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# The Effects of a Platform Digital Game-Based Learning Environment on Undergraduate Students Achievement and Motivation in a Multivariable Calculus Course

MALCOM W. DEVOE

*Georgia State University*

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## ACCEPTANCE

This dissertation, THE EFFECTS OF A PLATFORM DIGITAL GAME-BASED LEARNING ENVIRONMENT ON UNDERGRADUATE STUDENTS ACHIEVEMENT AND MOTIVATION IN A MULTIVARIABLE CALCULUS COURSE, by MALCOM W. DEVOE, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements of the degree, Doctor of Philosophy, in the College of Education and Human Development, Georgia State University. The Dissertation Advisory Committee and the student's Department Chairperson, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty.

---

Iman C. Chahine, Ph.D.  
Committee Chair

---

Joseph R. Feinberg, Ph.D.  
Committee Member

---

Mandy Swygart-Hobaugh, Ph.D.  
Committee Member

---

Natalie S. King, Ph.D.  
Committee Member

---

Ying Zhu, Ph.D.  
Committee Member

---

Date

---

Gertrude Marilyn Tinker Sachs  
Chairperson, Department of Middle and  
Secondary Education

---

Paul A. Alberto, Ph.D.  
Dean  
College of Education and Human Development

## **AUTHOR'S STATEMENT**

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Malcom W. Devoe Jr.

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of this dissertation is:

Malcom W. Devoe Jr.  
3714 Waterford Club Drive  
Lithia Spring, GA 30122

The director of this dissertation is:

Dr. Iman Chahine, Ph.D.  
Middle and Secondary Education  
College of Education and Human Development  
Georgia State University  
Atlanta, GA 30303

## CURRICULUM VITAE

Malcom Devoe

ADDRESS: 3714 Waterford Club Drive  
Lithia Spring, GA 30122

### EDUCATION:

|                  |      |   |
|------------------|------|---|
| Ph.D.            | 2018 | Georgia State University<br>Department of Middle and Secondary<br>Education |
| Masters Degree   | 2012 | Georgia State University<br>Computational and Applied Mathematics           |
| Bachelors Degree | 2004 | Morehouse College<br>Computer Science                                       |

### PROFESSIONAL EXPERIENCE:

|                |   |
|----------------|---|
| 2017 – present | Mathematics Instructor<br>University of West Georgia  |
| 2018 – present | Adjunct Mathematics Professor<br>Mercer University  |
| 2018 – present | Subject Matter Expert of Computational &<br>Applied Mathematics and Online Math Course<br>Designer<br>USG eCore |
| 2014 – present | Online Professor of Mathematics<br>USG eCore  |
| 2014 – 2017    | Professor of Mathematics<br>Atlanta Metropolitan State College  |
| 2013 – 2014    | Mathematics Instructor<br>University of West Georgia  |
| 2013 – present | Adjunct Professor of Mathematics<br>Atlanta Technical College   |
| 2013 – 2013    | Adjunct Professor of Mathematics<br>Atlanta Metropolitan State College  |
| 2009 – 2012    | Mathematics Instructor<br>Georgia State University  |

2011-2012

Math Support Teacher  
Georgia State University

PRESENTATIONS AND PUBLICATIONS:

Devoe, M. W. (2018, May). *The Effects of Digital Game-Based Learning on Undergraduate Student Achievement and Motivation in A Multivariable Calculus Course*. 2018 eCore Annual Meeting. Carrollton, GA

Devoe, M. W. (November/December). 'Round 'N' 'Round We Go!. *Mathematics Teacher Vol. 111, No. 3*, p.172 – 175

Devoe, M. W. (2017, October). *The Effects of Digital Game-Based Learning on Undergraduate Student Achievement and Motivation in A Multivariable Calculus Course*. 5th Annual Black Doctoral Network Conference. Atlanta, GA

Devoe, M. W. (2017, June). *The Effects of Digital Game-Based Learning on Undergraduate Student Achievement and Motivation in A Multivariable Calculus Course*. 11th Annual GAMTE Conference. Eatonton, GA

Devoe, M. W. (2017, March). *The Effects of Digital Game-Based Learning on Undergraduate Student Achievement and Motivation in A Multivariable Calculus Course*. 11th Annual GAMTE Conference. Eatonton, GA

Devoe, M. W. (2017, August). *The Effects of Digital Game-Based Learning on Undergraduate Student Achievement and Motivation in A Multivariable Calculus Course*. Georgia Scientific Computing Symposium. Athens, GA

Devoe, M. W. (2014, October). *Educational App Modeling and Game Design*, GAMTE Conference, Eatonton, GA

Devoe, M. W. (2012, May). *Cellular Neural Networks with Switching Connections*, Mathematics and Statistics Department, Georgia State University, Atlanta, GA

Devoe, M. W. (2011, September). *Pade` Approximation*, Mathematics and Statistics Department, Georgia State University, Atlanta, GA

Devoe, M. W. (2011, October). *Newton's Method for Solving Nonlinear Systems*, Mathematics and Statistics Department, Georgia State University, Atlanta, GA

Devoe, M. (2011, December). *Linear Finite Difference Method*, Mathematics and Statistics Department, Georgia State University, Atlanta, GA

PROFESSIONAL SOCIETIES AND ORGANIZATIONS

2018

(MAA) Mathematics Association of America

# The Effects of a Platform Digital Game-Based Learning Environment on Undergraduate Students Achievement and Motivation in a Multivariable Calculus Course

by

Malcom W. Devoe Jr.

Under the Direction of Dr. Iman Chahine

## ABSTRACT

This study examined the effects of a researcher-designed digital game-based learning (DGBL) environment called Adventures of Krystal Kingdom on undergraduate students' mathematics achievement and motivation in a Multivariable Calculus course. Multivariable Calculus is a specific area of computational and applied mathematics that focuses on the differentiation and integration of functions of several variables in fields like physics and engineering. The study employed a single exploratory embedded case study design with quantitative and qualitative techniques. A case study is the appropriate methodology for this study, which is a bounded system that facilitates a deeply contextualized understanding of a case through giving descriptions, analyses, and interpretations (Yin, 2014). The quantitative sample comprised 29 undergraduate students, and the qualitative sample included 6 students selected through stratified sampling based on the level of achievement. Quantitative data was collected using two surveys:

demographic and motivation surveys, and two tests: academic achievement test and a game performance test. Analysis of quantitative data used a paired sample t-test. Qualitative data were collected from interviews, observations, and artifacts. Analysis of qualitative data used coding procedures suggested by Creswell (2014) where patterns were identified and grouped to allow the emergence of themes. The results of the study indicated no statistical significance in achievement ( $p=0.88 > 0.05$ ), however, there was overall improvement found in achievement scores of the students who played the game. Three themes emerged from the study: 1) Undergraduate students saw the use of the Adventures of Krystal Kingdom as learning tool to enhance their understanding of concepts in Multivariable Calculus.; 2) Undergraduate students saw the use of the Adventures of Krystal Kingdom as a way to engage themselves in mathematical fun in a digital environment; and 3) Undergraduate students saw input semiotics, automated reflexes, Task Relevant Support and other core mechanics as components that affect students' gameplay. Results of the interviews, observations, and artifacts revealed that students benefited from using DGBL as an alternative approach to learning mathematics and to use such advanced techniques in biology, engineering, and computational neuroscience. The overall results indicate that DGBL used in the study was an appropriate teaching and learning tool to improve students' mathematics skills.

**INDEX WORDS:** Undergraduate students, Digital Game-Based Learning, mathematics computer games, educational video games, and mixed method techniques



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Degree of

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Mathematics Education

In

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Georgia State University

Atlanta, GA

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## CHAPTER 1: THE PROBLEM

### **Problem Statement**

During the 21<sup>st</sup> century, American employers have found it increasingly difficult to find candidates with the necessary skills to hold positions in the STEM fields. These positions include scientist, engineers, and physicists (Charette, 2016). Currently, data show that there has been a decrease in U.S. college graduates with degrees in engineering and computer science. In spring of 2006, the Conference Board, an international not-for-profit organization, performed a survey on human-resource professionals to determine whether the skills from college graduates were adequate for success in the today's STEM fields (Daggett, 2010). The results were negative in that the employers shared graduates were not gaining the knowledge that would enable them to be successful after graduation (Daggett, 2010). Thus, universities and colleges need to groom students who are ready to take on the jobs in our STEMS fields. According to the Conference Board, "The education and the STEM positions must agree that applied skills integrated with core academic subjects are the essential design structure for creating an educational system that will prepare our college graduates to be successful in the modern workplace and community life" (Daggett, 2010, p.10).

In addition to students not being prepared for STEM careers, advanced applied mathematics courses such as Multivariable Calculus, Linear Algebra, and Ordinary and Partial Differential Equation courses have been identified as the "weed out" courses that undergraduate students drop out and discourage them to change their major to a non-STEM degree because of the rigor. As a result, the mathematics department experience low enrollment in these advanced mathematics courses and less math majors involved in their department. On a website dedicated for video game enthusiasts, a physics student of a major university stated, "Sophomore year in general is tough because of the math requirements on top it (Calculus III [Multivariable

Calculus]) and Differential Equations. If you can make it through that... it just gets worse.” (What is the “weed-out” course(s) for your major?, 2015, para. 11). Another student stated “The weed out courses are Calc II (even though the higher math courses will weed people out) ... I have actually seen many people change their major after these courses” (What is the “weed-out” course(s) for your major ?, 2015, para. 29). A third student shared “As an engineering major, three [courses] that come to mind are Calc II, Statics, and Dynamics. I actually have a friend that dropped [a math course], and is now a Med Tech or something” (What is the “weed-out” course(s) for your major?, 2015, para. 46). “Americans’ performance in math and science is falling farther and farther behind; the National Center for Education Statistics reports that 29 countries outscored American students in math in 2012, and 22 in science” (Blake, 2016, The problem with weed out classes, para. 8).

Moreover, many college professors are constantly faced with engagement issues in the classroom. Lewis (2014) explained, “Currently in colleges and universities across the U.S. too many students pursuing a STEM career are not succeeding in freshman mathematics courses” (“APLU Science and Mathematics Teacher Imperative”, p. 10). The dismal rate of students not completing their STEM degrees causes the university to experience high DFW rates (student who receive “D”, “F”, or withdraw), low rates of persistence, and limited exposure to mathematical habits of the mind (Lewis, 2014). According to Freeman et Al. (2014), “[Engagement tools] increase students’ performance in science, engineering, and mathematics” (Freeman et. al, 2014, p.14). Using engagement strategies increases the students’ examination performance by half of a letter grade (Freeman et. al, 2014). Thus, it is suggested that professors use engagement strategies such as active learning to accommodate these issues (Lewis, 2014).

Therefore, there is a need to implement an alternate approach to learning and preparing students for STEM positions.

The purpose of this study was to examine how platform games affect the learning of undergraduate students in Multivariable Calculus. Specifically, the study addressed the following questions:

1. How does a platform game affect the learning of undergraduates in a Multivariable Calculus class? How does a platform game affect the motivation of undergraduates in a Multivariable Calculus class?
2. What features and dimensions of the platform game are necessary to maintain the engagement of the students during the learning and gaming process? What kind of threats do students face?

The study examined the following hypotheses:

1. There is a significant difference between the learning of the undergraduate students who received the platform game.
2. There is a significant difference between the motivation level of the undergraduate students who received the platform game.

### **Significance**

The study has theoretical and practical significance. The study is significant in that it studies the use of games in a college learning environment for the purpose of teaching advanced mathematics content at the college level. The challenging world of games is shaping students' cognitive abilities and expectations about learning (Papastergiou, 2009). In fact, many instructors and professors have noticed that creating scholastic content and practices seem tedious and meaningless to students (Papastergiou, 2009). Extensive studies have shown that

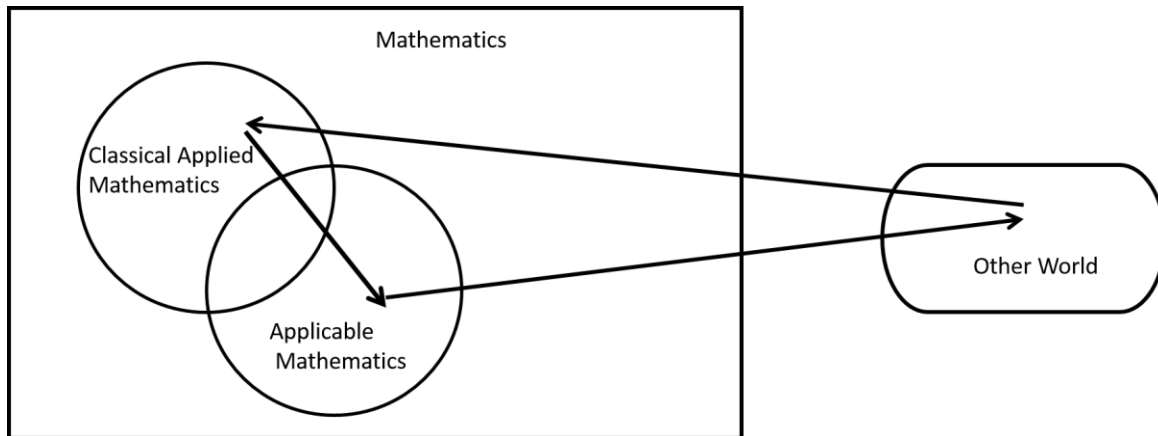
educational computer games significantly promote motivation towards learning, foster metacognitive regulation, and engage them in active cognitive thinking (Fe , 2008). Other studies have confirmed that DGBL is more effective in promoting knowledge of computer memory concepts for students than the non-gaming approach (Papastergiou, 2009). The use of DGBL environments would be essential if these findings can also apply to undergraduate students in advanced undergraduate applied mathematics courses. Pivec (2005) argues that, learning by doing, active learning, and experiential learning are key components of a game-like learning environment. This study could contribute to the emerging body of literature exploring the shift in the role of DGBL environments from being solely devoted to entertainment to its potential role as a driving force of motivation and engagement in student centered learning environments.

In this chapter, I examine Blum's Modeling Cycle and highlight the major historical development as it informed the teaching and learning of mathematics with a particular focus on instructional games. Blum's Modeling Cycle is a well-established and refined model that has been frequently used over time to improve mathematical teaching among educators (Werner & Borromeo Ferri, 2009). Another strength of the model is that its different stages are well-partitioned to depict potential cognitive barriers that could occur during the student's modeling process (Werner & Borromeo Ferri, 2009). This allows us to make the appropriate pedagogical adjustments such as supplemental instruction within one of the stages to remove any blockages and allow the student to experience transformational learning to move forward to the next stages in order to complete the whole cycle. I also discuss and analyz the Attention, Relevance, Confidence, and Satisfaction (ARCS) model (Keller, 1987), which was used to dissect the

motivational variable, an important component that is used to understand the effectiveness of games. The chapter ends with a list of key terms and their definitions.

### Mathematical Modeling Cycle

Mathematical modeling is defined as converting a problem into mathematical form to solve real-life problems (Berry & Houston, 1995; Cheng, 2001). According to Voskoglou (2014) during the mid-1970s, mathematical modeling was a method used by scientists and engineers for solving real-world problems in certain disciplines like physics, industry, constructions, economics and other science related fields. Pollack (1979) is one of the first scholars to have explicitly illustrated the use of mathematical modeling for teaching mathematics. Pollack's mathematical modeling cycle displays the interaction between mathematics and the real-world (Voskoglou, 2014). See Figure 1.



*Figure 1.* Pollack's Circle of Modelling. Adapted from Trapezoidal Fuzzy Method for Assessing Students' Mathematical Modeling Skills, by M. Voskoglou, 2014, American Journal of Educational Research, 2, p. 1.

Pollack's mathematical modeling cycle is also known as the circle of modeling, which showed that there was a continual looping between the other world (real world) and the universe of mathematics. More specifically, the cyclic process began by starting with a problem in the

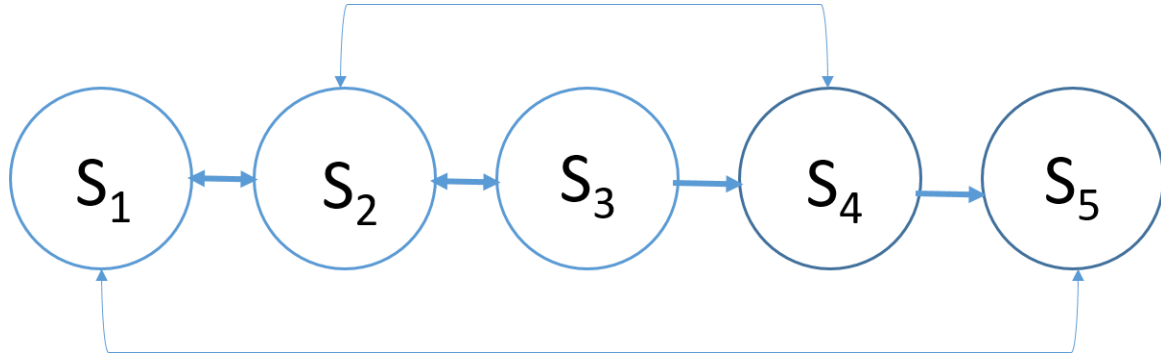
real world. From there, we move to the second scheme where mathematics is created and used to find the solution. Lastly, we go back to the real world to interpret and validate the mathematical results. However, it must be noted that if the results are invalid, then we revert to the previous circle again (Voskoglou, 2014).

Overtime, succeeding scholars such as Barry and Davies (1996), Edwards and Hauson (1996), Blomhøj and Jensen, Greefath, Blum and LeiB (2007), Berry and Nyman (1998), Adams (2001), Cheng (2001), Maull and Berry (2001), Blum et. al. (2002), Kaiser (2005), Borromeo-Ferri (2006), Zbiek and Conner (2006) have uniquely redefined the mathematical modeling cycle as a process that is made up of five main stages. Moreover, Voskoglou (2014) have analyzed and modified the process of mathematical modeling to use as a method for teaching applied mathematics. As a result of their work, the modified mathematical modeling cycle evolved into the following stages:

1. Stage 1( $S_1$ ): Analysis of the problem (understanding the statement and recognizing the restrictions and requirements of the real system).
2. Stage 2( $S_2$ ): Mathematization (formulation of the problem and construction of the model).
3. Stage 3( $S_3$ ): Solution of the model
4. Stage 4( $S_4$ ): Validation (control of the model, which is achieved by reproducing through the model, the behavior of the real system under the conditions existing before the construction of the model. In case of a system having no previous ‘history’ an extra [usually simulation] model can be used for this purpose).
5. Stage 5( $S_5$ ): Interpretation of final implementation of them to the real system in order to give the “answer” to the real-world problem (Voskoglou, 2014).



Below is the modified mathematical modeling cycle as Markov chain.

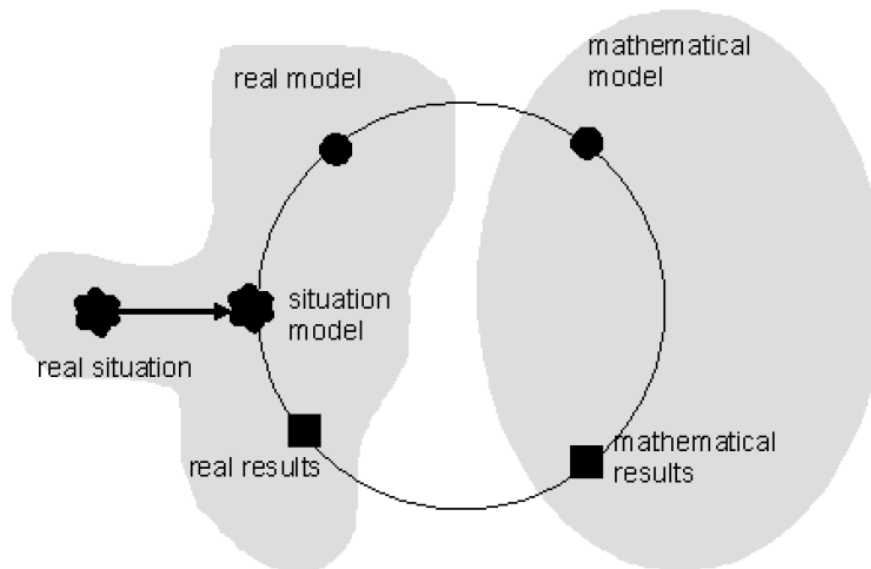


*Figure 2.* Flow-diagram the MM Success Adapted from Trapezoidal Fuzzy Method for Assessing Students' Mathematical Modeling Skills, by M. Voskoglou, 2014, American Journal of Educational Research, 2, p. 2.

However, there has been some debate on the strengths and weaknesses of the modified modeling cycle based on related literature. Blum (2011) identified several major strengths and weaknesses in the modified modeling cycle. One strength is that this model is able to identify various blockages that occur when a student works on a mathematical exercise. For instance, this cycle identifies blockages such as lacking algebraic skills, overlooking essential elements in the problem text, impeding formulation of problem text and blockages in communication. Additionally, this model can be extended to identify metacognitive competencies and other blockages that arise in modeling cycles. Another strength of this model is that it can identify the first barrier of the cognitive process and potential cognitive barriers that could arise (Blum, 2011). These modeling cycles allow students to develop mathematical competencies which is “the ability to construct and to use mathematical models by carrying out those various modeling steps appropriately as well as to analyze and compare given models” (Blum, 2011, p. 31). In contrast, in modeling, the solution path is not always clear and sometimes involves assumptions that lead students to reflect on if they made the correct assumptions (Kirst et al., 2015).

Modeling problems are unfamiliar to students in that the problem has never been presented to them before (Kirst et al., 2015). Sometimes the steps within each component of the modeling cycle are uncertain and have chaotic endings or results (Kirst et al., 2015). Another drawback is that one could find themselves constantly refining their mathematical models and solutions (Kirst et al., 2015).

**Construction of Blum’s Model.** Along with Pollack, many other scholars such as Walter Kintsch and James Greeno have created their own mathematical modeling cycle. As a result, Blum was able to construct his mathematical modeling cycle. Blum’s modeling cycle (See Figure 3) was designed to target applied mathematical problems to identify barriers, blockages, and magnify students’ knowledge in a specified mathematical content, help students to better understand the world, and support mathematical learning (Blum, 2011).



*Figure 3.* Blum and Lieb Mathematical Modeling Cycle. Adopted from *Mathematical Modeling in Class Regarding to Technology*, by H. Siller, and G. Greefrath, 2010, Proceedings of CERME, p.2136.

Since my study involves the use of mathematical modeling with technology, I used the extended mathematical modeling cycle depicted in Figure 4.

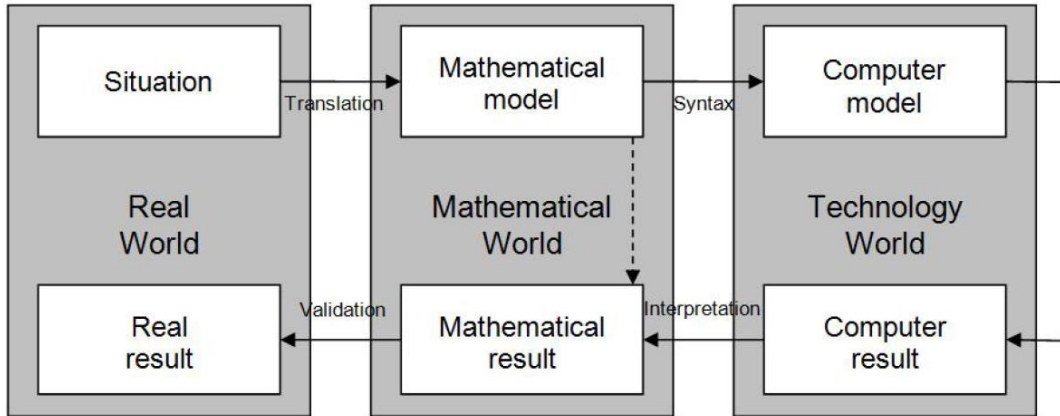


Figure 4. Extended Blum and LieB Mathematical Modeling Cycle. Adopted from Mathematical Modeling in Class Regarding to Technology, by H. Siller, and G. Greefrath, 2010, Proceedings of CERME, p.2137.

