	In-class learning activity, Individual Play, Collaboration (several students play together using 1 device)	1 session, 16 weeks
Klisch, Miller, Wang, et al. (2012)	Quantitative Study	Uncommon Scents	Lab-setting, Individual Play	5 sessions, 225 minutes, 3 weeks
Klisch, Miller, Beier, et al. (2012)	Quantitative Study	N-Squad	Lab-setting, Individual Play	3 sessions, 60 minutes - 120 minutes
Meluso et al. (2012)	Mixed-Method	Crystal Island	Lab-setting, Individual Play	3 days, 120 minutes
Chang et al. (2012)	Quantitative Study	Millionaire	In-class learning activity, Individual Play	2 sessions, 160 minutes, 2 weeks
Clark et al. (2011)	Mixed-Method	SURGE	In-class learning activity, Individual Play, Collaboration (several students play together using 1 device)	45 minutes
Eseryel et al. (2011)	Mixed-Method	McLarin's Adventures	In-class learning activity, Individual Play	2 sessions, 16 weeks, 1600 minutes
Spires et al. (2011)	Quantitative Study	Crystal Island	In-class learning activity, Individual Play	60 minutes
Annetta et al. (2010)	Qualitative Study	MEGA	After School / At Home, Multi-player (several students play individually and collaborate virtually)	
Gillispie (2010)	Mixed-Method	Dimension M	After School / At Home, Individual Play	3 sessions, 5 days, 100 minutes
Chen et al. (2010)	Qualitative Study	Formosa Hope	In-class learning activity, Individual Play	1 session, 6 hours, 6 weeks
Panagiotakopoulos (2011)	Mixed-Method	Play With Numbers	Lab-setting, Individual Play	4 sessions, 60 minutes
Lee and Chen (2009)	Quantitative Study	Frog Leaping Online	Lab-setting, Individual Play	6 weeks
Hickey et al. (2009)	Quantitative Study	Quest Atlantis	In-class learning activity (Game-based lesson plan), Individual Play	15 hours

Author(s)	Types of Study	Game Title	Gaming Context	Gaming Activity
St Clair-Thompson et al. (2010)	Quantitative Study	Memory Booster	In-class learning activity, Individual Play	6 - 8 weeks
Ke (2008a)	Quantitative Study	ASTRA EAGLE	In-class learning activity, Collaboration (several students play together using 1 device)	8 sessions, 320 minutes, 4 weeks
Sedig (2008)	Quantitative Study	Super Tangram	In-class learning activity,	10 sessions, 400 minutes
Ke (2008b)	Mixed-Method	ASTRA EAGLE	After School / At Home, Individual Play	5 weeks
Papastergiou (2009)	Mixed-Method	LearnMem2	In-class learning activity, Individual Play	2 hours
Houssart and Sams (2011)	Qualitative Study	Lines	In-class learning activity, Individual Play	60 minutes
Lynch et al. (2008)	Mixed-Method	Ootle-U	In-class learning activity (Game-based lesson plan),	19 days
Ke and Grabowski (2007)	Quantitative Study	ASTRA EAGLE	In-class learning activity,	2 sessions, 320 minutes, 4 weeks
Van Eck (2006)	Quantitative Study	Robot Vacuum Cleaner	Lab-setting, Individual Play	1 session, 50 minutes