According to Siller and Greefrath (2010) modeling with the use of computer algebraic system (CAS) or technology creates an environment for easy discussions on modeling problems which can be analyzed in the real-world of life and students. It is the CAS and the discussion where the motivation of mathematical education is affected because students begin to recognize the importance of mathematics in everyday life (Siller & Greefrath, 2010).

There are many reasons why mathematical modeling should be combined with technology. Geiger (2011) suggests that CAS provide the student with the chance to investigate real and complex applications of mathematics. He also states that CAS is a tool, which enable students to maintain and engage extremely complex problems (Geiger, 2011). Greefrath et al. (2011) suggest that CAS can be used to interpret and validate the solution as an important appendix to the modeling cycle. Fuchs and Blum (2008) advocate Möhringer's aims. Möhringer

suggests that five key aims can be reached using modeling with technology. In the pedagogical aims, Siller and Greefrath state “technology with the help of modeling cycle it is possible to connect skills in the problem solving and argumentation” (Siller & Greefrath, 2010, p.2138). Siller and Greefrath also argue “this approach indicates that students are able to learn application competencies in elementary or complex situation” (Siller & Greefrath, 2010, p.2138). For psychological aim, technology helps with understanding and interpreting modeling and it improves the memory of mathematical content (Siller & Greefrath, 2010). As for the cultural aims, with technology mathematical modeling provides visual representation of mathematics as science along with its affect in culture and society (MaaB, 2005a, 2005b). In pragmatical aims, technology with modeling aid in comprehending, grappling, and assessing known dilemmas (Siller & Greefrath, 2010). Technology is most helpful in modeling in that it helps to simplify difficult procedures, especially for computationally intensive or deterministic activities, and visualizing processes and results (Siller & Greefrath, 2010).

In this study, Blum’s Extended Mathematical Modeling Cycle was used to dissect and analyze the learning process in Adventures of Krystal Kingdom and its effect on the dependent variable of learning and achievement. The ARCS model (Keller, 1987) was used to discuss and analyze the dependent motivation variable. Blum’s Extended Mathematical model and ARCS model were used to show the role of the independent variables in the DGBL process.

**History of Blum’s Model.** Blum and LeiB first proposed their 7-step modeling cycle in 2005. The situation component of the model was derived from the research studies of Kinstch and Greeno (1985), Staub and Reusser (1995), and Verschaffel et al. (2000). The other element of their cycle originated from applied mathematical problem solving (Burghes, 1986; Burkhardt, 2006; Pollak, 1979). After deriving and constructing the model, Blum’s Mathematical modelling

cycle was first used in a study of project DISUM, which is the *Didactical intervention modes for mathematics teaching oriented towards self-regulation and directed by tasks*. It was used to analyze the empirical findings on the teaching and learning of mathematical modeling, particularly with grades 8-10. In addition, the study also focused on understanding the cognitive view on mathematical modeling behavior of students and teacher in learning environments with modeling tasks. Blum's model in this project was able to review some difficulties, competencies, and observable cognitive barriers that students experience during the mathematical modeling process (Blum,2011). Blum's and Leib's model was also used in Ji (2012). In this study, Ji discovered that instructional modeling significantly increased the students' mathematical competency ability. In Saeki (2016), he aimed to compare how Japanese and Australian teacher use opportunities to promote pupils' switching among the mathematical modeling cycle. The results from this study indicated the teachers' need to change the approach that was adopted to switch between modeling cycles to account for the various levels of students' ability. The findings from this study also revealed that the usage of the dual modeling cycle framework and its direct instructions on exchange between mathematical modeling deepened their understanding from 2D to 3D model. In fact, it even motivated all students to remain engaged and participate at their ability level and gain access to complex modeling in class discussions. Blum and Leib modeling cycle was found in Sol, Gimenez, and Rosich (2011). Their study was used to understand the difficulties that students had when performing the beginning steps and the validation process. Their study showed that functional reasoning was a missing link, which must be used in order for students to improve their initial mathematical modeling steps (Sol., Gimenez, & Rosich, 2011). In Frejd and Arleback (2011), Blum's and Leib's model was used to study Swedish upper-secondary students' mathematical modeling competency. The results from

their study showed that students were very proficient in the sub-competencies to formulate a problem and assign parameters, variables, and constants to a model with a sound understanding of the model and situation. It also showed that students were not so proficient in understanding the goal and selecting a model. Finally, Blum's and Leib's model was modified with a technology component. This was known as their extended mathematical modeling cycle. After using this extended mathematical modeling cycle in Geiger (2011), it revealed that using technology such as a Computer Algebraic System (CAS) gave students a chance to investigate authentic and complex applications of mathematics (Geiger, 2011). His study also showed that a CAS can be an instrument that enables a student to continue to engage in rigorous complex problems even when students may have some gaps in their current mathematical knowledge (Geiger, 2011). Using Blum's and Leib's model, Geiger (2011) unveils its consistency with the role of technology from Confrey and Maloney (2007) in that it should be used as a vehicle to engage with a problem in real life context (Geiger, 2011).

Blum's model among many others have been used to reduce the cognitive load when compared with the other teaching methods. For instance, Blum did a study in autumn 2006 and 2007 with a classroom where he compared students' achievements with students who do and do not use the modeling cycle. His findings showed that students who used his model showed significant progress than with those students who did not use the modeling cycle (Blum, 2011). Students showed a significant improvement in their modeling competency. In Ortiz's and Santos's (2011) study on mathematical modeling in secondary education, the results in their case study on high school students suggest that when using the mathematical modeling cycle students improved competence in distinguishing between relevant and non-relevant data. Blum's and Leib's modeling cycle was used for identifying competencies in terms of the cycle and

blockages of students who attempt to create a mathematical model (Schaap et al, 2011). Thus, the wide use of this framework in various studies in mathematics indicates that Blum and LieB modeling cycle contributes to students' success in understanding and conceptualizing, removing blockages, and justifying the meaning of their work and becoming better modelers (Stillman, 2011).

### **ARCS Model**

Motivation is recognized as one of the key components to stimulate student learning in various activities (Dweck, 1986; Keller, 1987; Klawe, 1998; Malone, 1981; Norman, 1993; Sedighian & Sedighian, 1996). There are many theories and other bodies of literature that use the factors of motivation in classroom environments. These theories can be found in ARCS Model (Keller, 1987), Intrinsic Motivation (Malone & Lepper, 1988), and Time Continuum Model of Motivation and Motivational Framework for Culturally Responsive Teaching (Wlodkowski, 1989, 1999). However, ARCS Model (Keller, 1987a) and the Intrinsic Motivation Theory (Malone & Lepper, 1988) are the most heavily used in terms of studies that relate to instructional games. Thus, I examined these models and theories.

According to the ARCS Model, there are four components that must be implemented to create a motivated learning environment: (a) Attention, (b) Relevance, (c) Confidence, and (d) Satisfaction; however, the Intrinsic Motivation theory recommends the four components to be (a) challenge, (b) curiosity, (c) control, and (d) fantasy.

Table 1

*The Comparison of Two Motivation of ARCS Model and Intrinsic Motivation*

| ARCS Model<br>Keller(1987)  | Intrinsic Motivations<br>Malone and Lepper (1988)  |
|---|--|
| <ul style="list-style-type: none"> <li>• Attention: obtaining and sustaining</li> <li>• Relevance: Meet the needs of the learners.</li> <li>• State goals.</li> <li>• Confidence: Develop an expectancy for success.</li> <li>• Satisfaction: How good do people feel about their accomplishments?</li> <li>• Give learners control over reaching goals that are intrinsically motivating.</li> </ul> | <ul style="list-style-type: none"> <li>• Provide optimally challenging activities.</li> <li>• Change sensory conditions to arouse curiosity.</li> <li>• State goals or allow goals to emerge.</li> <li>• Provide an optimal level of challenge.</li> <li>• Provide performance feedback.</li> <li>• Provide control over the learning environment.</li> <li>• Use fantasy to help the student experience power, success, fame, and fortune. Also helps learners relate new learning to a past experience.</li> </ul> |

*Note.* Adopted from “Motivation and Its Relationship to the Design of Educational.” By Blixer, 2006, Paper Presented at the NMC, Cleveland, Ohio, p. 13.

The two models seem to differ by the fantasy factor of Intrinsic Motivation Theory. The idea of the fantasy component has been debated with scholars (Habgood, Ainsworth, & Benford, 2005). There were other findings that indicate that the Intrinsic Motivation theory barely supports and encourages experimental studies. This is because it uses a narrow approach and does not use variables that can be measured (Astleitner & Wiesner, 2004). Thus, we used the ARCS model for this study to measure the effect of Adventures of Krystal Kingdom game on the learner’s motivation. This model has been known to be used to evaluate the learners’ motivations in several learning environments (Keller & Suzuki, 2004; Carson, 2006; Small, Zakaria, & El-Figuigul, 2004).



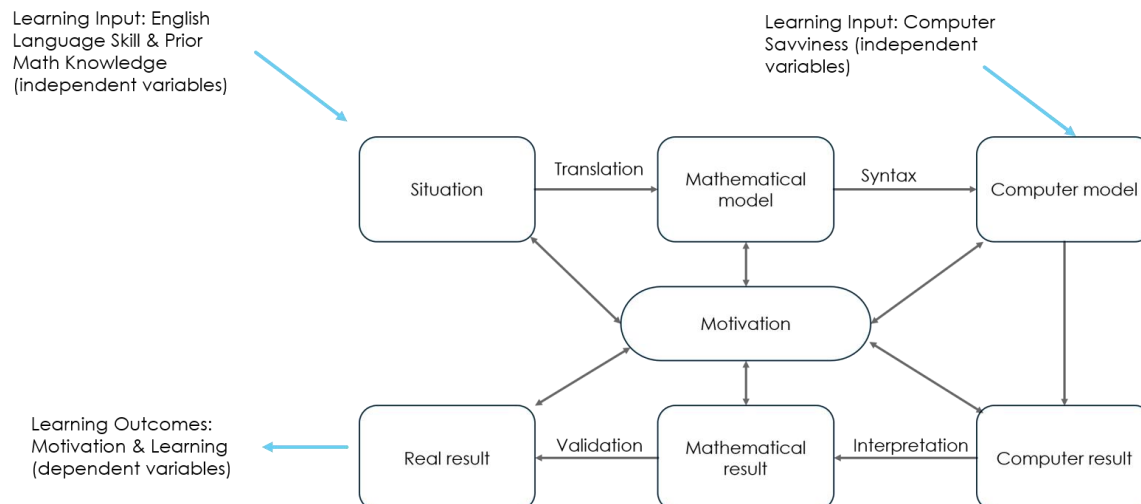
The *attention* component focuses on gaining and maintaining the attention of learners in a learning environment and can be reinforced through (a) continual arousal where acquiring attention through presenting easy and surprising activities, (b) inquiry of arousal which is where attention is gained by attracting a student's knowledge-seeking behavior (this is sometimes acquired through presenting questions and problems), and (c) variability, which is the ability to hold students' interest through presenting them with a variety of exercises (Keller, 1987a). The next component is *relevance*. Relevance deals with the things that we interpret as instrumental to meet the needs and fulfill the inner desires, along with personal goals (Keller, 1983). *Relevance* can be accomplished through (a) familiarity where we adjust our instructional style to the learners' previous knowledge, (b) goal orientation, which displays the importance of a lesson through connecting to the students on how this skill will be useful in their future courses, jobs, or research, and (c) motive matching: deals more with the instructional approach that a lesson is being taught than the content of what is taught; the use of teaching strategies in a group or individual activities or games allows the instructional process to be more appealing and stimulate interest in the lesson (Keller, 1987). The fourth component is *confidence*, which relates to the expectancy of the learners' success which is accomplished through (a) learning requirements, (b) success opportunities where different levels of achievement are available, and (c) personal control, which refers to students having some level of support and control over their learning environment and providing feedback, specifically corrective feedback, which may help the students to see what caused their mistakes, and what can be done to correct them (Keller, 1987a). Lastly, *satisfaction* centers around the learners' feelings about the achievements and how it can be enhanced through (a) natural consequences where they are presented with opportunities to use new knowledge in the real world or virtual environment, (b) positive consequences when

students are given feedback along with positive reinforcement, and (c) equity where the outcomes of the course are consistent with the initial purpose and expectation; this is achieved through making consistent standards and consequences for the students' accomplishments (Keller, 1987).

In this study, the effectiveness of Adventures of Krystal Kingdom instructional game on learners' motivation were measured by a motivation Survey (see Appendix A), which was created based on the four components of the ARCS model. The *relevance* component of ARCS model indicates that thorough understanding of the game rules and instructions to the students' prior knowledge affects the students' motivation. This shows that students with different background knowledge, computer savviness, and language can be stimulated heavily if the game relates closely to their background knowledge. Thus, I considered background knowledge, computer savviness, and language background as independent variables that may affect students' drive, achievement, and effectiveness of the instructional game.

In order to develop the conceptual framework of the study, Blum's and Lieb's extended modeling cycle (Greefrath & Stiller, 2010) and ARCS motivation model (Keller, 1987) are merged together (See Figure 5). The figure below displays the conceptual framework and the relationship among the variables and the adopted theories in the study. The conceptual framework includes three main parts: learning input, the game learning process within the extended modeling cycle, and the learning outcomes.

Figure 5 below displays three independent variables, English language skill, previous mathematical knowledge, and computer savviness, as components that affect the motivation and the game learning process in the extended modeling cycle. These components were inserted in the Blum and Lieb extended mathematical modeling cycle.



*Figure 5. Modified Extended Blum and LieB Model Cycle.*

In the extended modeling cycle, according to Blum and Fuchs (2008) and MaaB (2005a, b), students are able to learn application competencies in elementary and complex situation, and understand the content and improve their memory of mathematical content. Furthermore, the model supports a balanced picture of mathematics as science, and aids students in understanding, managing, and evaluating known situations.

Motivation was considered the center and an outcome of the cycle because motivation stimulated the game learning activity, and it was affected by the instructional game and the independent variables of the English language skill, prior mathematics knowledge, and computer skill. Achievement is the other outcome of the cycle in the game learning and motivation.

### **Definition of Key Terms**

*Platform Games*, “are cartoonish games in which an avatar moves through a vertically exaggerated environment, jumping on and off platforms at different heights, while avoiding obstacles and battling enemies” (Adams, 2014, p. 71).

*Role-Playing Game (RPG)*, refers to a game in which players take on roles of character in fictional or virtual setting where the players act out these roles within the narrative of the game (Adams, 2014).

*Digital game-based learning (DGBL) environment*, refers to an environment where learning occurs by using computer games for educational objectives (Erhel & Jamet, 2013).

*Flow*, is the state of being completely immersed in an activity that is interestingly enjoyable while the individuals [or gamers] are focused on their game play (Csikszentmihalyi, 1990).

*Motivation*, refers to the internal factor that stimulates people to work to specific goals (Keller, 1987).

*Learning*, refers to the acting of obtaining or achievement of knowledge or skills through study, experience, or instruction

*Adventures of Krystal Kingdom™*, is an instructional game designed by me, the researcher, that engages and teaches students Multivariable Calculus by involving players in completing three mathematics related missions within a 2-D immersive environment designed with advanced graphics.

*Multivariable Calculus*, refers to a specific area of computational and applied mathematics that focuses on the differentiation and integration of functions of several variables (Rogawski, 2012).

*Features and Dimensions*, refers to the core mechanics of a platform or role-playing game.

*Core Mechanics*, “consist of the data and the algorithms that precisely define the game’s central rules and internal operations” (Adams, 2014, p. 351).

*Virtual-Coupling environment*, refers to a DGBL environment.

*Internal economy*, includes all resources that are not part of the real-life economy (Adams, 2014).

*Physics*, refers to the science of motion and force (Adams, 2014).

*Progressive mechanisms*, governs the player's progress throughout a series of challenges (Adams, 2014).

*Tactical maneuvering*, is about the challenges associated with moving units through a space (Adams, 2014).

*Social interaction*, refers to players talking with one another, the rules that controls the relationships among players such as forming and breaking alliances, the nature of team play, and so on (Adams, 2014).

*Input semiotics*, refers to an ability to translate symbols on input devices into movement and interactions in-game (Davis et al, 2011).

*Automated reflexes*, a tactical maneuvering component that refers to quick automated movements and responses to game action (Davis et al, 2011).

*Cutscene*, refers to a sequence or event scene in a video game in which the player cannot interact during game play (Adams, 2014).

### **Summary**

In summary, this section gives the foundation for the variables that are to be studied. The Blum's Extended Mathematical modeling cycle suggest that the engagement of students in a virtual coupled environment or DGBL environment yields superlative achievement. This formed the foundation of the hypothesis that investigated the effect of students' playing the Adventures

of Krystal Kingdom game on their learning. ARCS model recommended the four factors in which the other hypothesis was tested to identify the effects of instructional games on motivation. Blum's Extended Mathematical Modeling cycle and ARCS Model suggest that students' computer savviness, mathematics background knowledge, and language background impact the effectiveness of instructional game.

## CHAPTER 2: REVIEW OF LITERATURE

### Introduction

Throughout the world, computers are changing the way we interact and stimulate each other. For instance, we use email servers, instant messaging and other electronic mediums to exchange information. Technology in video games functions as a stimulus for the brain. According to *Issue in Social Media and the Future of Games: The effect of online gaming on future generation*, studies by Rasul (2014) and Young et al. (2012) have shown that technology, specifically video games, improve “quick thinking, accuracy, strategy and anticipation, situational awareness, developing reading and math skills, perseverance, pattern recognition, estimating skills, inductive reasoning and hypothesis testing, mapping, memory, concentration, ability to rapidly and accurately recognize visual information”, teamwork and cooperation, management, and real world skills (Rasul, 2014). Moreover, digital games were more effective than the nongame instructional conditions in the learning outcome from the students’ cognitive competencies through a systematic overall review of the meta-analyses on digital games and learning from reviewed studies from 2000 to 2012 (Clark, Tanner-Smith, & Killingsworth, 2016). In fact, computers are changing the way we learn, communicate, shop, and entertain each other. Particularly in education, advancement in technology has transformed the landscape of the classrooms and created versatile spaces for student engagement and learning. This literature review is a synthesis of the research on digital game-based learning (DGBL) and how its usage has affected the learning outcomes of students and to investigate how role-playing or platform games affect the learning of undergraduate students in a Multivariable Calculus course. The purpose of this chapter two was to review the literature that relates to the key elements in the study. There are two sections for this literature review. First, I explored the key studies on the

structure and the instructional presentation of mathematics instructional games and its effects on learning. Second, I reviewed empirical research and literature reviews that discussed the effectiveness of instructional games and the design issues. I also explored key studies on gaming technology and briefly discussed the characteristics of the gaming environment. In addition, I examined common methodologies employed in the literature on games in education, highlighting major critiques, strengths and weaknesses, and future prospects.

## **Gaming Technology**

According to the Center for Implementing in Education, Computer Games and simulations are described as having dynamic elements with interactive multimedia under the user control (CITEd, 2015). A significant feature of these games is that almost all are conducted in the context of a pretended reality, in which the participants try to achieve one or more arbitrary goals by acting in accordance with rules (Adams, 2014). Examples of this pretend reality include, Super Mario World, Cut-the-Rope, Clash of Clans, and Angry Birds. In this chapter, we looked closely at the subset of video games, specifically role-playing games and platform games and the game's role in stimulating learning and motivation. A game is defined as "a system in which players engage in artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen & Zimmerman, 2003, p. 11). Video games are seen as a subset of the universe of all games (Adams, 2014). A video game is defined as "a game mediated by a computer, whether the computer is installed in a tiny keychain device such as Tamagotchi or in a huge electronic play environment at a theme park" (Adams, 2014, p. 33). Scholars such as Prensky (2012), Papastergiou (2009), Sedighian (1996), and Ke (2008a) along with many other scholars have widely argued that video games could provide learning and social benefits. Prensky (2012) claimed that video games help develop children's problem solving skills, especially role-playing



or platform games. The subset of video games for this literature review is the DGBL environment or virtual coupled learning environment. According to Erhel and Jamet (2013), digital game-based learning (DGBL) is defined as a competitive activity where students are required to reach educational goals. DGBL environment is also known as a virtual coupling environment that is intended to promote learning which features a set of rules, “set of dynamic responses to learners’ actions, and appropriate challenges enabling learners to experience self-efficacy, gradual, learning outcome-oriented [increasing] in difficulty” (Mayer & Johnson, 2010, p. 1). In order to develop a DGBL world, the developer must first start with developing the game world and merge in its educational objectives. The first step to developing a DGBL environment is to create a concept document and develop a game world. The purpose of the game world “is to entertain in its own right: to offer the player a place to explore and an environment to interact with” (Adams, 2014, p.138). When designing a digital game, the designer must keep in mind to structure the games world so that the player focuses on the enjoyment of playing the game (Adams, 2014). Therefore, if a player focuses on the DGBL core mechanics, then the player will become less interested in exploring the game world. Core mechanics are discussed later in the review. When developing the game world, the developer must find balance on what should or is not necessary to be implemented into the game world. The best way to determine the level of detail needed for the game world is use the following rule of thumb: “Include as much detail you can to help the game’s immersiveness, up to the point at which it begins to harm the gameplay” (Adams, 2014, p.152). “If a player must struggle to look after everything you’ve given him, the game probably has too much detail” (Adams, 2014, p.152). Next, the developer must develop the educational components to be implemented in the game world. Platform games are “cartoonish games in which an avatar moves through a vertically exaggerated

environment, jumping on and off platforms at different heights, while avoiding obstacles and battling enemies” (Adams, 2014, p.71). These components are discussed in the next paragraph.

### **Characteristics of Role Playing and Platform Educational Games: Effectiveness, and Design Issues**

To ensure that a designer’s video role-playing or platform games stimulate and motivate student learning, certain characteristics or features should be in place. Klawe (2010) argues that for computer games to increase motivation and make learning mathematics easier, they should include:

1. Subject matter that pupils are supposed to learn
2. Activities for learning
3. Representation of concepts
4. A basic learning model or models
5. The way and concept of presenting the content
6. Interface for manipulating with words and objects
7. Navigating structure and order of activities
8. Feedback information and rewards systems
9. Fun elements (graphics, sound, story, characters, humor) (Divjak & Tomic, pp. 22)

In addition, many scholars have found several design issues that have a significant role in determining the effectiveness of a virtual coupling or DGBL environment. These include motivation, gender, feedback and scaffolding, verbal and written reflection, genre, balancing content and game, presentation (delivery), and curriculum dilemmas.

**Motivation.** The connection between motivation and learning effectiveness of DGBL environment was often discussed by the game's designers (Elliot & Bruckman, 2002; Habgood et al., 2005; Lopez-Moreto & Lopez, 2007; Malone, 1981a; Rosas et al., 2003; Sedighian & Sedighian, 1996). The components that are necessary for expanding the motivation in games are (Sedighian & Sedighian, 1996): (a) situating mathematics learning in the games, (b) providing a set of goals to achieve, (c) providing a balance amount of challenges to get excited but not overwhelmed, (d) making games cognitive artifacts by incorporating two factors of interactivity and communication, (e) associating learning to pleasant memory, (f) providing sensory stimuli by including fancy graphics and animation.

**Gender.** All instructional games must be appealing to both genders. This includes making the core mechanics, the narratives, and cut-scenes of the game male and female friendly (Egenfeldt-Nielson, 2005; Klawe, 1998). In order to develop instructional games to appeal to both sexes, the developer must be careful to not build content that will limit the interest of, or offend either sex (Adam, 2014). For example, to avoid turning women away from gameplay, Adam recommends that the developer refrain from using hypersexualized female avatars, repetitive play, play without a meaningful goal, and single player structured games (Adams, 2014).

**Feedback and Scaffolding.** Feedback and scaffolding was found to be another component that contributed to improving the effectiveness of the games for instructional learning (Carmerson & Dwyer, 2005; Klawe, 1998). Having students to complete tasks that slowly intensify their cognitive challenge has been shown to be significantly effective with reinforcing learning (Klawe, 1998). "The value of the instructor in scaffolding learners is a critical (and somewhat over looked) component in the use of educational games, as are learner support strategies such as

the online help, cue/prompts, informative feedback, and other activities” (Ke, 2008a, p.9). According to Clark et al. (2016), the learning outcomes were significantly higher in digital games that used scaffolding than the digital games that just used simple success, failure, or points feedback. Although scaffolding does conflict with students’ interest in completing the activities, it is through a contentiously developed reward system that stabilizes the students’ focus or interest in wanting to complete the game (Klawe, Westrom, Super & Davidson, 1996).

***Verbal and Written Reflection.*** Verbal and written reflections, thinking, and discussions were also identified as key features to improve the effectiveness of mathematics games (Egenfeldt-Nelson, 2005). Developing verbal and written reflection in a meaningful real context can potentially be a very effective way for stimulating reflection in mathematics for the students (Waywood, 1992).

***Game Genre.*** The trend of video game attraction or genre contributes to the effectiveness of the DGBL environment. During the 1970’s and 1980’s the types of games that dominated that era were puzzle-like games (Kebritchi, 2008). In the 1990’s, strategy games began to dominate (Kebritchi, 2008). Lastly, in the 2000’s, adventure games took over the market (Kebritchi, 2008). In addition, there were other types of games that were developing during those times, for instance, the development of instructional action games (Kebritchi, 2008). These games incorporated face-game environment that enforced players to respond quickly to ongoing challenges (Kebritchi, 2008). Unfortunately, these games did not offer much time to reflect and were more useful for improving skills in speed and accuracy than for understanding complex concepts (Baker, Habgood, Ainsworth, & Corbett, 2007).

***Balance content and Game.*** According to Malone (1981), the effectiveness of educational instructional games depends on how the learning content is implemented into the game world. In

order to maintain the instructional value of the game, the core mechanics of the games suggest that the instructional process proceeds the mechanics of the game (Habgood et al., 2005).

***Delivery Conflicts.*** Delivery issues that arise in the literature include, curriculum, outcome, and technical issues.

***Curriculum Problems and Technical issues.*** One of the major problems with educational mathematics games is its alignment with the course curriculum. Instructors usually experience difficulty with balancing time with gaming and instructional time along with their course syllabus (Gros 2003; Rosas et al., 2003). This is because educators are given a limited time window to deliver content, especially with video adventure games. Gros (2003) suggested that the developer creates a simple platform or adventure game. This will allow the students to use less time to become familiar with the game, adjust, and adapt quickly. Using simple models allow teachers to have time to play, learn and manage the instructional games appropriately (Gros, 2003). Time is another factor that negatively affects the students who are not technology savvy (Gros 2003; Rosas et al., 2003).

***Outcome Issues.*** There is some doubt that the knowledge and skills transferred from games to classroom exercises and other enrichment activities affect the presentation of mathematics games in the school systems (Egenfeldt-Nielsen, 2005; Gros, 2003; Klawe & Phillips, 1995). Although constructivist theorist would argue that learning through real tasks expands the transfer of learning and encourages pupils to apply what they have learned in school to other activities, it is not easily shown and has not been completely consistent (Gros, 2003).

***Weaknesses and Limitations.*** A number of weaknesses and limitations have been cited in the literature when studying the role of video games in the classroom. For instance, instructors must do the analysis to determine whether the content of the digital game is appropriate for

certain ages and meets the curriculum standards to reinforce learning (Deubel, 2006). Instructors must also determine whether there will be a sufficient amount of digital games available for all students (Griffiths, 2002). According to Keesee (2012), one weakness that exists is that “games don’t fit well on a time table.” In other words, it is difficult to determine how much time is needed for a student to complete sub-stages and complete the entire game. This can create a conflict for instructors who need to determine how long it will take for a unit to complete or cover. Although there could be a deadline set for when a student should complete the video game and go on to a new section, we still collide with the problem of students feeling discouraged from not successfully completing the games (Dermont, 2010). However, if instructors decide to allow students to stay on the video games until they finish, then we run the risk of some students failing behind others (Keesee, 2012). Another disadvantage is that the students are likely to encounter a completely different experience from someone playing the same game, but making different decisions, which leads to another problem (Dermont, 2010). The problem is that if each student is learning and experiencing something different, then the instructors will have a difficult time keeping track of who learned what (Dermont, 2010).

Another major limitation is that digital games are constantly being updated. This makes the evaluation process of measuring effectiveness of educational games difficult (Griffiths, 2002). Annetta, Minogue Holmes, and Cheng (2009) claimed that some educational games only serve to hook students by distracting and disengaging them with too much emphasis on background, music, and other core mechanics attractions. Additionally, the over use of long tracts of text can sometimes create additional cognitive demands and can be a cognitive challenge, which could act as a barrier and inhibit the motivation and learning from students

(Lowe et. al, 2010). This reinforces Adam's theory on game balancing on what is necessary for creating a robust video game.

In addition, there is a lack of face-to-face interaction and feelings of social isolation, which could have a negative effect on the learning of students. Coffey (2014) validates this through his findings. He states that the inability for students to pose questions in the digital games increases the chances for students to misunderstand how to navigate through the game world. As a result, students become frustrated with unclear objectives, lack of discussions, interaction and feedback (Lowe et al., 2010). This drives students into a negative space of self-driven learning and searching for support (Reynolds, 2011).

Another disadvantage is the chance of over-usage. When instructors and students rely too heavily on the use of video games to learn or review material, they risk losing the skills that allow them to function outside of a digital source (Keesee, 2012). This usually happens when students becoming addicted to playing video games. Moreover, social interaction must be physical and mental, which is one of the main shortfalls of Educational Gaming without classroom interaction (Keesee, 2012). Without classroom interaction among the instructor there is no way to make sure that the students are properly meeting the standards of the course content.

**Strengths.** Video games have become a useful measurement tool that is frequently used in research. For instance, video games have been used in research to measure performance on a various task, and can be easily modified, standardized, and interpreted (Griffiths, 2014). They can also be used to examine characteristics such as self-esteem, self-concept, goal setting and individual differences (Griffiths, 2014).

According to Gray (2015), gamers outperform the non-gamers on tests taken in his experimental study. Gray (2015) found that people who play video games or simulations

improved on the measure of basic perceptual and cognitive abilities while those in the control group did not. In fact, another important benefit of using video games or gaming technology is that it attracts all individuals across many demographic boundaries (Griffiths, 2014).

In addition to entertainment, educational video games are highly engaging and help students with focus, self-esteem, and memory (Keese, 2012). This is because students unknowingly begin to practice patience while they are waiting to reach the next level. Keese (2012) explains that playing video games aid students' self-esteem in that they have a faster reaction from the game system. Video games force students to actively engage, think, and make decisions (Dermont, 2010). The students visually are able to see how their accomplishments are taking place. RPG (role-playing games) or platform games are an interactive approach to learning in that it teaches students rules, adaptation, video games, and problem-solving in one setting. Educational video games provide students with essential needs of learning by providing enjoyment, structure, motivation, ego gratification, adrenaline, creativity, social interaction, and emotion (Dermont, 2010).

***Additional Issues with Learning, Motivation, and Engagement.*** According to Klawe (1998), in order for learning activities to be meaningful and successful, a high level of interactivity is necessary. The activity must affectively engage the students when students use the majority of their time constantly interacting in the virtual world. Activities should give frequent and immediate feedback on the results of their action to maintain engagement. Studies have shown that students are not interested in being engaged in passive activities like reading, listening, and watching for extended periods of time. The exception to this is only when a student needs a wealth of information to achieve a goal that is meaningful to him or her or when the activity places them in a state of relaxation. Activities must be motivating in real life in order



for them to be motivating in a virtual coupling environment. In addition, activities with clearly defined goals in the DGBL environment seem to work best for students to learn. However, there are restrictions on this when females are involved in the learning environment. As for the representation of concepts, it is important that the developer uses a representation that connects with what the instructor wants the student to think about. Using conceptual representation that is similar or equivalent to those from mathematical educational sources like textbook, lectures, and worksheets will enable student to transfer and relate understanding among these different sources. When developing interfaces to manipulate concepts and objects, Sedighian and Westrom (1997) state that “interfaces that involve direct interaction with a representation of a concept to be learned are better than those that manipulate an object being used to illustrate the concept.” Svendsen (1991), Golightly (1996), and Sedighian and Klawe (1996), state that distorted or oblique interfaces are better than the basic interfaces for capturing the learner’s attention. For instance, if the instructor wants the student to reflect on the choice of a numeric value, it is suggested that the student types in the value rather than using a graphical interface to click on the value or using a slider to select a value. In a navigational structure and sequencing of activities, Sedighian and Klawe (1996, 1997, & 1998) explained that when students complete a sequence of related activities where the cognitive challenge is gradually elevated, the student learning is enhanced dramatically. One could also use this navigational structure to set up questions to verify that the student understood a main concept to obtain a reward for completing a simulation or involving the concept. For instance, in the Hexagon puzzle in *Phoenix Quest* student are directed to discover a pathway through a hexagonal like figure so that the collection of numbers on the tiles would have a similar property. Once the path is found, students are instructed to determine which one of the four properties in the sequence of numbers are satisfied

(e.g. multiples of 2, perfect squares, prime numbers, or numbers that have 5 as a remainder when divided by 6). Prior to inserting this question, they learned that the students were finding the path through trial and error. After they added this question, they found that students were engaged in reflecting on the properties and patterns that might be showed when searching for a pathway (Klawe, 1998). Another navigational structure that has been found to be most useful to student learning is instructional modules or practice areas. Instructional modules were sought after and become most useful to students when they are stumped in the middle of an extremely engaging challenge prior to beginning the challenge. However, if the instructional modules cause the student to not lose his progression that he has made in the game, the student will be hesitant to leave the challenging activity (Klawe, 1998). Therefore, it is in the best interest of the designer to grant students access to instructional and practice modules as they maintain their current position in the game or activity (Klawe, 1998). In addition, Clark et al. (2016) findings suggest that game conditions that use motivation tactics improve the overall intrapersonal learning outcomes compared to the nongame instructional conditions. However, Young et al. (2012) suggest that there is a missing link, and motivational and engagement outcomes must be examined further by the game researchers.

### **Gaps in the Literature**

An overview of the literature showed that despite the emerging number of studies on gaming, several issues that explain the potential of this technology in the classroom still need to be investigated. First, there is a need to provide empirical evidence to understand and study the impact of RPG or platform games on undergraduate students in terms of motivation and learning outcomes in relation to curricular objectives. Second, further research is needed with undergraduate mathematics, science, and engineering majors to highlight their experience as they

engage into RPG/platform video games. Here, we question whether RPG/platform games will keep the students motivated in learning or the relearning process to improve or maintain their scholastic competence in a virtual environment. Third, there is a need to identify the necessary or minimum core mechanics to ensure that the video game is a balanced platform game. Fourth, more studies are needed to investigate the effectiveness of RPG/platform games compared to traditional educational practices with regards to undergraduate student motivation.

The major empirical research studies from 2002 to 2016 suggest that there are several issues that need to be investigated. First, further research is needed to fully understand the impact of Digital Game Based Learning on student success in terms of lessening the cognitive load, increasing one's own motivation to learn, and learning outcomes in relation to curriculum objectives with specific mathematics areas (Cankaya & Karamete, 2009; Karakus, Inal, & Cagiltay, 2008; Vos, Van der Mieijden, & Denessen, 2011; Young et al, 2012). Further research is needed especially for the advanced college level mathematics, specifically Multivariable Calculus. Specifically, we question what components are needed to keep students motivated in the learning process with advanced mathematics. New forms of technology have made their way to the classroom to assist our students in the learning process. It should be investigated whether role-playing/platform games are motivational and effective with students compared to traditional educational practices with or without the current educational technology.

### **Review of Relevant Literature of DGBL**

There have been many studies conducted around the area of educational technology particularly in role-playing games. These studies show that the use of Digital Game-Based Learning has positive outcomes on student learning of the content and engagement and motivation. Current Digital Game-Based Learning (DGBL) research targets the exploration of

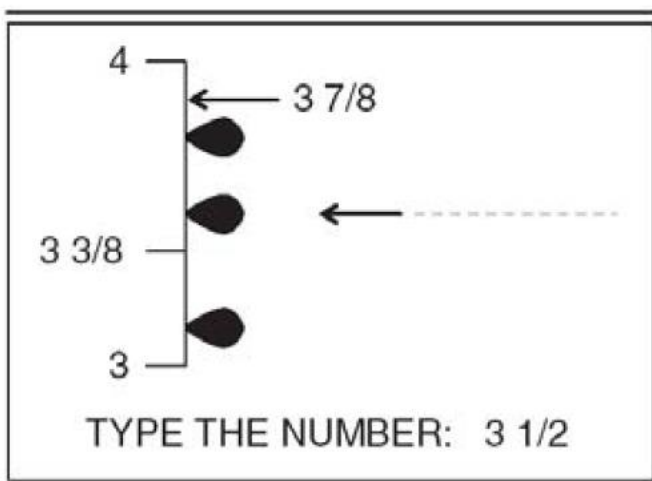
content support for learning motivation and other similar game features. For instance, in his study on DGBL Woo (2014) focuses on understanding what kind of DGBL design method is able to be implemented to apply numerous game features that meet the needs of the motivational strategy techniques. In addition, the research also examines the empirical relationships that exist between motivation, cognition, and performance in DGBL using Keller's MVP theory framework (Woo, 2014). The study used the responses of 63 second-year university students to analyze their responses after completing a computer game training. The data was collected using instructional materials motivation survey, a cognitive load scale, and performance scales. Results of the study showed that digital games with multimedia structures attracted a player's attention and that an external portion of the game content must be added to maintain game value (Woo, 2014). The data analysis also revealed that motivation and cognitive load showed a significant correlation with performance. Furthermore, Woo (2014) found that when extraneous but interesting material are included, students can interpret multimedia-based explanations clearly, however, decreasing the extraneous but interesting materials declines the learners' attention (Woo, 2014).

By the same token, Adam (2014) reaffirms the importance of game balancing, which is necessary to hold the attention of the players. Most importantly, his findings recommend that when designing a DBGL environment, the designers must increase the motivation and germane cognitive load to enhance learning effectiveness (Adams, 2014). Germane cognitive load refers to effort made to create a permanent of store of knowledge (DeLeeuw, 2008). Other studies suggest that learning followed with motivation stimulation can improve the learning experience of students (Yang, 2012; Wang & Chen 2010).

Furthermore, Ke (2008a) analyzed and deciphered the interaction between alternative learning applications and different classroom structures such as individualistic, competitive, or cooperative students' mathematical learning outcomes. In addition, Ke was interested in determining if computer games will, in contrast to paper-and-pencil drills, be more effective in promoting math learning outcomes. He even examined whether alternative classroom goal structures influence the effects of computer games and conventional drills on math learning outcomes. His findings showed that computer games were significantly more effective in promoting learning motivation than compared to pencil-to-paper drills. He also found that computer games were not significantly different in facilitating cognitive math test performance and metacognitive awareness. His study also revealed that alternative classroom goal structures mediated the effects of computer games on mathematical learning outcomes (Ke, 2008a). The MANCOVA analysis displays a significant effect of the experimental groups on the outcome variables of mathematical learning,  $F(15,289) = 2.66, p <.01$ . It also shows that there is a significant main effect for the learning applications,  $F(1,263) = 5.16, p <.01$ , and there is a significant main effect for the classroom goal structures,  $F(2,263) = 3.07, p <.01$ . Through additional MANCOVA analysis, Ke learns that students score significantly higher than those in the paper-and-pencil drills groups, and computer games promote significantly more positive attitudes towards learning (Ke, 2008a).

Qualitative findings indicate that computer games afforded greater retention overtime than paper-and-pencil drill. Game-playing participants demonstrated focused attention and enjoyment and expressed reluctance to leave the computer labs when a gaming session was ended (Ke, 2008a). In other words, computer games, compared with paper-and-pencil drills, are significantly more effective in promoting learning motivation (Ke, 2008a). As a result, his

findings confirm the results of the quantitative analysis that the participants in computer game groups developed significantly more positive math learning attitudes than those in paper-and-pencil drills groups (Ke,2008a). Ke’s findings also tell us that cooperative goal structure significantly enriches the effects of computer games on learning motivation. One of the oldest instructional games was a Dart game from Plato project in 1973. This game was designed to teach the students fractions. It used a conceptual framework on intrinsic fantasy through connecting fictitious balloons and arrows to show students how to estimate fractions (Malone, 1981a) (see Figure 6).



DARTS Game

*Figure 6.* The Screen Layout of the Darts Games. Adopted from “Toward a theory of intrinsically motivating instruction”, Cognitive Science by T.W. Malone 1981a 5(4) p. 349.

Other games such as, Harpoon and Sonar, were developed in 1981. These games originated from that Dart game. The purpose of those two games was to instruct a new way of

learning arithmetic. The results from this had shown to be successful in that it motivated and engaged players in learning mathematical concepts of arithmetic (Levin, 1981).

During the 1980's, an education programming language called Logo was created. Its purpose was to develop mathematical instructional games. The pedagogical approach in using Logo is to teach mathematics through getting the students to create and design their own mathematics games (Egenfeldt-Nielsen, 2005). This approach follows Kafai's (2001) concept of learning by the construction. Surprisingly, there has been many studies that advocate the effectiveness of this method in teaching mathematics (Kafai, 2001; Kafai & Resnick, 1996; Papert, 1996; Kafai, Frank, Ching & Shih, 1998).

During the 1990's, there were two research projects, Electronic Games for Education in Math and Science (E-GEMS) and Through the Glass Wall, that uses instructional mathematics games. Two games were made in this project. The first game of the E-GEMS project is Super Tangram (ST). It was created in 1996 for teaching transformational geometry to 6th graders (Sedighian & Sedighian, 1996). The game had several puzzles that increasingly became difficult. Sedighian (1996) developed this game to offer a fun, engaging, and motivational learning environment. The second game, Phoenix Quest, of the E-GEMS project was developed in 1997. The games were designed to attract and motivate boys and girls. Both of these games were centered around completing puzzles with varying approaches. In figure 7, it displays Super Tangrams as an activity-oriented game and Phoenix Quest as a story-oriented game (Sedighian & Sedighian, 1996). Through the Glass Wall project demonstrated that mathematics must be part of playing and stimulate mathematics-related reflecting and discussion (Sedighian & Sedighian, 1996). It also stresses the significance of the narrative frame and gender neutral approaches in developing games (Egenfeldt-Nielsen, 2005).

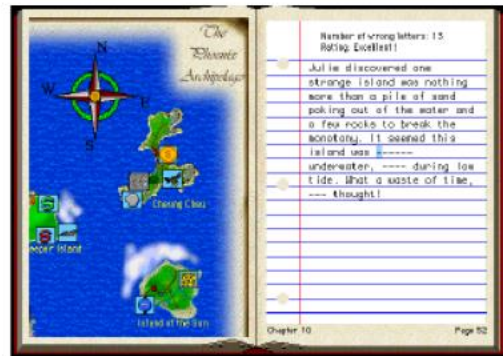


Figure 7. Screenshots of Super Tangrams and Phoenix Quest. Reprinted from “Effects of A Computer Game on Mathematics Achievement and Class Motivation: An Experimental Study, by M. Kebritchi p.29.

During the 2000’s, instructional games or DGBL environments with 3-D features came upon the rise. 3-D interfaces were used in several virtually coupled learning environments like AquaMoose (Elliott & Bruckman, 2002) and Zombie Division (Habgood et al., 2005). Yet, the development of games was with less sophistication. Some of these games include games that are like the Nintendo’s Gameboy games (Rosas et al., 2003), web-based ASTRA EAGLE games (Ke & Grabowski, 2007) and Interactive Instructors of Recreational Mathematics (IIRM) (Lopez-Moreto & Lopez, 2007). The AquaMOOSE was a 3-D DGBL environment that was developed to help students learn about the trajectory of parametric equations. In this virtual coupling learning environment, learners studied mathematics through design and construction activities. Particularly, students learn mathematics through designing interesting graphs and creating mathematical challenges and games (Elliot & Bruckman, 2002). This DGBL environment contains other games. For example, the Ring game is a game where students swim through various rings with a function. Figure 8 displays this below. The results from this study suggest



that the artistic qualities of the environment motivated students, however, the lack of its user-friendliness caused conflict. Another 3-D adventure game, *Zombie Division*, is a combat game where the players divide skeleton in combat battle (see Figure 8) (Habgood et al., 2005). The focus of this game was to develop a constant flow or flow experience for players to improve the learning effectiveness of the games (Kebritchi, 2008). Flow experience is defined as “the feeling of total concentration, distorted sense of time, and extension of self that is the root of engagement power of digital games” (Habgood et al., 2005, p.9). The creators of this game shared that an action adventure game with emphasis on combat should ensure the creation of a flow experience (Kebritchi, 2008). It is because of Csikszentmihalyi’s (1990) theory of flow that game developers are able to develop and captivate gamers to be fully engaged in a game world. It is also suggested that any learning content should be displayed during the highpoints of the game, and there should also be some sort of external quiz towards the end (Kebritchi, 2008).

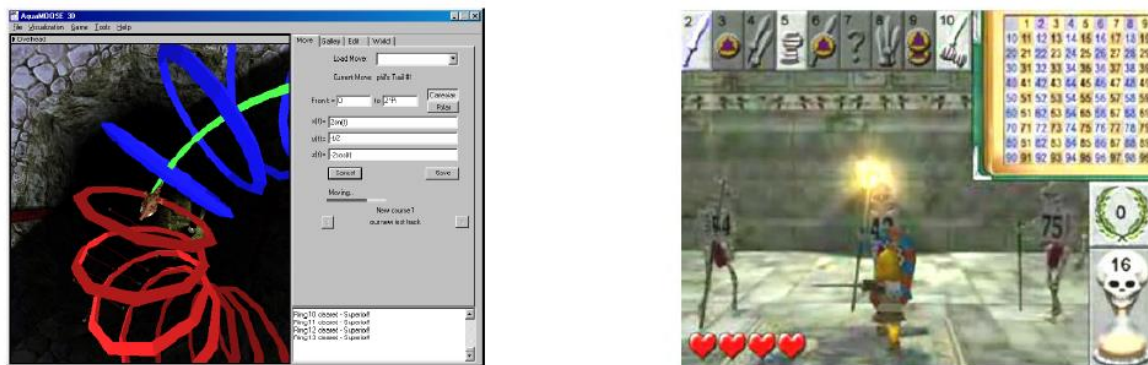


Figure 8. (a) (b)

(a) Screenshot of Ring game in AquaMoose. Reprinted Adopted from “Design of a 3-D Interactive Mathematics Learning Environment,” by J. Elliot and A. Bruckman, 2002, Proceeding of DIS 2002 (ACM conference on Designing Interactive Systems). London, UK, p. 6.

(b) Screenshot of Zombie Division Adapted from “Endogenous fantasy and learning in digital games”, Simulation & Gaming, by M. P. J. Habgood, S. E., Ainsworth, & B. Benford, B. (2005), P. 495.

Overall, Oblinger’s findings indicate that games constitute potentially powerful learning environments. Specifically, he showed that: (a) they can support multi-sensory, active, experiential, problem-solving, (b) they favor activation of prior knowledge given that players must use previously learned information in order to advance, (c) they provide immediate feedback enabling players to test hypotheses and learn from their actions, (d) they encompass opportunities for self-assessment through the mechanisms of scoring and reaching different levels, and (e) they increasingly become social environments involving communities of players (Oblinger, 2004).

McFarlane (2002) claims that game playing can also favor the development of various skills, such as critical thinking and problem-solving skills. Another research finding found that the use of games on portable devices led to improved motivation and learning outcomes compared to traditional teaching within primary schools (Rosas et al., 2003). Virvuo, Katsionis, and Manos (2005) reported that virtual reality games were very motivating and that it helped elementary students retain or improve their knowledge.

**Simulation of Games from Pre -K to Grade 8.** Vos, Van der Meijden, and Denessen (2011) conducted an experiment with primary school students with a sample size of 235. The study sample included two groups of students. Group 1 comprised of 128 students were encouraged to develop and design their own game. Group 2 included students who were instructed to play an existing game. Results from this study indicated that students who created and designed their own games showed improvement in motivation levels and made learning

easier by allowing students to be a part of the game development process. In another study involving the analysis of a geography lesson with computer games, findings suggest that there are significant differences in learning and motivation as well as greater independence with students who play computer games during learning (Divjak & Tomić, 2011). A study by Burguillo (2010) detected that a combination of game playing and friendly competition resulted in students' strong motivation and helped increase learning effectiveness. Regarding spatial skills, Yang and Chen (2010) argued that spatial skills can be improved after playing digital mathematical computer games.

Furthermore, Young-Loveridge (2004) examined on the learning of mathematical concepts in early childhood. In this study, the researchers established how computer games affected basic mathematical skills around 105 students. Over 105 students participated in this study. The measures were done through task-based interviews to examine children's numeracy before and after intervention. Pre- and Post- tests were also used to assess students' knowledge. The findings from this study revealed that the mathematical knowledge of students who play computer games was much better when compared to the knowledge of students who did not play computer games (Young-Loveridge, 2004). Perhaps this is because these students saw learning mathematical concepts as a game or fun activity. This indicates that using mathematical concepts at that time induces positive feelings, which increases their motivation for learning mathematics.

In 1998, Klawe performed a study which was done to determine the factors or components that affected educational computer games and its efficiency to improve learning mathematics in primary schools. The components he considered are: software and hardware design, different methods of teaching with games, and gender differences (Klawe, 1998). He

found that computer games are capable of being extremely efficient (better motivation, better knowledge, satisfaction with mathematics as a subject) (Klawe, 1998). In his study, he was able to show and prove that different factors like students' and teachers' expectations, the level of integration with other educational activities and game design effect, the final result (Klawe, 1998). Therefore, it is important that an instructor pays attention to these factors when using computer games in teaching (Klawe, 1998).

Another study conducted by Rosas, Nussbaum, Marianov, Correa, and Floor (2003) focused on analyzing the effects of introducing educational computer games into teaching as well as their influence on motivation and learning. The researchers performed their study with 1274 students that were separated into experimental, control, and external control groups. The experimental group played computer games for 30 hours over a three-month period (Rosas et al., 2003). The mathematics skills and motivation of the students were analyzed along with the teacher's expectations. After performing an ad hoc test and an observational analysis on students from the teachers' prospective, results showed a significant difference between experimental, control and external control group in favor of the experimental group (Rosas et al., 2003). This test indicated that the mathematical games were a useful aid in motivating and promoting learning mathematics. These findings inferred that computer or educational video games help identify educational goals, and they also help improve motivation and make learning easier. This is also showed and proven through the research study by Ke and Grabowski (2007). Their study consists of a sample size of 125 students who were divided into cooperative groups in a competitive setting. The students were assessed with pre- and post- mathematical tests. The analysis from their data confirmed that playing computer or video games influences motivation, attitudes and learning mathematics in primary school (Ke & Grabowski, 2007). The findings of

these authors' study confirm that playing computer games are more efficient than doing traditional mathematical tasks. This implies that games improve the students' tests results, motivate them, and create a positive attitude toward mathematics regardless of their individual differences (Divjak & Tomić, 2011).

Other research studies show that educational computer games can be used as tools to support teaching methods to improve teaching and learning goals. For instance, a study conducted by Sedighian (1996) shows that by playing Super Tangrams students understood geometry better and had fun learning it. Most importantly, this study showed that there are numerous possibilities for using mathematical computer games, particularly in teaching geometry, and for increasing motivation and student educational achievement (Sedighian, 1996).

Another research study by Yang and Chen (2010) focused on using a computer game to aid developing students' spatial abilities. Their results indicated that playing computer games can help develop spatial orientation and spatial abilities (Yang & Chen, 2010). Ping Lim (2008) performed a case study through observing, interviewing, and testing primary school students. In this study, the students play a game where they presumed the role as global citizens where they learn mathematics and other subjects. The findings from this study showed that using computer games for teaching increased students' active participation and motivation as well as their socialization (Yang & Chen, 2010).

Moreover, a study by Costu, Aydm, and Filiza (2009) analyzed how playing browser-based educational games in lessons affected the motivation and learning of primary children. There was a sample of 16 students who played the game in a lesson. After completing the games, students' attitude and opinions were dissected with a 5-question interview. The results

from this study express that most students' attitudes had a positive impact on their learning motivation and it made learning easier and more interesting (Costu, Aydmb, & Filiza, 2009).

Another study by Harter and Heng-Yu (2008) examined a sample of 98 students. The students were divided into two groups. A pretest was given to all students. The first half was taught in traditional setting, and the other half had computer games integrated with the traditional teaching. The findings from here show that students who played computer games had better results on a posttest than the other group of students.

A study performed by Sedighian (1996) focused on investigating the students who dislike mathematics and found the subject boring. Their study also delved into issues connected to child's psychology of learning mathematics in the context of mathematical computer games. The researchers dove heavily into the understanding what elements of a computer game made learning satisfactory. The research was performed for two years in 50 groups of students. The students were instructed to play educational games. Each group was visited once each week to observe the students playing games for over a year. They also observed student discussions. Later, the students were introduced to another game, where it consisted of a number of riddles that slowly increased its level of difficulty. Students were then given an unannounced test. As a result, the findings from this study were: computer games are an integral part of students' lives, and learning mathematics in a computer environment becomes important and motivating (Sedighian, 1996). They also discovered that learning with computer games (game-based learning) makes mathematics more meaningful and useful for students (Sedighian, 1996). Overall, these studies suggest that computer games have an impact on positive attitudes towards mathematics and their motivation (Divjak & Tomić, 2011). Another benefit of using computer games is that they help reduce the cognitive load significantly. For example, Moreno (2002)

shared his findings on cognitive learning theories using multimedia and its impact on individual learning. Here, he studied the analysis of students who were taught addition and subtraction with a computer game. The results from this study showed that the cognitive load was significantly reduced, particularly for students who were inexperienced in using computer technologies. This is because games provide a fun and interactive way to visually and symbolically understand arithmetic procedures.

Additionally, Ya-Ting Carolyn Yang (2012) examined the effectiveness of DGBL on students' problem solving, learning motivation, and academic achievement. For the learning outcome, they found that the study showed that the DBGL approach is effective in promoting students' problem-solving skills. They even found that the results showed that only DGBL improved the students' motivation for learning in a semester. The results from their study also showed that the quantitative improvement in problem solving and learning motivation indicated that DGBL can serve as a supplemental tool to aid students in effective learning while enhancing the course. Overall, this study showed that DGBL can better foster students' learning motivation, problem solving, and achievement than the traditional learning methods.

Sung and Hwang (2013) examined the collaborative game-based learning approach to improve students' learning performance in a science course. This study was performed in an elementary school in a natural science course. They performed an ANCOVA, where  $F(2,89) = 4.84$ , which revealed that the learning attitudes of the different groups of students are significantly different. This means that the learning motivation was much higher than the students in the control groups.

**Simulation of Games for Grade 9 through 16 [College Level].** A study by Kebritchi, Hirumi, and Bai (2010) examined the impact of mathematical computer games on high school students' motivation and achievements. The findings from their study showed that the group

who played computer games reach higher achievements and motivation than the group who did not play computer games (Kebritchi, Hirumi, & Bai, 2010). It is noted that prior knowledge, computer, and language skills did not play a role in affecting the student's achievement or motivation. In a DGBL study, Papastergiou (2009) examined how effective is the learning process and the attractiveness of a digital learning environment and computer memory skills. The data analysis from her study indicated that using a DGBL environment was more effective in increasing pupils' knowledge of memory skills and more engaging than the pencil-to-paper approach. The study also demonstrated that DGBL can promote curricular knowledge and student motivation in core academic subjects of high school such as computer science (Papastergiou, 2009). Moreover, her findings indicated that within high school computer science, educational computer games can be exploited as effective and motivational learning environments (Papastergiou, 2009). In another study, Lopez-Martelo and Lopez (2007) conducted a study that is centered around the impact of electronic cooperative surroundings on learning mathematics in high school. In their study, they developed educational software for mathematics to serve the needs of high school students. Results from the study revealed that using electronic cooperative surroundings had an impact on developing positive attitude to mathematics (Lopez-Martelo & Lopez, 2007). It also strengthens the motivation for learning it. In a similar research study conducted by Kebritchi and Hirumi (2008), the researcher analyzed the effects of computer games on students' mathematical achievements and motivation for learning. They also studied the resultants of prior mathematics knowledge and computer skills. The results of their study concluded that there was a significant improvement in student achievement in mathematics between students who played computer games and those who did not. Divjak and Tomić (2011)



found that students developed enhanced meta-cognitive skills and decision-making skills from using DGBL.

### **Future Prospects**

Today's technology allows us to have access to learning and knowledge through a wireless PDA. There are so many social network apps that can be installed on the cell phone. Because of this, individuals have unlimited paths to construct their knowledge of any subject of interest to him or her. Today's generation of students are becoming less stimulated to learn without technological devices. In the future, STEM research findings will project that students will learn from video games. In addition to modifying DGBL environments for our elementary, middle, and high school students, further research is needed to fully understand the impact of Digital Game Based Learning on college student success. This includes lessening the cognitive load, increasing one's own motivation to learn, and learning outcomes in relation to curriculum objectives with specific mathematics areas, specifically in Advanced Analysis. In order for this to work we as educational game designers must understand how the characteristics or conventions of good commercial games to design compelling virtual worlds, that develop situated knowledge, game players, which develop effective social practices and skills in navigating complex systems, and how those skills can support learning in other complex domains (Shaffer, Squire, Halverson, & Gee, 2006). Video games have the power to alter the scene of mathematics education.

### **Summary**

In summary, this section gives a brief synthesis of the evolving of mathematics instructional games and conceptual and highlighting the structure and delivery issues that significantly impact the effectiveness of the games. According to our review, Adventures of

Krystal Kingdom is classified as a modern role-playing game with 2-D Platform Interface and a learning environment that advocates learning through active interaction with the gaming environment and other students. This literature review also suggests that as one studies and analyzes the effectiveness of instructional games, we must examine structure and delivery features: (a) technical issues, (b) outcomes, (c) curriculum, and (e) time and purpose. With this knowledge of the current conflict that exist in instructional game, we seek to optimize learning, and reduce a number possible of components that could create negatives effects in the study.

## CHAPTER 3: METHODOLOGY

The purpose of this study was to examine how platform games affect the learning of undergraduate students in Multivariable Calculus. Specifically, the study addressed the following questions

1. How does a platform game affect the learning of undergraduates in a Multivariable Calculus class? How does a platform game affect the motivation of undergraduates in a Multivariable Calculus class?
2. What features and dimensions of the platform game are necessary to maintain the engagement of the students during the learning and gaming process? What kind of threats do students face?

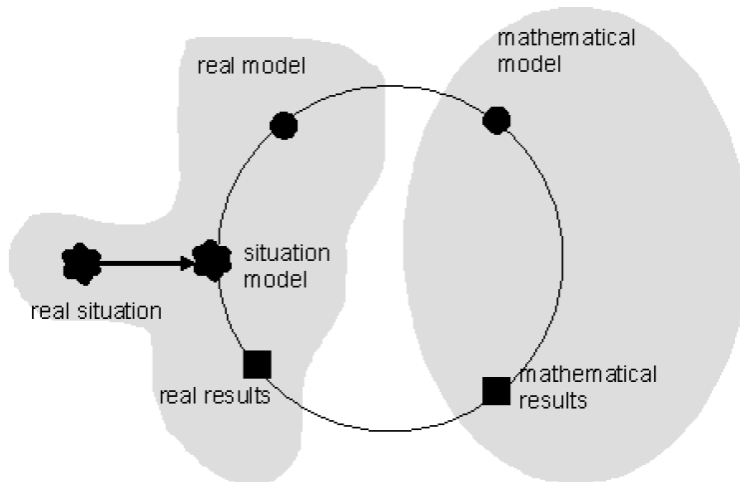
The study examined the following hypotheses:

1. There is a significant difference between the learning of the undergraduate students who received the platform game.
2. There is a significant difference between the motivation level of the undergraduate students who received the platform game.

Chapter three presents the design and method of this study. The chapter is subdivided into seven sections. In section one and two, the researcher discussed Blum's Modeling Cycle, the research design, study sample, procedure and a description of the intervention. In section three and four, the researcher described the procedure used in designing the instrument and collecting data and provided an explanation of the statistical and qualitative instruments used to analyze the data. In section five and six, the researcher covered interview protocols and the Research Permission and Potential Ethical Issues. Lastly, the researcher discussed the potential limitations.

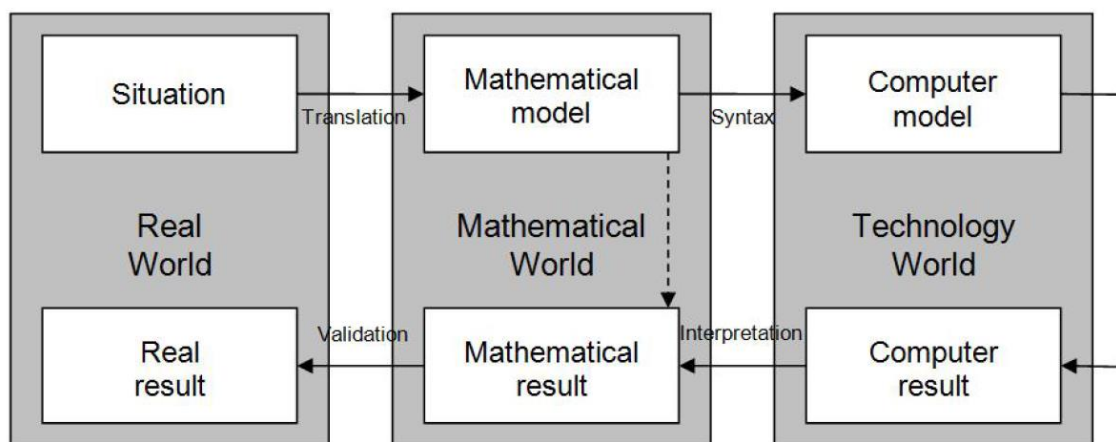
## Blum's Modeling Cycle

Blum's modeling cycle was designed to target applied mathematical problems to identify barriers, blockages, magnify students' knowledge in the content, help students to better understand the world, and support mathematical learning (Blum, 2011). A diagram of Blum's Model is illustrated Figure 9.



*Figure 9.* Blum and LieB Mathematical Modeling Cycle. Adopted from Mathematical Modeling in Class Regarding to Technology, by H. Siller, and G. Greefrath, 2010, Proceedings of CERME, p.2136.

Since this study involves the use of mathematical modeling with technology the researcher used the Extended Mathematical Modeling Cycle as shown in Figure 10.



*Figure 10.* Extended Blum and LieB Mathematical Modeling Cycle. Adopted from Mathematical Modeling in Class Regarding to Technology, by H. Siller, and G. Greefrath, 2010, Proceedings of CERME, p. 2137.

According to Siller and Greefrath (2010) modeling with the use of Computer Algebraic System (CAS) similar to a digital game-based learning environment creates an environment for easy discussions on modeling problems which can be analyzed in the real-world of life with students. Although the CAS and DGBL [Digital Game-Based Learning] environments are both computer models, they differ in that a DGBL environment is a competitive virtual environment where students have set educational goals and encourages knowledge acquisition (Erhel, 2013). On the other hand, a CAS is a computer model that manipulates algebraic expressions (Ginsburg, Groose, Taylor, & Vernescu, 2016). As mentioned, it is the digital technology and the discussion where the motivation of mathematical education is affected because student begin to recognize the importance of mathematics in everyday life (Siller & Greefrath, 2010).

### **Research Design**

This study employs a single exploratory embedded case study design using quantitative and qualitative techniques. A single exploratory case study is defined as a study that examines a

modern phenomenon in depth and in its real-world context whose purpose is to explain how or why some conditions came to be (Yin, 2014). An embedded case study is a case study that has more than one sub-unit of analysis where quantitative and qualitative methods are implemented in a single study (Scholz & Tietje, 2002; Yin, 2014). A case study is the appropriate methodology for this study, which is a bounded system that facilitates a deeply contextualized understanding of a case through giving heavy descriptions, analyses, and interpretations, by observation (Merriam, 2009; Stake, 1995; Yin, 2014). This study is a bounded case because it focuses on particular groups of students and a DGBL environment where the researcher can collect heavy descriptions of the students' experience in a DGBL environment. The wealth of details in the description and understanding from a case acts as a powerful learning tool for the researcher. Flyvbjerg (2006) states, "If researchers wish to develop their own skills to a high level, then concrete context-dependent experience is just as central for them as to professional learning any other specific skills" (p.223). Thus, carrying out a case study with in-depth description from the interviews and observations along with explored experiences about the effects of student learning mathematics in a virtually coupled environment is one of the best approaches to examine this study. Creswell et al. (2003) states that the core purpose for combining both qualitative and quantitative methods is to give us a rich understanding of the research topic. Maxcy (2003) argues that pragmatism opens the door to the multiple methods, different world views, and assumption as well as different forms of data collection and analysis in the mixed method study.

## **Context**

The study was conducted at one of the diverse universities in southeast of the U.S. At the time of the study, it is expected that the demographics of the undergraduate student body

population was comprised of approximately 25,000 students almost 10 % of which are estimated to be Latino, less than 50 % African American, less than 35% Caucasian, less than 1% American Indian, less than 15% Asian, less than 1% Native Hawaiian, and almost 10% miscellaneous.

The class selected for the study is a Multivariable Calculus course. Multivariable Calculus is a specific area of computational and applied mathematics that focuses on the differentiation and integration of functions of several variables. This course is a 3-credit hour course that requires students to complete Calculus II as a prerequisite for the course.

Multivariable Calculus is found in many different areas of mathematics such as differential geometry and partial differential equations. Multivariable Calculus is also found in fields like physics and engineering. In particular, we see them in electromagnetic fields, gravitational fields, velocity fields, fluid or air flow fields, and electric force fields in biological and social sciences. We can think of forces, velocities, and other quantities as Multivariable functions that are usually modeled in 3D-space.

Typically, the students in this course major in the following areas: mathematics, physics, engineering, and computer science. Students take this required course to complete their program of study in their respective degrees. The classroom is usually arranged in a lecture style desk arrangement where the desks are set in rows with the students' chest out, feet down, and eyes forward. Approximately, every two or three weeks towards the end of class students are arranged into cooperative groups to complete group assignments. The institution usually has two or three sections during the fall and spring terms with a typical enrollment of 30 to 40 students per section. It is usually taught by a mathematics professor and lasts for one-hour and forty-five minutes for when the class that meets twice weekly and one-hour and ten minutes for a class that meets three times weekly.

## **Study Sample**

**Quantitative Sample.** The quantitative sample was comprised of students enrolled in one section randomly selected from all the course sections ( $N = 25$ ). Students enrolled in the selected sections were invited to participate in the study upon the instructor's approval. The course has a typical mix of (a) ethnicity population of Spanish, Caucasian, Indian, Pakistani, African American, and Asian with different language backgrounds, and (b) students with low, average, and high achievements. The diverse population allowed the researcher to examine the effects of games on participants with different linguistic background and achievement levels.

**Qualitative Sample.** Eight students were purposefully selected from the quantitative sample using stratified sampling based on the level of achievement: low and average. Based on the instructors' assessment of the students, the researcher selected a student from each subgroup of the population. When sampling in a stratified approach, it allowed the researcher to select a representative sample of students that differ in performance level, which revealed the effect of the video game on participants who have different performance levels.

## **Data Collection**

**Quantitative Instruments.** Data was collected through quantitative instruments including two surveys: demographic and motivation surveys, and two tests: academic achievements and game performance tests. The instruments are listed and described below.

*Demographic Survey.* Demographic information from students was collected by using a demographics survey. The survey inquired about the students' gender, ethnicity, education, game-playing and computer skills. There are 24 questions in the survey. The structure of the survey varies among multiple choice, ordering, and fill-in-the-blank.



*Motivation Surveys.* The motivation survey consists of 20 Likert scale items ranging from Not true = 1 to Very true = 5. Pre- and post- surveys were used to collect students' motivational status. The survey is based on Keller's ARCS Model (1987) and measures the motivation along four major components of Attention, Relevance, Confidence, and Satisfaction. Attention deals with whether the students' interest is captured and sustained during the educational activities. Questions 2, 6, 10, 15, and 16 measure the attention component. Relevance determines whether a student sees the activity as a personal need. Questions 5, 7, 11, 12, and 18 measure the relevance component. Confidence is used to measure the students' expectancy to succeed in the activity. Questions 1, 3, 8, 14, and 19 measure the confidence component. Lastly, satisfaction looks into the rewards that the student expects from the activity. Questions 4, 9, 13, 17, and 20 measure the satisfaction component.

*Academic Achievement Tests.* The following were used to collect and assess students' performance: Multivariable Calculus exam and *Adventures of Krystal Kingdom*. The exam is in Appendix A.

*Game Performance Test.* There are three problems in the game. The exercises address learning concepts with differentiating and integrating vector-valued functions, writing a set of parametric equations for lines in space, and writing a linear equation to represent a plane in space. The game performance exercises were graded using a point system. Correct answers received 14 points. Incorrect answers received no points. See Figure 11 below.

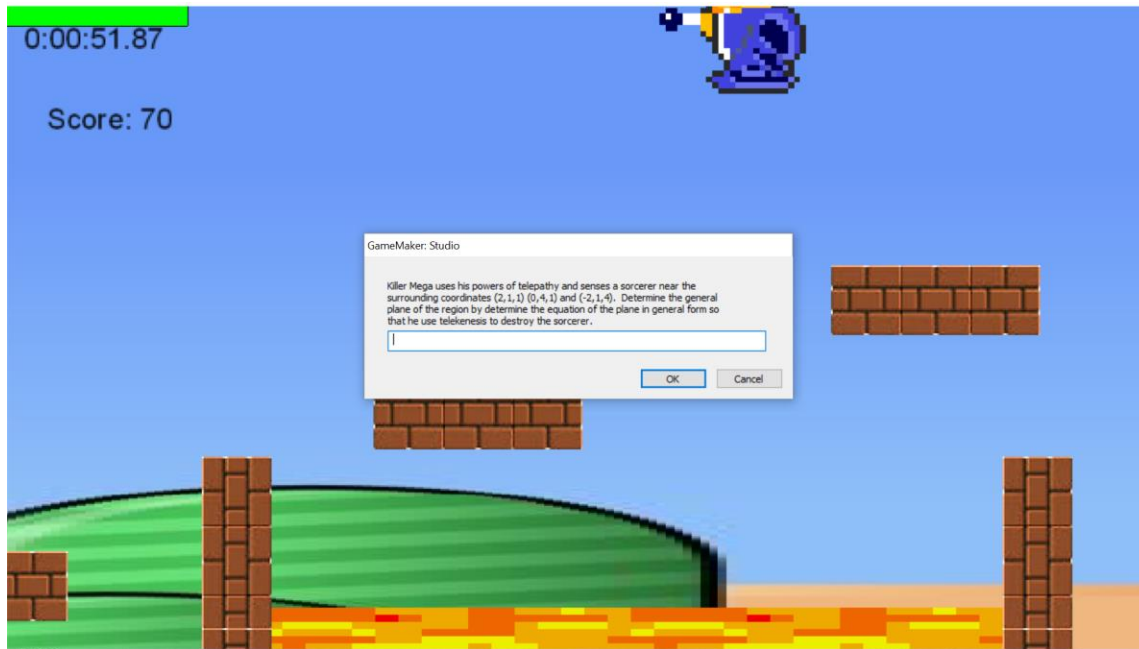


Figure 11. This screenshot of Adventures of Krystal Kingdom shows a stage in the game where Mega is required to use his knowledge on vectors and planes to solve the problem.

**Qualitative Instruments.** Four qualitative instruments were employed: observations, interviews, artifacts and researcher introspection.

*Observation.* Observations were conducted prior to the first interviews to establish background and rapport with the students. Observations were conducted twice a week in a course where the instructional period lasted about 80 minutes. Observations were focused on the qualitative sample during the use of the platform video game. Field notes were be taken at each observation and interview.

*Interview Protocols.* Semi-structured interviews were conducted to understand how platform games supplement the professor’s instruction in class. Student interviews were held outside of the classroom and lasted for approximately 30 minutes. The interviews were recorded, documented and transcribed. About 15 questions were posed during interviews and sought to understand what stimulates a student to learn, be engaged, and motivated in a Multivariable

Calculus course during the gaming process (See Appendix A). A summary of the semi-structured interview was given to the interviewees to review and perform a member check to validate the accuracy of my interpretation (Stake, 1995).

*Artifacts.* Artifacts such as DGBL log files and mathematical modeling activity sheets were analyzed using visual content analysis. DGBL log files were recorded and obtained. These files contained the time spent completing the game, game score, mathematical modeling input answers. The data collected on the mathematical modeling activity sheet were used to summarize the appropriate pedagogical adjustments within one of the stages to identify and hopefully remove any blockages that halts the student's learning process.

*Researcher Introspection.* The researcher kept a journal that reflects on one's own position as the researcher. Researcher Introspection is one of the many common strategies that is used for ensuring internal validity and credibility (Merriam, 2009). "The process of reflection helps to bring the unconscious into the consciousness and thus open for inspection" (Ortlipp, 2008, p. 703). Reflexivity or researcher introspection states that the researchers must reveal themselves in the study to understand their role in or influence on the study (Cohen, Mansion, & Morrison, 2011).

## **Procedure**

The study was conducted from 4 to 8 nonconsecutive weeks during the Fall semester of 2017 (See Table 2). After getting approval from the department chair, a letter was sent out to inform and recruit mathematics professors. The professors who volunteered to participate in this study, signed the professor informed consent forms. After gaining approval from the professor, the students were invited to participate in this study. Those who volunteered signed a

consent form. The students of the participating professor or professors returned his or her signed consent forms.

Table 2  
*Study Timeline*

| Weeks  | Task  |
|--------|---|
| Week 1 | Meet with the professor to discuss and schedule when to distribute the consent forms, surveys, achievement test, and interviews |
| Week 2 | Distributing consent forms and demographic and motivational survey  |
| Week 3 | Distributing Pre-Test and collecting data through classroom observation   |
| Week 4 | Treatment group plays game.   |
| Week 5 | Treatment group plays game.   |
| Week 6 | Treatment group plays game.   |
| Week 7 | Distributing Pre-Test and motivational survey   |
| Week 8 | Select and schedule students for semi-structured interview  |

*Note.* Outline of the Study Time.

During the first week of class, the researcher worked with the instructor to determine a time to present the study to college students and to administer the survey and Pre-test. The researcher collected quantitative survey data and information from the site. During this time, the researcher covered information about the study and handing out consent forms. Approximately a week later, the researcher returned to administer the survey to those participants who have signed the consent and assent forms.

After collecting the students' consent forms, the instruments were administered for the experimental group. The surveys and tests were answered on Scantrons and questionnaire forms.

During week seven of the study, the researcher selected the participants for the qualitative sample, and the qualitative sample were interviewed. The researcher was careful of the power

differential issues that may negatively influence candid answers to the research questions with students. Therefore, it is critical that participants understand that the researcher's role during the study. The researcher made sure that information shared was confidential and listened as objectively as possible to the students.

Data was collected from tests, interviews, surveys, field observations, and student work. Semi-structured interviews were conducted. Specifically, interviews with students in the qualitative sample ( $N = 8$ ) were conducted as informal meetings consisting of semi-structured and open-ended questions. The experimental group used the treatment which is the Adventures of Krystal Kingdom game. Verbal and written reflection was presented during the mission in the form of a mathematical modeling activity sheet from the students' work. At the beginning of the semester three sets of instruments were used: the demographics survey to identify the participants' demographic information, an exam, and the motivation survey to understand the students' motivation in mathematics. There were two interviews conducted. The first interview discussed the students' past experience with learning mathematics and their perception of video games and educational technology. The second interview discussed their experience in using the virtual coupled or DGBL environment, and how it has affected their motivation and understanding of Vector functions and Vector Geometry.

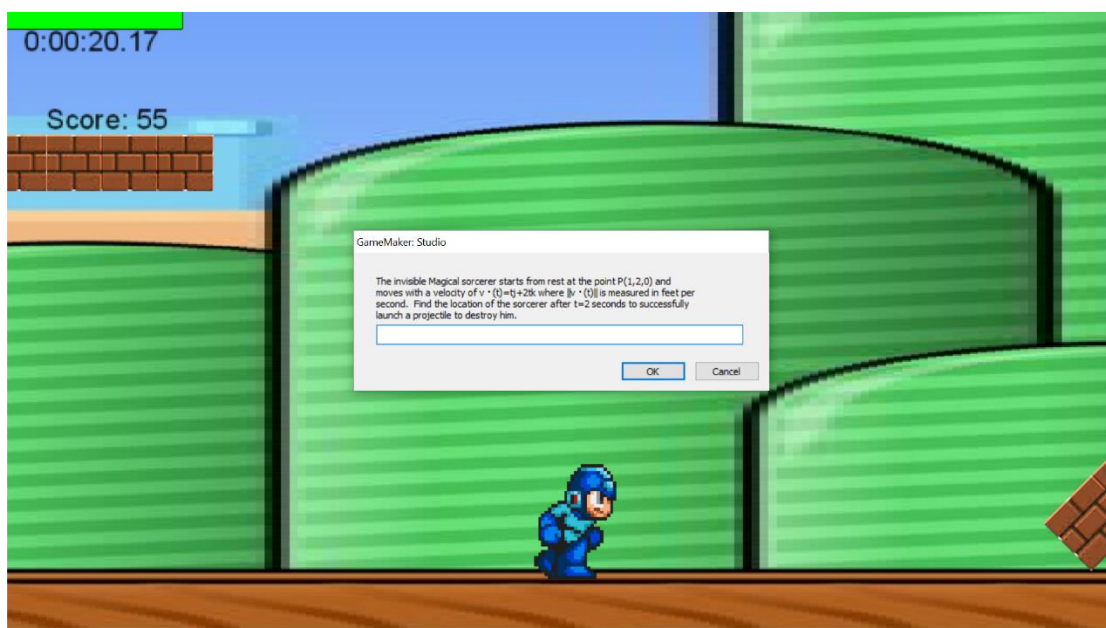
### **Game Description**

The game that was designed is called Adventures of Krystal Kingdom. It is an educational video game that is designed to engage students in a fun learning environment where STEM students learn Multivariable Calculus in a fantasy world. The game is designed to target our eager STEM undergraduates who struggle with understanding topics in a traditional lecture

setting and need a differentiated instructional approach involved with gaming. The game also serves as an enrichment tool to personalize their understanding using digital learning.

### Intervention and Game Design

The research intervention is called Adventures of Krystal Kingdom. Adventures of Krystal Kingdom game reinforces and teaches Multivariable Calculus by involving a player to complete three mathematics related missions in a 2-D virtual coupled learning environment or DGBL environment. The researcher designed the game to align with the content of the course. Specifically, the game is a single player platform game in which the player competes against villains through the computer by collecting points through solving mathematics problems and collecting coins in their related obstacles along with hand and eye coordination and speed skills. Feedback and scaffolding will be provided by a health bar, points counter, clock, screen prompting and message boards throughout the game. This game has a platform genre that aligns with current modern games that are used in instructional game-designs today. The players became engaged in mathematical oriented missions to free Krystal Kingdom. The game was designed with appealing visual effects and to be user-friendly. See Figure 12 below.



*Figure 12.* Adventures of Krystal Kingdom is a DGBL environment. This is a screenshot that shows the first stage of the game where Mega is required to use his knowledge on integration techniques with vector-valued functions to solve the problem.

**Game Design.** The researcher designed the game specifically for this study. The design process involved the construction of sprites, backgrounds, and objects. The researcher used a game engine called GameMaker to develop the game. In addition to using GameMaker, the researcher used an editor within GameMaker called Sprite Editor. This editor provides functionality of creating and modifying the image of sprites. A sprite is “a two-dimensional image or animated image that plays a specific role, often independently manipulated, with a larger image environment” (Jassen, 2017, p. 23). An object is “a [sprite] in a game that the player can see and/or interact with.” (Game Design Novice, 2017, p. 40) The researcher also used the editor to handle some of the animations. This includes animations for the playable character, enemies, the boss, and special effects.

*Player Object.* The player object is named after the current character being played and can be identified by Killer Mega. The object has the obj\_Player script on it, which is used to act according to the input from the user, this is done by programming the keyboard to listen to events from the user’s input. This object is also connected to a sprite, sprite14 (Killer Mega), so that the player can be animated according to his actions.

*Enemy Objects.* The enemy objects come in 6 different variations: obj\_hatter (Broom Hatter), obj\_poppy\_bro (Poppy Bro), obj\_Waddle\_Doo (Waddle Doo), obj\_Waddle\_De (Waddle Dee), wizard\_obj (Wizard), and spacecraft\_obj (Alien spacecraft). The scripts among each enemy vary by the game designer’s needs in the game. They are placed in different parts of the game.

*Boss Object.* This object is identified by the object, obj\_main\_enemy and is named Dark Heart. The boss has been coded with a semi-complex script that cause the boss to randomly generate attacks on the player object.

*Power Up Objects.* The game has a Power Up object in the shape of potion bottle, which recovers the player's lost health. There are three power up objects that are placed at different stages of the game.

*Trigger Objects.* There are four different kinds of these objects. They are objectTrigQ1, objectTrigQ2, objectTrigQ3, and obj\_warp. The first three triggers make sure that the player cannot leave the defined sublevel without answering the displayed mathematical exercise when he is colliding with it. The other trigger, obj\_warp, transports the player object to another room or level in game world.

Game Maker has some predefined functions that run on different times. When a game is executed the first function that will be ran is the Game\_Start() function. Appendix F shows a partial breakdown of how the boss's and the player's scripts are implemented in the game world.

The delivery issues from the previous chapter mentioned curriculum issues, outcome issues, and technical. These issues related the necessary core mechanics of the instructional game and were investigated during the delivery of Adventures of Krystal Kingdom through the assessment tools that were mentioned above.

### **Gameplay and Additional Descriptions**

During gameplay, students were able to maneuver through the game by using the arrow keys on the keyboard to move protagonist to the left and right. Students could also make the protagonist jump by pressing the arrow up key. To destroy the foes and enemies in his path, the player can press the F key or the spacebar to launch projectiles at them. During gameplay, the



player can collect coins or answer a math question to gain points. Throughout the game, power-ups are placed in different stages of the game to allow the player to recharge his life bar when needed. When a math question is displayed after hitting a hidden trigger, the students would read and workout the problem on the MML worksheet. The MML worksheet is designed to scaffold the student's problem-solving process to construct a well-designed mathematical model to find a solution. When a problem is solved, points are earned when a student submits the correct solution in the input box. Students spent about 10 to 20 minutes playing the game.

From a game designer's perspective, the game had more gaming components than educational components. It was designed this way to ensure that the engagement level does not drop during gameplay. Otherwise, the designer would run the risk of losing the students' interest or desire to play from over populated exercises throughout the game. This reaffirms Adams' (2014) findings that too many internal economy components can make the game too difficult for a player to stay engaged in gameplay.

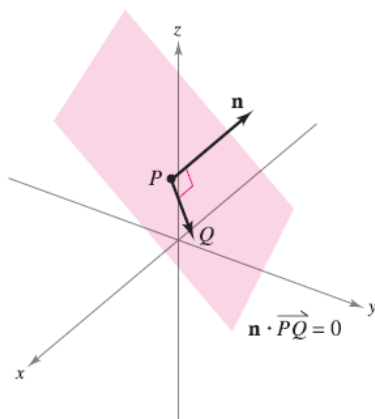
The mathematical concepts that students will engage in solving are Vector Geometry. Specifically, students will be engaged in a multivariable calculus platform game that assist students in understanding Lines and Planes in Space, and Differentiation and Integration of Vector-Valued functions. Details of the basis of the mathematical content of Vector Calculus is discussed in the Vector Geometry Content Brief below.

### **Vector Geometry Content Brief**

In order for students to be ready for advanced topics such as Line and Surface Integrals in Multivariable or Vector Calculus, student must have a foundational understanding of Vector Geometry with lines and planes, and vector-valued functions, which are the topics that are depicted within the video game.

In calculus, we define a plane as a flat, two-dimensional surface that extends without bound (Boyd, Cummins, Malloy, Carter, & Flores, 2004). When writing the equation of a plane in space, two components must be known, a point that lies in the plane and a normal vector as in Figure 13 below. A normal vector is a vector that is orthogonal to the plane. Consider a plane that contains a point  $P(x_1, y_1, z_1)$  that has a nonzero normal vector  $\mathbf{n} = \langle a, b, c \rangle$  as shown in the Figure 13. The plane consists of all points  $Q(x, y, z)$  that vector  $\overrightarrow{PQ}$  is orthogonal to  $\mathbf{n}$ . Then the equation of the plane can be represented in the following forms:

- 1) Vector form:  $\mathbf{n} \cdot \langle x - x_1, y - y_1, z - z_1 \rangle = 0$  or  $\mathbf{n} \cdot \overrightarrow{PQ} = 0$
- 2) Scalar form:  $a(x - x_1) + b(y - y_1) + c(z - z_1) = 0$  or  $ax + by + cz + d = 0$ .



*Figure 13.* This illustration shows the geometric representation of a plane in 3-space where the normal vector  $\mathbf{n}$  is orthogonal to every  $\overrightarrow{PQ}$  in the plane. Adopted from Lines and Planes in Space, R. Larson, 1998, Calculus, p.738.

A line is defined as a set of collinear points that extent infinitely in two directions (Boyd, Cummins, Malloy, Carter, & Flores, 2004). When working in three-dimensional space, it is best use vectors to determine the equation of lines. When writing the equation of a line in space, two components must be known, a point that lies in space and a direction vector as in Figure below.

Consider a line that passes through point  $P(x_1, y_1, z_1)$  and that is parallel to vector  $\mathbf{v} = \langle a, b, c \rangle$  as shown in the Figure 14. If we consider that this line consists of all points  $Q(x, y, z)$  where vector  $\overrightarrow{PQ}$  is parallel to  $\mathbf{v}$ , then the line can be represented in the following forms:

- 1) Vector parametrization form:  $\mathbf{r}(t) = \overrightarrow{OP} + \overrightarrow{PQ} = \langle x_1, y_1, z_1 \rangle + t\mathbf{v}$  or  

$$\mathbf{r}(t) = \langle x_1, y_1, z_1 \rangle + t\langle a, b, c \rangle$$
- 2) Parametric equation form:  $x = x_1 + at, y = y_1 + bt, z = z_1 + ct$  (Larson, Hostetler, & Edwards, 2013).

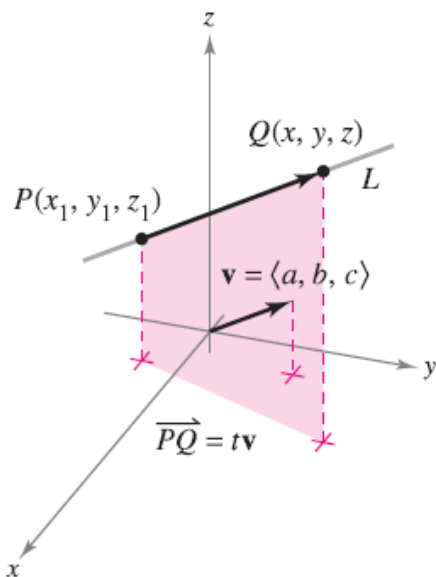
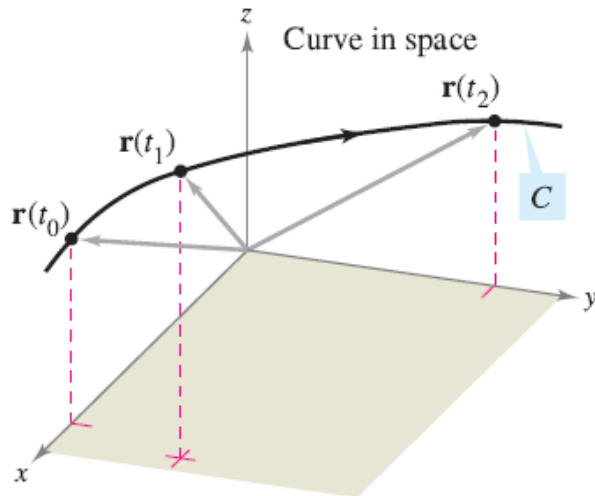


Figure 9. Line  $L$  and the direction vector. Adopted from Lines and Planes in Space, R. Larson, 1998, Calculus, p.737.

A Vector-valued function “is any function  $\mathbf{r}(t)$  of the form  $\mathbf{r}(t) = \langle x(t), y(t), z(t) \rangle = x(t)\mathbf{i} + y(t)\mathbf{j} + z(t)\mathbf{k}$  whose domain  $D$  is the set of real numbers and whose range is a set of position vectors” (Rogawski, 2012, p. 738). The variable  $t$  is defined as a parameter and the functions  $x(t), y(t)$ , and  $z(t)$  are named the components or coordinate functions. The vector

function  $\mathbf{r}(t)$  points from the origin to the position of an object along the space curve  $C$  as shown in Figure 15.



*Figure 15.* Curve  $C$  traced out by the position vector. Adopted from Vector-Valued Functions, R. Larson, 1998, Calculus, p.769.

An example of a vector-valued function that the students learned from the course is the Helix parametric curve. The Helix curve is described by a curve traced by  $\mathbf{r}(t) = \langle 4 \cos t, 4 \sin t, t \rangle$  as shown in the Figure 16.

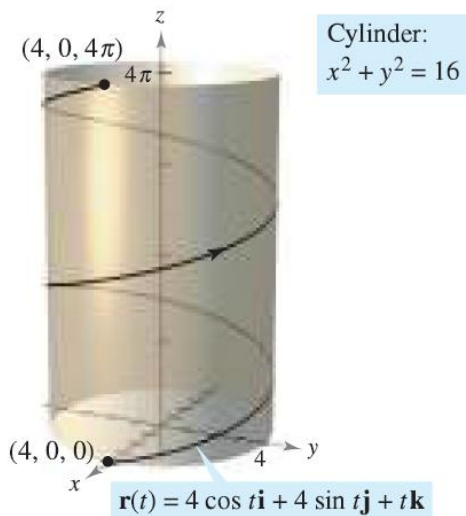


Figure 16. Helix curve is traced out. Adopted from Vector-Valued Functions, R. Larson, 1998, Calculus, p.770.

### Description of Game Integrated Exercises

The game exercises are partitioned into three parts: (1) vector-value functions, (2) vectors and the geometry of planes, and (3) vectors and the geometry of lines. In stage 1, students learn to differentiate and integrate a vector-valued function. The question focuses on how to find the position function,  $\vec{r}(t)$ , using integration techniques and using an initial condition. Question 1 states, “The invisible Magical sorcerer starts from rest at point  $P(1,2,0)$  and moves with a velocity of  $\vec{v}(t) = t\mathbf{j} + 2t\mathbf{k}$  where  $\|\vec{v}(t)\|$  is measured in feet per second. Find the location of the sorcerer after  $t=2$  seconds to successfully launch a projectile to destroy him.” In stage 2, students learn to write the equation of a plane given a set of coplanar points. Question 2 states, “Killer Mega uses his powers of telepathy and senses a sorcerer near the surrounding coordinates  $(2,1,1)$ ,  $(0,4,1)$ , and  $(-2,1,4)$ . Determine the general plane of the region by determining the equation of the plane in general form so that he can use his telekinesis to destroy the sorcerer. In stage 3, students learn to construct the equation of two lines and determine whether the lines are

parallel, intersecting, or skewed. Question 3 states, “Two spacecrafts are coming from opposite directions on a diagonal path where spacecraft 1 travels along  $(1,-7, 2)$  to  $(7,8,-1)$  and spacecraft 2 travels along  $(1,11,4)$  to  $(5,9,1)$ . Will they intersect and explode, or will they miss each other? If they explode, enter the coordinates. If they don't, then typed SKEWED OR PARALLEL.”

### **Data Management Plan**

The raw data was collected and managed and organized into two categories such as digital and paper artifacts. All data including video and audio tapes, interviews, completed observation logs, mathematical modelling forms, mathematics achievement scores, and responses to the course motivation survey were stored in a locked room in the researcher's development laboratory.

### **Data Analysis**

The unit of analysis includes student work while immersed in a platform game environment in a Multivariable Calculus course. Student motivation and achievement were examined as they took on the role of the adventurer in the game world. The students were observed as they encountered several situations by individually participating in a platform game that will assess their learning skills.

***Quantitative data analysis.*** Three data analysis techniques were conducted: Descriptives, dependent *t*-test, and reliability analysis. The researcher ran Descriptives to examine the demographics of the sample. Reliability analysis was be done to analyze the internal consistency of the achievement test and motivation survey. Cronbach's alpha was used to measure internal consistency of the tests and the motivation survey. The reliability and validity of the course motivational survey was confirmed by Kebritchi (2008) for the total scale of the 20 items. Kebritchi (2008) confirmed that Cronbach alpha was approximately 0.86. A

dependent sample *t*-test was used to compare the means of the achievement pre- and post- test and the motivation pre- and post- surveys of the experimental group. The null hypothesis for the achievement dependent sample *t*-test states that there is no difference in the means of the pretest and posttest administered. For the motivation pre-survey/post-survey, the null hypothesis states that there is no difference in the mean scores for each subscale of the motivation pretest and posttest.

*Dependent sample t-test Assumptions.* According to Minium and Clark (1982), all statistical analyses like the *t*-tests must have specific assumptions met in order to hold valid results. First, the distribution of the data must be measured on a continuous scale. Time, ratio values, and exams scores are examples of distributions on a continuous scale. Second, data must come from two related groups. Third, there should be no presence of outliers (Minium & Clark, 1982). This is because outliers negatively affect the outcome of the dependent sample *t*-test. Lastly, the two related groups must be normally distributed.

*Qualitative data analysis.* Transcriptions from interviews and observations were analyzed using qualitative techniques. Data from the interviews was transcribed into word processing files. Once transcribed, data analysis began by generating a list of themes and codes to provide evidence of other interpretation (Mertens, 2005). I used the verbatim transcription technique to transcribe the interviews. After reviewing the transcripts, I used open coding techniques to identify unique concepts in the data. Coding is a powerful data analysis technique that brings together a wealth of material into some order and structure (Cohen, Mansion, & Morrison, 2011). Using coding allowed the researcher to detect frequencies in which codes were occurring mostly and the patterns in which codes occurred (Cohen, Mansion, & Morrison, 2011).

Developed themes were compared to an existing body of research. Themes and interviews were used to explore concordance and discordance from the quantitative phase of the study.

Artifacts such as DGBL log files and mathematical modeling activity sheets were analyzed using visual content analysis. In many ways, artifacts such as documents resemble observations in that it gives the researcher a snapshot into what author believes is significant, specifically their personal perspective (Merriam, 2009). In addition, these types of artifacts reveal to the researcher the deeper meaning of an event or they may show content of highly unusual or eccentric human experiences (Merriam, 2009). In the artifacts, evidence of learning, engagement, and achievement were identified. Student notes, drawings, and mathematical modeling construction in the student mathematical modeling activity sheet were coded equally as the classroom observations and interviews. Coding was done to study and analyze patterns that could appear. The coding process was done to triangulate the data with previously collected data. Particularly, Creswell's (2014) six step process on coding was used.

Step 1: "Organize and prepare the data for analysis" (p. 247). In this step, the researcher reviewed the recordings from the interviews and transcribe them onto word documents.

Step 2: Read through the data (p. 247). At this step, the researcher reflected on the overall meaning to gain a general sense of the data and ideas that the participants disclosed.

Step 3: Start the coding process for all data (p. 247). the researcher followed Creswell's process in rearranging the data into segments. This was done by retrieving the text data and partitioning the sentences in categories. Afterwards, the researcher labeled those categories based on the language from the participants.

Step 4: "Use the coding process to generate a description of the setting or people as well as categories or themes for analysis" (p. 249). the researcher used this procedure to develop



codes for the descriptions, which resulted to creating a small number of categories or themes. Next, the researcher analyzed the themes that arose and collected several cases into a general description for the bounded case.

Step 5: “Advance how the description and themes will be represented in the qualitative narrative” (p. 249). At this step, the researcher merged the themes into narrative passages to logically express each participants’ responses.

Step 6: Understand and interpret the meaning of the results. While doing the interpretation, my experience as the researcher and games designer enlightened and inform my understanding of the participants’ journey in the Digital Game-Based Learning environment. In addition to expressing the participants’ perceptions of their experiences accurately, the researcher particularly focused on what they were saying, and the conclusions they drew. The themes that evolved from this study were derived from my awareness of the appropriate tension among my own biases and the participants’ own understanding and interpretive process.

### **Reliability and Validity**

Having reliable and valid data for the surveys are paramount for the quality of the research. In order to ensure reliability, the research used a method that has demonstrated high reliability in prior empirical studies. The researcher determines the reliability of the measure by performing consistency measurements using Cronbach’s alpha formula. The reliability of the Course Motivation survey is estimated based on the Cronbach’s alpha measure with a total subscale of 20 items for motivation, and pre- and post- exams. The total scales along with every subscale with the exception of relevance and confidence meet the requirement of the alpha value being greater than .7, which is recommended by Nunnally (1978). Validity indicates how accurate is our instrument at measuring data (Huck, 2008). Kebritchi (2008) confirmed that Cronbach

alpha was approximately 0.86. The validity of the Motivation survey has been validated by the experts who designed and modified the motivation survey. In addition, Trochim (2006) claims that there are four threats to the interval validity of pre- and post- exam data. These include the maturation, testing, history, and instrumentation. In order to avoid these threats, the pre- and post- data had gone through an analysis with other data sources. The exam and questionnaires were examined for internal consistency using the Cronbach's alpha measure.

Having trustworthiness and credible data are important for the quality of research. Having credibility shows the internal validity among the correspondence with the participants' perspective and how the researcher interprets their perspective (Mertens, 2005). In order to have credibility the researcher used extensive engagement, progressive subjectivity, member checks, and triangulation (Mertens, 2005). During the interviews, the researcher obtained their views during a 30-minute session. In these sessions, the researcher used succinct and descriptive statements to ensure that he is accurately capturing the participants' voices. Throughout the researching process, the researcher kept a log journal of his thoughts, feelings, and reactions to acknowledge, reveal, and supervise his personal views/biases. The researcher reviewed his personal journal with a committee member to lessen the impacts of his personal experiences and biases on the data. In addition, member checks were conducted to have credibility. For member checks, the researcher paraphrased what participants shared over the course of the session. The researcher may choose to contact the participants after the session to verify that he is interpreting the participants' voice in a way that is credible and reliable. Data was collected from the interviews, and researcher journal was triangulated to examine consistency.

## **Potential Limitations**

The results of this study were indications of the effects of Adventures of Krystal Kingdom in a highly diverse research institution in a southeastern state in the United States of America. Thus, the study is a limited sample from this population. There was limitation on the amount of the time usage and location. For instance, the amount of time spent on the game and the location varied among the exploratory study. There is also a possibility of shrinking our sample size because the number of students may change or withdraw from the class. Other limitations include the generalization of the outcomes among similar populations using similar instructional games. The sample size (N = 25) is a limitation in terms of generalizability. There is also the possibility that the use of time and location with the DGBL environment could possibly affect the achievement level and motivation outcomes of the students.

## **Research Permission and Potential Ethical Issues**

Before conducting the research study, the researcher submitted Institutional Review Board (IRB) protocols and comply with district policies pertaining to research at the proposed school site. The researcher received permission to perform the research from the professor at the school site. The students and educators received consent and/or assent forms describing the voluntary status of this study and outlining guaranteed rights that they have as participants. Confidentiality of the participants was maintained through the use of STUDY ID codes for the questionnaires. Confidentiality of the participants during the qualitative sections of this study was maintained by keeping the students' names anonymous throughout the research process with use of initials or STUDY ID codes for identification purposes. Additionally, pseudonyms for the school was used for this study. Data collected during the quantitative and qualitative sections of

this study was kept in a locked file cabinet and/or password protected computer. Findings from the study were presented during the researcher's dissertation defense and to the school site.

## CHAPTER FOUR: RESULTS

### **Data Analysis and Results**

The purpose of this study was to investigate and describe the effects of using a DGBL environment on undergraduate students in a Multivariable Calculus course. The chapter is divided into four main sections including: (a) introduction, (b) the research hypotheses, (c) interviews, and (d) artifacts and class observation. This chapter examined the findings from the case study that include qualitative and quantitative samples. The quantitative sample included 25 students from an undergraduate mathematics course and the qualitative subsample included 8 students selected purposively from the course. The case study addressed the following questions:

1. How does a platform game affect the learning of undergraduates in a Multivariable Calculus class? How does a platform game affect the motivation of undergraduates in a Multivariable Calculus class?
2. What features and dimensions of the platform game are necessary to maintain the engagement of the students during the learning and gaming process? What kind of threats do students face?

The following two research hypotheses were proposed in this study:

1. There is a significant difference between the learning of the undergraduate students who received the platform game.
2. There is a significant difference between the motivation level of the undergraduate students who received the platform game.

Quantitative and qualitative data were collected to address the concerns of the research questions. The quantitative data collected included students' responses to a demographics survey, pre/posttests to measure achievement or learning, game performance test, and a

motivation and engagement survey to measure engagement. The qualitative data collected consisted of semi-structured interviews, observations and student artifacts. Artifacts included samples of students' work using the Blum's and Lieb's mathematical modeling cycle. After the discussion of the techniques and results, a summary will be provided.

## **Quantitative Data Analysis**

### **Analysis Techniques**

A dependent *t*-test with the *Intent-to-Treat* analysis was employed to test hypothesis 1. The null hypothesis stated that there is no difference in the means of the pretest and posttest administered. For the motivational pre- and post- surveys, the null hypotheses stated that there is no difference in the mean score between the two tests. A two-tailed test using a significance of .05 was used for both. Dependent sample *t*-test assumptions were tested with descriptive methods and data management verification. The results informed the proper use of data. The following section discussed the results for learning and then engagement.

### **Learning and Performance**

**Testing Assumptions.** There are four assumptions that must be met to run a dependent *t*-test (Triola, 2010). First, the dependent variable must be measured on a continuous scale. Examples of this would be time and test scores. Second, we have two categorical groups, the pre- and post-exams and pre- and post- motivation surveys. The scores from the pre/post tests were continuous and from matched pairs. Triola (2010) states that the third assumption states that there should be no outliers present. Third, we have no significant outliers in our two related groups. See Figures 17 and 18. Lastly, the data must be normally distributed. A normality test was performed on the data using the Shapiro-Wilk test. Thus, the data is normally distributed.

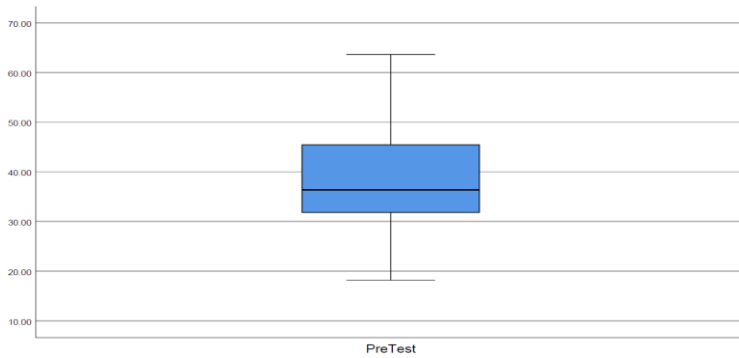


Figure 17. Stem-and-Leaf Plot: Pre-Test Scores (N=25).

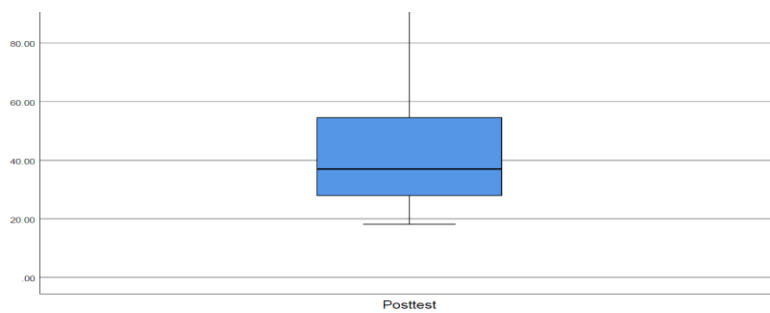


Figure 18. Stem-and-Leaf Plot: Post-Test Scores (N=25).

According to the Shapiro-Wilk's test with respective significance of  $p = .283 > .05$  and  $.388 > .05$  on the pre-motivation and post-motivation. Therefore, the pre- and post- test data are not significantly different from a normal distribution. Thus, the pretests and posttests, and the pre- and post- tests data are normally distributed. Table 4 presents the results of the Shapiro-Wilk test.

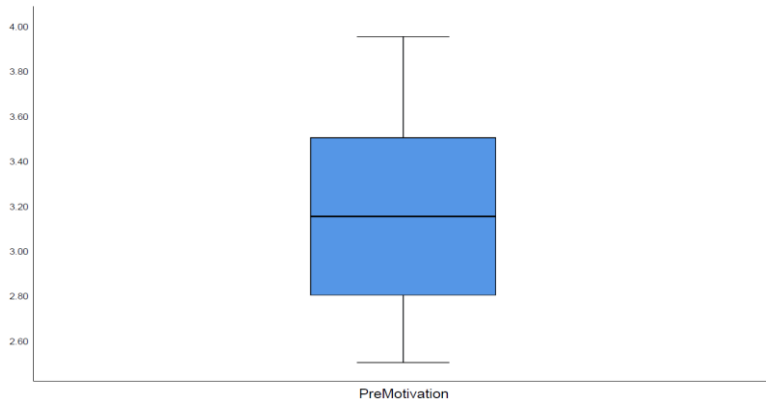


Figure 19. Stem-and-Leaf Plot: Pre-Motivation Scores (N=25).

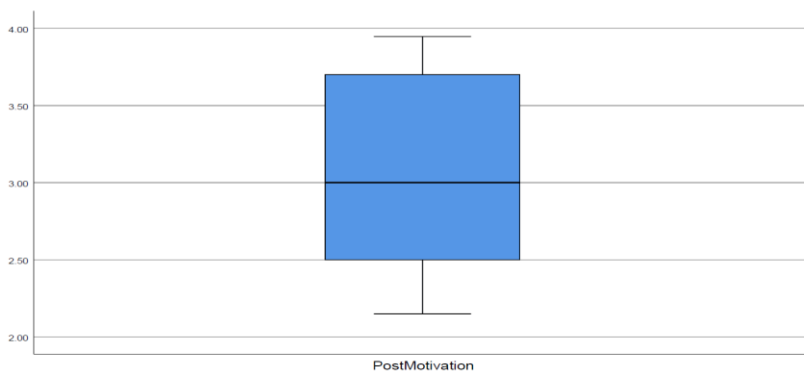
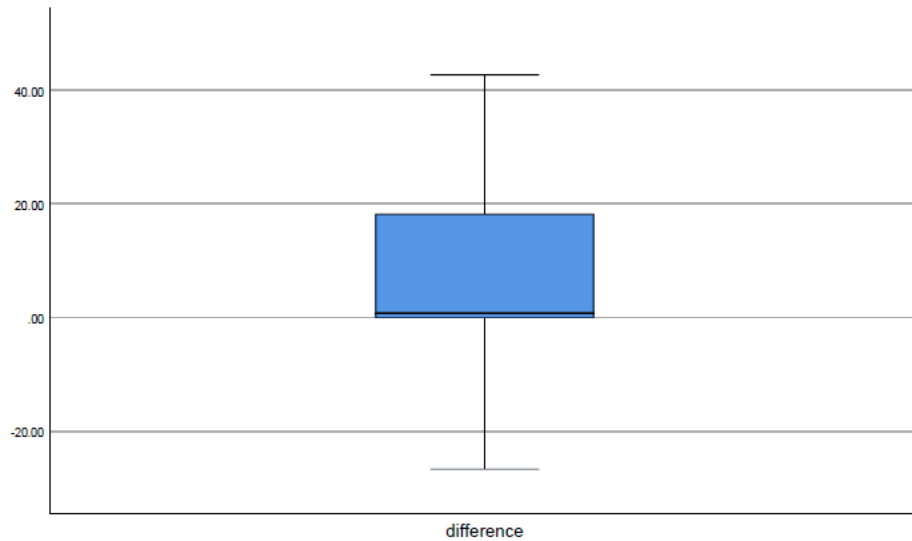


Figure 20. Stem-and-Leaf Plot: Post-Motivation Scores (N=25).

According to Triola (2010), it is suggested that one of the two conditions must be satisfied when the sample size in question to insure validity within a dependent  $t$ -test: The sample should be large where  $n > 30$ . However, if  $n < 30$ , then the differences of the paired values that are from the population must have an approximately normal distribution to be considered in the  $t$ -test.

Since our data set contains a sample size of 25, then the researcher must check for normality of the differences and for the outliers among the differences. After running the Shapiro-Wilks test, we found that normality is satisfied ( $p = .328 > .05$ ) and there were no outliers present. See Figure 21 below. Thus, the dependent test requirements are satisfied.





*Figure 21.* Stem-and-Leaf Plot: Differences among Scores (N=25) also shows that there are no outliers present.

**Intent-to-Treat Analysis (ITTA).** In addition to using a dependent *t*-test, the quantitative data was examined using the Intent-to-Treat Analysis. ITTA is a statistical method that is used to prevent effects of attrition (Higgins and Green, 2000). Therefore, no students are excluded in the study, and all students are examined whether or not the student received the intervention or treatments. In order to include students' data who had withdrawn from study, we must impute their outcomes. Since the majority of our students show a steady improvement in their achievement scores, then it would be reasonable to assume that the dropouts continue to improve their achievement scores according to ITT's method of imputation. Similarly, the quantitative motivation data will be imputed as well.

**Reliability Analysis.** Cronbach alpha was used to determine and confirm the internal consistency of the items on the post survey. The reliability of the Course Motivation survey has been estimated based on Cronbach's alpha measure for the total scale with 20 items for the motivation survey. Cronbach's alpha for the survey was found to be strongly reliable ( $\alpha = .729$ ).

In addition, the effect size was calculated to be  $d = .03$ , which is small. Effects size provides us with an alternate way to quantify the difference between groups (Coe, 2002). Coe argues that the effect size quantifies the size of the difference between two groups and given indications that the difference between the pre-motivation and post-motivation scores of 25 undergraduate were extremely small.

Table 3

| <i>Reliability Statistics</i> |            |
|-------------------------------|------------|
| Cronbach's Alpha              | N of Items |
| .729                          | 20         |

**Dependent sample *t*-test.** In measuring learning and performance, the results indicated that there was no statistically significant difference in group mean scores ( $p = .273 > .05$ ) between the pretest and posttest. However, the results indicated that the mean of the posttest ( $M = 44.1$ ,  $SD = 19.6$ ) was greater than the mean of the pretest ( $M = 39.1$ ,  $SD = 12.7$ ) where  $t(df = 22) = -1.123$ . Although there is no significant difference, there was around a five-point improvement on the exam when compare with pretest and posttest.

### **Engagement**

**Testing Assumptions.** Again, parametric statistics have assumptions that must met and validated. There were four assumptions tested for the paired sample t-test for the motivational survey. The first two assumptions were tested just as it was done for the pre/posttests for achievement. It was noted that the responses from the motivational survey were continuous and from the dependent sample. There have been some arguments among DeWinter and Dodou (2010) about using the five-point Likert data parametric or nonparametric test. This is because

of the issue with normality. Through studying several forms of distribution from the 5-point Likert item surveys, the *t*-test was found to be accepted and favored. According to the Shapiro-Wilk test with  $.567 > .05$  and  $.143 > .05$  the pre-motivation and post-motivation data are not significantly different from a normal distribution. Thus, the pre-motivation and post-motivation data are normally distributed.

Table 4

| <i>Test of Normality: Exam Scale Score (N=25)</i> |              |    |      |
|---|--------------|----|------|
|   | Shapiro-Wilk |    |      |
|   | Statistic    | df | Sig. |
| Pretest   | .934         | 25 | .283 |
| Posttest  | .943         | 25 | .388 |

Table 5

| <i>Test of Normality: Motivation Scale Score (N=25)</i> |              |    |      |
|---|--------------|----|------|
|   | Shapiro-Wilk |    |      |
|   | Statistic    | df | Sig. |
| Pre-motivation  | .959         | 25 | .567 |
| Post-motivation   | .919         | 25 | .143 |

**Dependent sample *t*-test.** In measuring engagement, the results indicated that there was no statistically significant difference in the group mean scores ( $p = .088 > .05$ ) between the pre- and post- motivation surveys.

The motivational survey is divided into four subscales. The subscales are attention, relevance, confidence, and satisfaction from the ARCS Model as discussed in chapter 2 and 3. To compare the means across the four motivation and engagement subscales, a dependent sample *t*-test was employed for each subscale using the pre- and post- raw scores.

Across the three subscales, there were no statistically significant differences in the means. The attention subscale had similar means of the post-survey ( $M = 3, SD = .6$ ) and pre-survey ( $M =$

3,  $SD = .5$ ) where  $t(df=24) = 0.244$  with  $p = 0.809$ . The relevance subscale also had similar means of the post-survey ( $M=3$ ,  $SD = .5$ ) and the pre-survey ( $M=3$ ,  $SD = .5$ ) where  $t(df=24) = .741$  and  $p = 0.466$ . Also, the confidence subscale had similar means of the post-survey ( $M = 3.1$ ,  $SD = .44$ ) and the pre-survey ( $M=3.1$ ,  $SD = .4$ ) where  $t(df=24) = .222$  and  $p = 0.826$ .

However, with the satisfaction subscale, the results of means of the post-survey ( $M = 3.23$ ,  $SD = .9$ ) was statistically significantly greater than the mean of the pre-survey ( $M = 3.7$ ,  $SD = .73$ ) where  $t(df=24) = 2.96$  and  $p = 0.007$ .

In summary, there was no significant difference in learning in pretest and posttest. There was no significant difference in the pre-motivation and post-motivation surveys. However, the students improved their overall exam score by five points after using the intervention.

### **Qualitative Data Analysis**

#### **Method of Analysis: Coding**

Yin (2014) shows us several key elements that must be discussed when examining a case study. First, Yin states that the researcher must keep up with and monitor all the qualitative data. In this research study, the DGBL mathematical modelling artifacts sheets and interviews were the basic unit of analysis that were analyzed to gain a deeper understanding into how the DGBL environment effected the students learning in an undergraduate course in Multivariate Calculus course and how students utilize a DGBL environment as a tool for learning Multivariate Calculus. In addition, interviews, artifacts, observations, and the researcher/teacher's journal were dissected to reveal the process of how students used a DGBL environment to influence their learning and engagement in mathematics.

In addition, Yin (2014) also stresses that the researcher must discuss the most vital features of the research. Using the 6-step protocol suggested by Creswell (2013), the codes,

categories, and concepts were extracted to identify the emerging themes throughout the analysis of the data. Based on the researcher's interpretations and introspect, the data gathered from the transcribed interviews, mathematical modelling artifacts, observations, and the researcher's journals were coded to create categories and general concepts. Highlighting and color coding were utilized to identify critical indicators of engagement and learning, and digital learning issues on several instances: (1) when student engaged in conversations and interactions during gameplay, (2) when students used pictorial representations and mathematical modelling such as diagrams to solve the digital exercise, (3) how students identified the real-world connection with the exercises, (4) how the DGBL environment affected the learning and engagement in the Multivariate Calculus content, (5) what digital learning features or issues were identified during gameplay, (6) students' behavior during the interaction with DGBL environment, and (7) students' behavior during the problem-solving and learning process. With these key focal points, the researcher was directed through the six-step process offered by Creswell (2013).

**Step 1: Organize and prepare the data for analysis.** Creswell (2013) defines a code as a method of structuring collected data and by bracketing chunks of qualitative data and writing a word symbolizing a category in margins (Creswell, 2013). As recommended by Creswell (2013), the interviews data was transcribed, field notes were typed up, mathematical modelling sheets were sorted and arranged.

**Step 2: Read through the data.** As recommended by Creswell (2013), the researcher carefully read through the interview transcripts, artifacts, and field notes to gain and reflect on the overall data meaning to gain a general sense of the data and ideas that the students shared.

**Step 3: Start the coding process for all data.** The coding process started as soon as the data was collected. Reviewing the data at that time during the study allowed for the developing of codes to explore many aspects of the unit of analysis. The following codes were identified by hand but not necessarily in the order of identification: (1) learning, (2) engagement, (3) game features, (4) digital game-based learning, (5) career goals, (6) student perception of digital game-based learning environment, (7) student self-perception, (8) application of concepts, (9) student and DGBL environment relationship, (10) classroom environment, (11) student thinking, (12) knowledge acquisition, (13) digital and data representation, (14) emotional, (15) use of technology, (16) perseverance, (17) technology frustration, (18) classroom discussion, and (19) skill transfer. the researcher followed Creswell's process in rearranging the data into segments. This was done by retrieving the text data and partitioning the sentences in categories. Afterwards, the researcher labeled those categories based on the language from the participants.

**Step 4: Use the coding process to generate a description of the setting or people as well as categories or themes for analysis.** Creswell (2013) states that we can generate codes from the description of the setting, people, categories, themes, places, and events in a setting. The researcher used this process to generate codes for the description, which led to developing a smaller number of categories and themes. Then, the researcher analyzed themes that emerged and collected various cases into a general description for this bounded case.

**Step 5: Advance how the description and themes will be represented in the qualitative narrative.** At this step, Creswell (2013) states that we put together the emerging themes into narrative passages to logically express each participants' responses.

**Step 6: Understand and interpret the meaning of the results.** While doing the interpretation, my experience as the researcher and game designer enlightened and informed my understanding of the participants’ journey in the Digital Game-Based Learning environment. In addition to expressing the participants’ perceptions of their experiences accurately, the researcher particularly focused on what they were saying, and the conclusions they drew. The themes that evolved from this study were derived from my awareness of the appropriate tension among my own biases and the participants’ own understanding and interpretive process.

Table 6  
*Categories, Concepts, and Themes*

| Category   | Concepts   | Themes  |
|--|--|---|
| <ul style="list-style-type: none"> <li>• Learning</li> </ul> | <ol style="list-style-type: none"> <li>1. Resistance in Learning journey (Quality Instruction)</li> <li>2. Conducive Learning Environment</li> <li>3. Self-directedness</li> <li>4. Relevance and Pragmatism</li> <li>5. Interactive Classroom and Effective Management</li> <li>6. Making links</li> <li>7. Choosing ways to do things</li> <li>8. Having their own ideas</li> <li>9. Learning environment</li> <li>10. Learning from others/social interaction</li> <li>11. Real World Learning</li> <li>12. Learning is fun and intrinsically motivation</li> </ol> | <p>Undergraduate students saw the use of the Adventures of Krystal Kingdom as learning tool to enhance their understanding of concepts in Multivariable Calculus.</p> |

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|   |  |  |
|---|--|--|
| <ul style="list-style-type: none"> <li>Engagement/Motivation</li> </ul> | <ol style="list-style-type: none"> <li>The struggle to stay in engaged</li> <li>Weak Professor-Student Bonds</li> <li>Technology</li> <li>Inquiry-Based Opportunities</li> <li>Classroom Atmosphere</li> <li>Finding out and exploring</li> <li>Playing with what they know</li> <li>Being willing to “have a go”</li> <li>Being Involved and concentrating</li> <li>Kept on trying</li> <li>Enjoying achieving what they set out to do</li> </ol>                       | <p>Undergraduate students saw the use of the Adventures of Krystal Kingdom as a way to engage themselves in mathematical fun in a digital environment.</p>             |
| <ul style="list-style-type: none"> <li>Game Features</li> </ul>         | <ol style="list-style-type: none"> <li>Activities for learning</li> <li>Representation of concepts</li> <li>Interface for manipulating with objects</li> <li>Navigating structure and order of activities</li> <li>Feedback information and rewards systems</li> <li>Fun elements</li> <li>Delivery Conflicts (Mechanics)</li> <li>Physics</li> <li>Internal economy</li> <li>Progression mechanism</li> <li>Tactical maneuvering</li> <li>Social Interaction</li> </ol> | <p>Undergraduate students saw core mechanics such as internal economy, tactical maneuvering and other core mechanics as components that affect students’ gameplay.</p> |

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## **Emerged Themes**

Three themes emerged as a result of data analysis providing evidence in regard to the effects of DGBL environments on learning and engagement, and game features.

Learning:

1. Undergraduate students saw the use of the Adventures of Krystal Kingdom as a learning tool to enhance their understanding of concepts in Multivariable Calculus.

Engagement:

2. Undergraduate students saw the use of the Adventures of Krystal Kingdom as a way to engage themselves in mathematical fun in a digital environment.

Game Features:

3. Undergraduate students saw the core mechanics such as internal economy, tactical maneuvering and other core mechanics as components that affect students' gameplay.

## **Learning**

**Theme 1: Undergraduate students saw the use of the Adventures of Krystal Kingdom as learning tool to enhance their understanding of concepts in Multivariable Calculus.**

Sedig's (2007) study indicated that the use of Digital Game-Based Learning environments plays a significant role in increasing or improving their achievement levels in mathematics. The usefulness of Adventures of Krystal Kingdom as a learning tool to further undergraduate students' understanding was synthesized from observations, artifacts, and interviews during and after intervention. During the observations, benefits of Adventures of Krystal Kingdom as a learning tool for undergraduate students were revealed. The undergraduate students from the multivariate calculus course openly discussed the different concepts that they noticed in Adventures of Krystal Kingdom as they were engaged in the DGBL environment.

As the participants engaged with Adventures of Krystal Kingdom, I jotted notes of the conversations that were occurring. Participants discussed the mathematical concepts presented within Adventures of Krystal Kingdom as they played the game. The following researcher's journal excerpt provides an example of how the participant noticed the mathematical concepts with Adventures of Krystal Kingdom:

The students were having an open discussion during gameplay concerning how to answer first multivariate calculus question that popped up during games. I spotted two students across the room. The students were looking at each and asking each other in wonder and pondered what they should do. One of students were able to determine which mathematical model was best to construct to solve the problem. (Research journal, session 1 excerpt).

Student #12 shared that the game was one of the more helpful education games out there in understanding calculus: "The game forced me to have a deeper understanding of vectors than what we had learned in the lecture." Student #12 shared that the game helped her "personalized it" in that she was able to see how vector-valued functions are used in real-life applications of engineering using advanced mathematics. Comments like, "It [the game] was one of the most helpful educational games out there... As far as understanding calculus, there not many educational games", "It [game] personalized it, which is a good things about games... and make it more important in your mind...", and "It revealed my lack of understanding of [vectors, planes, vector valued functions, and surfaces from the traditional lecture setting] (Student #12, first interview excerpt 4).

Student #8 stated that the game provided a real world understanding of how vector-valued functions are used in the field of engineering. Student #8 also shared the game had some

effect on her math skills in that it increased her confidence and desire to help other classmates with the game, and she now has a better understanding of how vectors function in Multivariable Calculus. She also affirmed that it reinforced what she should have been learning in the classroom. Student #8 stressed that the game had a positive effect on her learning. Comments like "... perfectly, helps what I don't know", "It [the game] [helped] me validate what I do know", and "It [the game] help because it was kind of the same questions [from the classroom]". Overall, Student #8 concludes that the game brought a sense of realization in that vectors can be found in all kinds of real-world situations (Student #8, second interview excerpt).

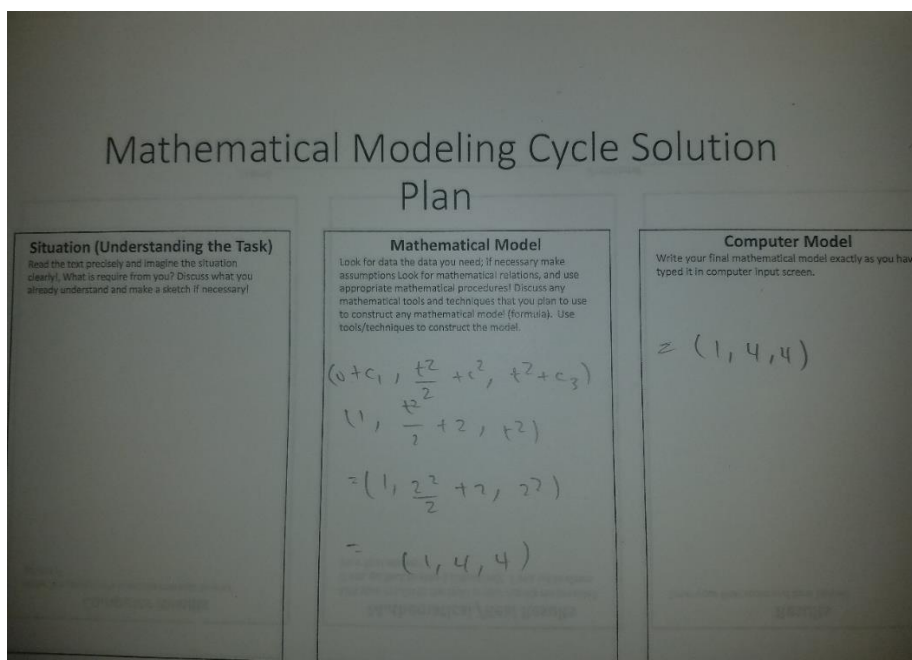


Figure 22. Student #6 constructed a mathematical model of a vector-valued position function to identify the position of the wizard in order to shoot him down.

The mathematical modeling worksheets (Appendix A) were part of the artifacts provided for students to complete as they played Adventures of Krystal Kingdom. The first questions is as follows: *The invisible Magical sorcerer starts from rest at point  $P(1,2,0)$  and moves with a*

velocity of  $\vec{v}(t) = t\mathbf{j} + 2t\mathbf{k}$  where  $\|\vec{v}(t)\|$  is measured in feet per second. Find the location of the sorcerer after  $t=2$  seconds to successfully launch a projectile to destroy him.



Figure 23. A snapshot of a stage in the game where students were asked to construct a vector-valued function to identify the sorcerer's position to destroy him.

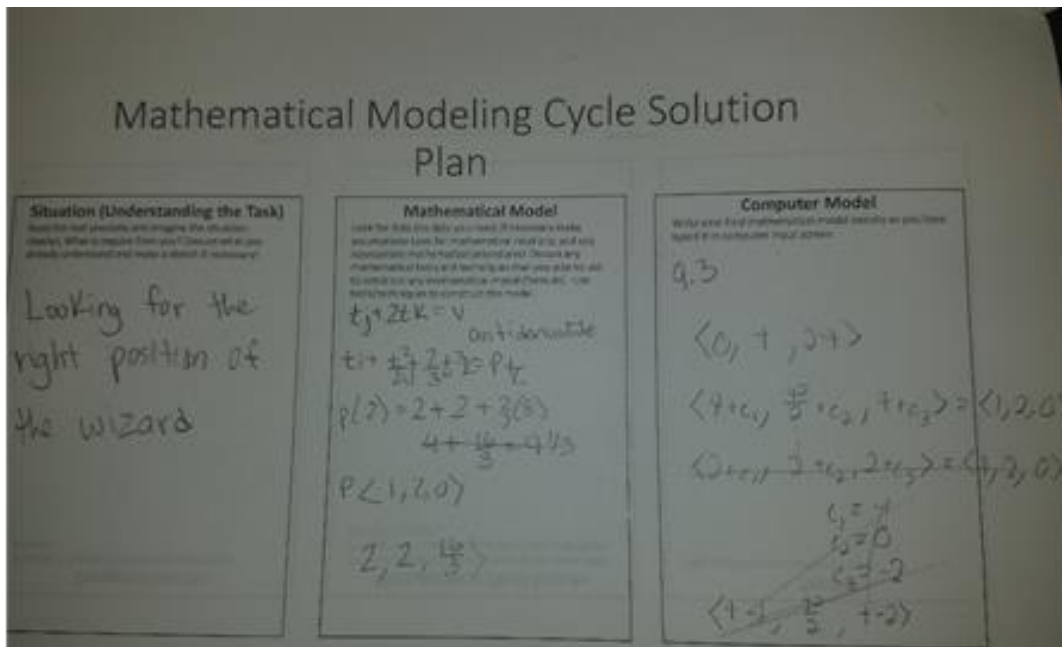


Figure 24. Student #8 constructed a mathematical model of a vector-valued position function to identify the position of the magical sorcerer in order to shoot him down.

Figure 24 demonstrates Student #8's thought process using the modified mathematical modeling cycle to construct the appropriate model to the problem in the first exercise. The concepts from Adventures of Krystal Kingdom included analyzing and sketching curves given by vector-valued functions, extending the concepts of limits and continuity to vector-valued functions, space curves, differentiating and integrating vector-valued functions, finding the cross product of two vectors in space, writing a set of parametric equations for lines in space, and linear equation to represent a plane in space.

Reflections were also used to have the participants ponder and share their experiences with Adventures of Krystal Kingdom. The participants discussed how the game set the foundation of topics that they did not learn in the course.

The Adventures of Krystal Kingdom game tied parts of chapter 11 and 12 together of the course book. The game presented provided a real-world scenario on how to use vector calculus concepts on how to determine the space curve trajectory of a target in space. When the students calculated the correct answer, they were further stimulated in what would happen next in the game world. (Student #5, Student # 6, Student #7, Student #8, Student #12, Student #14, Student #21, and Student #22, reflection two excerpt 3).

This excerpt below reveals the students' emotional excitement from calculating the correct solution on question 1.

Student #5 and Student #6 were successfully able to construct the appropriate vector-valued functions using integration techniques to find the position of the invisible sorcerer. After the response box popped up to notify the students that they had entered the solution correctly, Student #6 perked up a smile and widen his eyes and shouted, "Yes, got it!", and immediately motioned his hands across the arrow keys on the keyboard to resume gameplay. (Student #5 and Student #6, reflection four excerpt 7).

The following excerpts reveals the students' frustration and satisfaction after completing question 1 correctly.

During gameplay, Student #7 and Student #8 were not successful in entering the solution correctly in the input box. The students responded by expressing their frustration through grunts and moans after seeing the dialog box pop up stating that they were incorrect. Student #7 noticed that Student #8 forgot to enter ">" key to indicate that this was a vector solution. Student #7 reentered the solution with the missing syntax, ">". After submitting the correct solution and seeing the dialog box pop up with a

message that said, “Correct!”, Student #8 quickly press the “OK” button and yelled, “ Go go go.”

During gameplay, Student #5, Student # 6, Student #7, Student #8, Student #12, Student #14, Student #21, and Student #22 took turns in helping each other with the game exercises when one or more of them were unsure about how to complete the problems in the game. The students sometimes experienced levels of frustration but they continued to enjoy the process. During the interview, Student #14 stated, “...it was just slightly frustrating that I couldn’t get the answer in; but even then, it wasn’t something I disliked. It was all just kind of funny to look at.” Student #14 also states, “I mean, I figured it [the correct answer] out... I didn’t put it in in a way that made it say it was correct.” Student #15 reflected on how she observed others learning and play through the game. She also reflected on how she was entertained by their frustration. Student #15 states, “Well, I liked everyone getting frustrated. So, I thought it was funny. ... you know you’re learning something when you’re grunting and moaning.”

Student #5, #8, #12, and #22, discussed how Adventures of Krystal Kingdom connected with the topics in the textbook, and how the video game helped them to better conceptualize where these mathematical models would be used in engineering, biology and mathematics.

The Adventures of Krystal Kingdom game connected to the topics from the textbook. In stage 1, the student was able to visual and personalized how space curves were used to depict the motion of an object, specifically, the sorcerer. The game helped with reinforcing concepts that participant 13 had forgotten. Comments like “Going back and redoing that stuff helps keep it in our brain,” It [the game] helped refreshed what I we had been doing in the beginning of the course”, “Yes. That [the game] was the helpful thing because it helps me to teach [my classmates how to complete the square with

cylindrical and quadric surfaces and surfaces of revolution].” I was completing the square every other day and I got it.”, and “I taught myself how to complete square thanks to your game” affirms that the students saw the game as a learning tool or a reinforcement learning tool to help them conceptualized how vector-valued functions are used in real-world situations (Student #5, #8, #12, and #22, reflection five excerpt).



Figure 25. Student #8 constructed the vector-valued function in Figure 24 to solve the real-world problem in Figure 25.

As illustrated through Figure 24, Student #8 recalled her previous knowledge about vector-valued functions and used the Blum and LieB’s modified mathematical modeling cycle to construct a model that would find the location of the invisible sorcerer. She shared that she had used the general mathematical model of vector-valued functions from the class lesson.



## Engagement

### **Theme 2: Undergraduate students saw the use of the Adventures of Krystal Kingdom as a**

### **way to engage themselves in mathematical fun in a digital environment.**

Games provide an alternative interactive approach to learning because DGBL environments actively engulf students in the productive learning environment (Tobias & Fletcher, 2012). The study revealed several instances in which the students were deeply engagement in the DGBL environment. During the first intervention, the researcher found evidence of engagement through observation in multivariate calculus game. Students discovered that there were different stages of the game that were challenging. The game contained exercises at three stages. These exercises were similar to the exercises that the student would see in a traditional classroom where the student participated in completing their exercises on a mathematical modeling sheet. Student #8 was observed, interviewed, and discussed her experienced in play the game. During the intervention, it was observed that Student #8 intensely focused on helping the protagonist destroy the foes in the game world as they walked towards her. During this moment of gameplay, she maintained a level of focus and fun. However, when she set off a trigger in the game, a mathematical question appeared and asked her to a position vector-valued function to shoot down the invisible sorcerer. Her engaged face went from smiling to thinking and intensely focusing on understanding the question that was being asked of her from the game. "... the questions just come out of nowhere...", was stated by Student #8. Student #12 also comments saying "... problems coming out of nowhere... a lot of times the problems come out of nowhere and you want to get back to the game...". Student #8 shared that she was really wanted to help Killer Mega, the protagonist, on his journey to reach the end of the game. Student #8 states, "You gotta help the little guy." The discussion about the saving the "little guy" struck up a conversation among all five

interviewees on how it was important to save the protagonist. Student #8 was also able to recall several parts that make up the core mechanics in the game. For instance, she was able to identify the power up flask/potion. She was also able to recall and discuss the energy status bar of the Killer Mega. From the interview, she states, “Yeah, I definitely, noticed that [power bar].” Another form of engagement was revealed through social interaction. Her and other students were engaged in side-conversations with their peers trying, finding out and exploring ways to attack the exercises within each stage or physically manipulating the computer keyboard to move the avatar/protagonist throughout the game. Additional evidence of engagement was shown when the students were able to recall specific internal economies and other game mechanics without a model of the game during interview. Interaction among Student #7 and Student #5 recalled their gaming experience and discussed how they were being willing to “have a go [at it.]” See excerpt below:

Student #7: I consider that, if I can remember correctly at that point in time playing the game. It was like, I don't know what I'm doing. I'm not playing this. Kind of attitude. And I tried. You try to learn it, but you just like ... I don't know what I'm doing.

Student #7: Like took the game you at least knew a little bit of what was going on. But the rest of us was like, I don't know what going on. I would ask Student #5. He'd be like, "I don't know."

Student #5: I'd be sitting there working it out a sheet of paper.

Student #6: I was like, man, what are you doing?...You can't do that.

Student #7: It would be like, what? But I guess at that point in time Student #5 said it was late and we had passed that section. So any in that so bad that should not happen in a math class, but at that point, any recollection of anything that [crosstalk 00:36:49] just blocked it out and went the other way. It was whatever we were learning was just probably more crazy than back there was just consumed our brain at that point.

This excerpt of the interview demonstrated how students were willing to “have a go” , finding out and exploring DGBL environment for learning and playing. Thus, this exemplifies elements and characteristics of engagement. It also demonstrates the student’s perseverance,

which is identified as an engagement characteristic. This is because the student displayed the desire to continue to do a mathematical task, despite experiencing difficulty.

Another example of engagement and motivation was demonstrated among Student #7 in the interview excerpt:

Student #7: [I] was like shoot, shoot, shoot, shoot, pushing

Interviewer: Okay

Student #7: Then go, go, go question.

Student #7: and then go, go, go...

Student #7 reflected on her experience in playing the game. She tried playing with what she knew about how to manipulate and move the avatar in the DGBL. This also demonstrates that the student was engaged in that she showed her willingness to discover and explore the game by working through exercises, entering solutions, and moving the avatar to the next stage of the game. It also shows that the student was being involved, emerged and concentrating in the game world. McDonough (2007) discovered that a students' willingness to continue was a key element for engagement to occur.

Student #6 also showed evidence of engagement and motivation in gameplay. This participant was the only participant that made it to the very end of the game to the *Dark Heart*, the antagonist. Student #6 shares and recalls elements of the game features. He also described his emotions such as frustration and heightened excitement that emerged during gameplay in the interview excerpt below.

Interviewer: Mm-hmm (affirmative). What about you, Student #6? What do you want to share about how the game ... Explain your feelings when playing the game.

Student #6: I was pissed though.

Interviewer: You were upset?

Student #6: I was upset.

Interviewer: Why were you upset?

Student #6: I was one of the few people who got to the end, and I couldn't beat that guy. The spiky guy. I don't know what his name was.

Interviewer: He's called Dark Heart.

Student #6 [inaudible 01:07:42] the huge spiky monster with force fields was pissing me off. Shooting at it, nothing happened.

Interviewer: It takes a while to kill him.

Student #6: It was kind of annoying though.

Student #5: Yeah, Student #6 was trashed. He couldn't dodge anything.

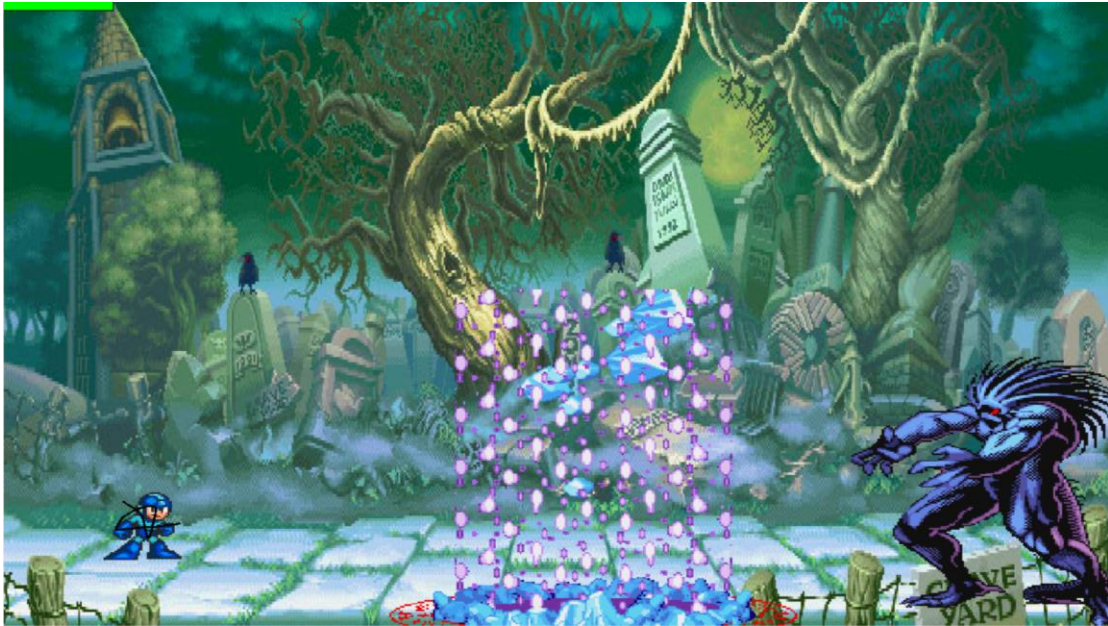
Student #6: I was like shooting it. I'm not going to run away [crosstalk 01:08:07].

Student #5: Oh shit.

Student #6: Yeah, that's how it was. I was kind of irritated that I couldn't vacuum, because it seemed so much like a Kirby game. I was like why can't I vacuum? I need to swallow this- [crosstalk 01:08:34] What's going on? Then I'm shooting, and like you said I'm shooting and I'm trying to run away while I'm trying to shoot them. I was like why am I depositing coins all over the place? It just- [crosstalk 01:08:49] It was like that. But jump was a pretty impressive jump for a little guy like that. He could jump really high. I was impressed.



*Figure 26.* The first part of part two of the game where Student #6 was excited and nervous about being introduced to a new stage with the “Big” boss, Dark Heart.



*Figure 27.* The second part of part 2 of the game where Student #6 was upset because of the losing battle with Dark Heart.

Student #14 shares experience of what engaged or motivated her in the course:

Interviewer: Do you recall any activities in you class that attracted your attention?

Student #14: I think your game was the most interesting thing that happened.

Student #14: I recognized both characters in them. Interesting physics.

Student #14: ... and Kirby's anime's.

Student #14: I didn't get past the first question. So, vectors.

Interviewer: ... how would you describe your feelings when you were playing the game? How did you feel in the game overall?

Student #14: I agree that the change in pace was nice, and the game was cute, so. It was just fun to play instead of doing direct math.

It is here that Student #14 exemplifies engagement in that she reflects on her experience with the game. Being able to recognize the characters in the game brought on a sense of familiarity and curiosity on what would happen if she engaged with familiar characters in an

educational digital environment. This is because she had never seen these characters in an educational designed digital environment. For her, these characters, *Broom Hatter*, *Poppy Bro. Jr.*, *DarkHeart*, *Akira*, *Waddle Doo*, and *Waddle Dee* were so familiar that it brought her comfort and wonder about how these characters are functioning in an educational environment and not used for leisure. She is being self-aware and reflecting her own and peer's engagement. Student #21 also demonstrated his interest and desire to engage in the game. See interview excerpt below.

Interviewer: ... how would you describe your feelings when you were playing the game? How did you feel in the game overall?

Student #21: I was just glad Professor Z stopped talking.

Interviewer: Okay. So you were happy about seeing the game a little bit?

Student #21: Yeah. Glad Professor Z stopped.

Student #21 expressed his excitement to see me when I visited the classroom. He was always looking for relief from the classroom that he and his peers classified as demotivating. The educational game provided some form of escape from the rigor of class.

Student #15 revealed her evidence of engagement through reflection on herself and her peers during game play:

Student #15: I work on that problem with Student #14, and so there's not really much I [could] contribute. But, I did see Student #12 and Student #6. Student #6 didn't seem to have a problem with it, it was just the controls he kept messing up on; because he kept falling into the lava. But it seemed like Student 12, she was able to do it... It's... I don't know, it almost seemed like she was having trouble as well. But, she was able to do it and get through the game. I think she got halfway through.

Student #15: I think Student #6 finished it, right?

In the next excerpts, the students discuss the reasons why they prefer learning with gameplay versus the traditional classroom learning environment.

Interviewer: Compared to other forms of mathematics at school where, that's what it was, do you like playing a game, a mathematics game, compared to school

work? So, if you had a choice between school work and play a mathematic game, on a scale of one to five, which are you less, are you a lot less likely to play the game versus the school work, or less, or about the same? Or more? Or a lot more? Would you play the game compared to school work?

Student #5: It depends.

Student #6: Like the current version ...

Student #5: Yeah, that's what I was about to say. It depends on the version of the game. So, I can tell you right now, school work, if you gave me one section worth of problems and you said, "Here's 15 problems in this section, go do them." But, if you had those 15 problems loaded into a, like, you know, whatever the hell you need, like a story, essentially, and if you get it wrong, then you stay there and then other problems generated and the solution to the one before was given to you, afterwards. And then other problems generated and you don't move on, then I think that's a better form. You keep doing it, and you'll know once you've got it. You'll keep going on.

Interviewer: So, if it's tailored to whatever lessons you're currently looking at.

Student #5: Yeah, and if it's incremented in learning, and stops and gives you the solutions for one of them, then you move on to the next one once you've gotten that specific type of problem.

Student #6: If it's like a Prince of Persia kind of game with puzzles, like Student #5 said, you solve one puzzle and you're like, "Okay, now I get an idea of how to solve the next one so I can keep on going like that." If it's something involved like that. If you know you might be frustrated that you're not getting the answer right, you'll still wanna do it because you'll wanna beat it. You wanna beat the game.

Interviewer: Is that what you were trying to do? You were trying to beat the game so much?

Student #6: Oh, yeah. You put in the hours, you put in the effort. And it's fun. It's annoying, but it's still fun.

Student #5: I think that only effects a very small percentage of users that are serious nerds, like me and Chuck, but like ...

Student #7: Please, I used to beat the crap out of games because I'd get frustrated. I would not quit until I did it.

Student #6: I'm a "completionist", I guess. Like I'm the kinda guy to get 100% completion.

Interviewer: 100%, yeah.

Student #6: Get everything.

Interviewer: So would you feel the same way, if you had opportunities between schoolwork and games? If the game was tended towards ...

Student #7: I just feel that until you give me a [text] book, or give me a video game, you'd just rather do the game. 'Cause you've been doing book problems all your life. It's like, "Aren't you tired of it?" And it's not like you really learn anything nowadays. You don't learn anything from books, so you have a program that gives you how to do something. And if you get it wrong, you go "Okay, this is how you do it. And if you know how to do this, then you can try and do it again." I feel you learn that better because when you do books you're like, "I don't know what I'm doing wrong." And you can go and try to read the examples, but that's not gonna really ...

Interviewer: Sometimes, yeah.

Student #7: Sometimes it's not gonna help you. You just gotta find other ways to help yourself.

Student #6: It also depends, the game would be like an art, essentially. There's time in between the questions. If you were just doing questions from the book, you'd just take a question, do it. "Did I do it right? Oh, no, I didn't do it right. Alright, let me get another one." Then we do it, and then you're not taking any time between playing a game. The game needs to be short and fun. Get you from stage to stage playing the game.

Student #7: Yeah, that's true. And it shouldn't be like, "Oh, here's a question. Go through straight to another question." You have to make sure that somebody's completely engulfed in the game, so then they feel like they're doing work. If that make's any sense.

The excerpt above shows that the students preferring learning in digital game-based learning environment than in the traditional classroom setting. This corresponds with Marteo and Lopez (2007) in that “electronic cooperative surrounding has impact on developing a positive attitude towards mathematics which strengthened their motivation for learning it” (p. 24, Divjak & Tomic). This also aligns with Sedigahian and Sedigahian (1996) findings in that educational video games are an integral part of students’ lives and learning mathematics in a Digital Game-Based Learning environment becomes important and stimulating for the students.

### **Game Features**

**Theme 3: Undergraduate students saw core mechanics such as internal economy, tactical maneuvering and other core mechanics as components that affect students’ gameplay.**



Adams (2014) defines core mechanics as the data and algorithms that structures the game's central rules and internal operations. There are four major types of game mechanics: physics, internal economies, progression mechanisms, tactical maneuvering, and social interaction.

Adams suggest that the following characteristics are necessary for a well-balanced game: (1) The game provides meaningful choices, (2) The role of chance is not so great that player skill becomes irrelevant, (3) The player perceives the game to be fair, (4) Any player who falls behind early in the game gets a reasonable opportunity to catch up again before the game ends, (5) The game seldom or never results in stalemate, particularly among players of unequal ability (Adams, 2014). Although there were positive learning and engagement feedback from game, there were some difficulties with maneuvering through the three main mechanics: physics, internal economies, and social interaction that the participants reflected on during the interview.

Examples of the difficulties with the game features were found in the excerpt reflections of the interviews that are provided below.

Student #14: I think you could maybe like you were saying, using hints for the problems. Maybe you could make that more subtle, and incorporate that into maybe something an NPC tells you; or, you go through a tunnel, or something...

Student #14: But like the game teaches you how to do it, what I mean, But as part of the game, not just telling.

Student #15: Yeah. So, maybe give an example, or just a hint to show you how to set it up and set up the answer. Because, like with Student #14, the problem was not putting it in correctly.

Student #15: Yeah. But, dislike? I think just the ... different visual aspects of it, and it's not really uniform together. So, it's kind just like looking at a collage of different games being put together; which isn't necessarily a bad thing, but I think to grab someone's attention, it needs to be all uniform.

Interviewer: Okay, good. Wonderful. Now, when you say uniform, you mean making sure everyone's consistent, with the same figure looking the same, and consistent throughout the game world, versus different dimensions of the other figures.

Student #15: Yeah. It's like background, the moving parts, even the traps in the game. Like, you've got your lava-

Interviewer: Oh, the spike. You talking about-

Student #15: ... The spikes, or the lava. Because, in some things, they do need to be different; but, they don't need to be-

Interviewer: Not to be obviously different.

Student #15: Yeah.

Interviewer: Okay, good. Good point. What about you?

Student #21: There was nothing I really disliked about the game. It's just, it was a tad bit frustrating,

This excerpt shows the students were heavily engaged to be able to accurately recall some of the internal economy features that the students discovered through the game world. Student #21 suggest that there should be some helpful hints in place or some form of social interaction with a Non-Playing Character (NPC) to direct the student to the next step when the student is lost on what to do. This confirms what Adams suggest for game balancing in a *player vs. environment (PvE)* game. He advises that a game should not force a player to make critical decisions without adequate information; we must provide the players with the information that they need to solve the problem and move to the next scene (Adams, 2014).

The next interview excerpt reveals the students' feelings towards the game, their engagement and excitement about the features and modifications that they would like to see in the game.

Student #12: Well, I feel like the game was fun and all, but I feel like the question kind of came out of nowhere. It would be nice if there was a summary before ... You go through a level, so summarize what kind of questions were going to be on there. [crosstalk 01:04:15]

Student #8: I don't want to sound mean or anything.

Interviewer: No, no. I want you to be honest. [crosstalk 01:04:18] Yeah, be completely honest.

Student #8: I was-

Student #8: What?

Student #5: No, keep going.

Student #8: I think I was talking about it earlier, about [inaudible 01:04:37]. But yeah, the questions just come out of nowhere a little bit. But in comparing them to other educational games that I've done in the long run, I think if there's a way to help come up with the answer instead of just a question and answer would definitely help me a lot.

Student #12: Yeah.

Interviewer: So scaffolding. [crosstalk 01:05:02]

Student #5: Yeah, some guidance.

Interviewer: Okay.

Student #8: Yeah, guidance. Because otherwise it's just more problems to deal with.

Interviewer: This is good feedback. This is good feedback. Good. [inaudible 01:05:12] So syntax. Okay.

Student #8: Oh yeah.

Student #12: Syntax.

Interviewer: This is good.

Student #22: Because I spend forever on one problem trying to figure out okay, so I do open parenthesis, then I pick the number comma space next number, or is there no space? Stuff like that.

Interviewer: Okay. That's good. This is what I need to hear. Anything else you want to share about what you feel as you're playing the game?

Student #5: I like the game, but you're just playing MegaMan until you get to a checkpoint and you do a calculus problem.

Student #12: Yeah.

Student #8: Yeah.

Student #5: I think that you could get creative and do something with some sort of rockets. We have vectors, so there's all sort of angles involved and magnitudes.

Interviewer: Good.

Student #5: But I think you can get creative and involve any information that's going on in the game if you really wanted. But if not, either way there still needs to be some sort of hints beforehand.

Interviewer: Good. So scaffolding for you, too. Good.

Student #5: Show some hints.

Student #8: Or even maybe talking about it.

Student #12: Yeah.

Student #8: Like oh this character is-

Interviewer: Oh like a storytelling in the beginning?

Student #8: Yeah, yeah.

Student #12: A storyline would kind of test people.

Interviewer: So like a cut scene.

Student #12: Yeah.

Interviewer: I was debating on when to put it in, but yeah. Okay, good. Wonderful. So cut scene. Anything else? [crosstalk 01:06:38]

Student #5: That sounds a little advanced.

Interviewer: Yeah, that seems like a lot of time.

Interviewer: No, it's possible to do. I would just ... I left it out, because this is just a small platform but I'm building off information from y'all to see what's happening.

Student #5: Okay.

Student #8: Or if there's a formula you use, maybe a way to-

Interviewer: Like a hint.

Student #12: Hints.

Student #8: -put the formula together yourself. That way you know [inaudible 01:07:01].

Interviewer: Okay. Wonderful.

Student #8: We need a sidekick is what we're saying.

Interviewer: Sidekick. Okay.

Student #5: Yeah, you should make it Mario this time.

Interviewer: Mario.

Student #5: Like Luigi behind him. He pops up with a voice box behind him that tells you the hint.

Interviewer: Use this formula. Huh?

Student #5: Yeah.

Interviewer: Okay. That's good. Thanks for sharing that.

Student #5: Mario could throw fireballs.

Interviewer: Mm-hmm (affirmative). What about you, Student #6? What do you want to share about how the game ... Explain your feelings when playing the game.

Student #6: I was pissed though.

Interviewer: You were upset?

Student #6: I was upset.

Interviewer: Why were you upset?

Student #6: I was one of the few people who got to the end, and I couldn't beat that guy. The spiky guy. I don't know what his name was.

Interviewer: He's called Dark Heart.

Student #6: [inaudible 01:07:42] the huge spiky monster with force fields was pissing me off. Shooting at it, nothing happened.

Interviewer: It takes a while to kill him.

Student #6: It was kind of annoying though.

Student #5: Yeah, Student #6 was trash. He couldn't dodge anything.

Student #6: I was like shooting it. I'm not going to run away [crosstalk 01:08:07].

Student #5: Oh shit.

Student #6: Yeah, that's how it was.

Interviewer: Did anyone stop to talk-

Student #6: I was kind of irritated that I couldn't vacuum, because it seemed so much like a Kirby game. I was like why can't I vacuum? I need to swallow this- [crosstalk 01:08:34] What's going on? Then I'm shooting, and like you said I'm shooting and I'm trying to run away while I'm trying to shoot them. I was like why am I depositing coins all over the place? It just- [crosstalk 01:08:49] It was like that. But jump was a pretty impressive jump for a little guy like that. He could jump really high. I was impressed.

Interviewer: It's the gravity room. I had made changes to the gravity room.

Student #6: That was something that I felt was important. I felt like some of the questions, especially the one that I asked about the wizard kind of seemed off-putting, if that's okay, because it didn't really seem to relate to what I was doing, the task at hand. So it seemed out of nowhere, out of the blue. It's like okay, the wizard is here. Blah blah blah. Then after you solve it correctly, we don't see the wizard vanquished or anything. We don't see him vaporized. He just ...No, nothing. There's no ... I guess there no reward for good or bad decisions, bad choices. It seems kind of separate from what we're familiar, what we were used to from the contemporary themes that we're exposed to.

Student #5: This was like a hundred times harder, but since this is multi-variable calculus, make a 3D game and that would apply-

Student #12: Whoa. Whoa.

Student #5: But it's literally like a hundred times harder than a 2D game.

The excerpt shows that not only the students were engaged and immersed in the game world, but they were also able to identify scaffolding issues that negatively affect the game world. For instance, this group felt like questions just came out of nowhere with no warning

or prompting to guide them through the process on how to setup their mathematical models such as the vector-valued functions. Some of the students, were unclear on how to enter their solutions into the answer box, which relates to the disconnect with a component of the internal economy. This correlates to the checks and balances needed with the social interaction feature and designing so that the gamer has enough information to make appropriate decisions in the game. This also affirms one of Adams' (2014) mandatory elements of a well-balanced game where clues must be provided for the gamer to make a critical decision in the DGBL environment. However, the students still revealed they enjoyed the game because it allowed them to see how the techniques that they studied are and will continue to be used in a potential real-world situation in applied mathematics.

## **Summary**

An embedded, exploratory case study using mixed methods techniques was chosen to investigate the effects of using a Digital Game-Based Learning environment of Adventures of Krystal Kingdom, on undergraduate students in a Multivariate Calculus course. The quantitative data was used to measure the motivation and achievement levels before and after playing the game. The data showed that there were no statistically differences from pretest to the posttest and from the pre-motivation to post-motivation survey.

The embedding of the qualitative data was in this broader design intervention for determining; how undergraduate students, particularly STEM majors were affected in their achievement and motivation using the DGBL environment and what game features were necessary for this digital learning environment as they engaged in the game during the study. As the participants engaged with the DGBL environment of Krystal Kingdom, three themes emerged that helped explained the effects of using Krystal Kingdom on the undergraduate

students to examine their motivation and achievement levels. Data was triangulated from the researcher's journal, artifacts, and transcribed interviews. The participants indicated the perceived use of Krystal Kingdom as a fun learning tool and an exciting way to learn mathematics the classroom. It also allowed the students to see how the mathematical models that they constructed in the classroom would be used in their related STEM fields of study. The participants expressed other game features that allowed to maintain continual engagement with ease. The themes that transpired from the triangulation of qualitative data and the quantitative data will be reviewed through the lens of the casual model of triadic reciprocal causation.



## CHAPTER 5

### Discussion

The primary aim of this study was to determine if the platform game of Adventures of Krystal Kingdom affected the learning and motivation of undergraduate students in a Multivariable Calculus course. An embedded, exploratory case study design using mixed methods was chosen to investigate this and was guided by the Modified Extended Blum and LieB Model Cycle Conceptual Framework. Two research questions guided this study:

1. How does a platform game affect the learning of undergraduates in a Multivariable Calculus class? How does a platform game affect the motivation of undergraduates in a Multivariable Calculus class?
2. What features and dimensions of the platform game are necessary to maintain the engagement of the students during the learning and gaming process? What kind of threats do students face?

This concluding chapter will revisit the major findings, situate the findings of the study within the literature, implications for actions, and recommendation for further research. This chapter also includes interpretation of the research findings as guided by the Modified Extended Blum and LieB Model Cycle Conceptual Framework.

### Major findings

In examining the effects of using the Adventures of Krystal Kingdom on the undergraduate students, three themes emerged. Appropriately, three themes emerged describing the undergraduate students' perceptions concerning Adventures Krystal Kingdom, and they include:

1. Undergraduate students saw the use of the Adventures of Krystal Kingdom as learning tool to enhance their understanding of concepts in Multivariable Calculus.
2. Undergraduate students saw the use of the Adventures of Krystal Kingdom as a way to engage themselves in mathematical fun in a digital environment.
3. Undergraduate students saw core mechanics such as internal economy, tactical maneuvering and other core mechanics as components that affect students' gameplay.

### **Situating the Findings with the Literature**

In reviewing studies that measured the effects of the digital game-based learning environment on students (Woo, 2014; Ke, 2008; Rosas et. al, 2003; Vos, Van der Meijden, Densessen, 2011), there were similarities to the current study in the way that motivation and achievement were measured. Broadly, Digital Game-Based Learning environments are seen to be effective tools to help increase student understanding, motivation, and achievement.

The results of my research study indicated that the undergraduate students did not show any significant change from the pre to post Krystal Kingdom intervention. The lack of significant change in achievement and motivation could be attributed to the fact that the duration of immersion using Krystal Kingdom was not sufficient to provide a mastery experience with the participants and possible the sample sized may have contributed to it as well. Due to the short exposure, the undergraduate students were unlikely to develop an elevated sense of confidence in affecting student learning using Krystal Kingdom. Although there is no significant difference, there was around a five-point improvement on the exam when compared with the pretest and posttest. Knowledge acquisition in mathematics is one of the most potent aspects for increasing motivation and achievement. Divjak and Tomic (2011) argued that computer games create positive attitude towards learning mathematics, and the students' acquisition of mathematical

knowledge, skills and routines becomes more efficient resulting in a better quality of the teaching process. I argue that the knowledge acquisition from the game would have allowed the students to gain chunks of knowledge to allow them to easily apply to the construction of vector valued functions, equations of plane and lines, and using vectors would have allowed them to see many facets of how applied mathematics is used in their respective fields of study and create an extension for curiosity for other models to be derived such as the *curl* function and the *normal* vector functions. In a study regarding the source of the effects of computer games, Young and Loverdige (2004) studied 106 students and the results showed that the mathematical acquisition knowledge of the students who played were much better than the students who did not play the computer game. Kebritchi (2008) conducted a similar study with 193 students in an algebra course, and the results also showed that the students with the computer game had an extremely higher acquisition of knowledge than students who do not have the computer game. One of the major differences in the intervention for Kebritchi and Young and Loverdige was that the students were undergraduates and the students had less exposure to the computer games than the other studies. However, the students were still successful in improving their pre- and post- test overall average.

### **Undergraduate Students' Motivation, Achievement, and Perceptions with Respect to Using Krystal Kingdom**

Three themes that related to the undergraduate students concerning the effects of the Krystal Kingdom on students' learning, engagement, students' perception of the game features are interpreted through the literature that discuss using Digital Game-Based Learning environments in education.

**Undergraduate students saw the use of the Adventures of Krystal Kingdom as learning tool to enhance their understanding of concepts in Multivariable Calculus.** The students discussed and described Adventures of Krystal Kingdom as a tool for learning or relearning topics in Multivariate Calculus. Many of the participants were able to discuss and list different mathematical concepts and topics that related to the course work within the Adventures of Krystal Kingdom game. Participants also commented and discussed with each other how the game forced them revisit topics that they had forgotten. Several of the students stated that because of the game they had mastered how to complete the square of a multivariate and  $n$ -dimensional surfaces equations and functions. Some of the surfaces include ellipsoids, paraboloids, and hyperboloids. Rose et al. (2003) agrees with the findings and provides that the use of computer games leads to the improved learning outcomes compared to traditional teaching methods. Bokyeong, Hyungsung, and Youngkyun (2009) also agrees with the findings in that there was a positive effect on improving mathematical learning using computer games.

**Undergraduate students saw the use of the Adventures of Krystal Kingdom as a way to engage themselves in mathematical fun in a digital environment.** Majority of the students in the course found Krystal Kingdom to be engaging. The students stated that they would rather play the game instead of listening to an instructor in a traditional lecture. During gameplay several characteristics emerged from the classroom. Six of these characteristics were: enjoying and achieving what they set out to do, being involved and concentration, kept on trying, finding and exploring, and being willing to “have a go.” From the interview excerpts, one can see how they expressed their enjoyment from the game. As a result of this, it ignited extrinsic motivation and engagement to stay in the classroom and be late for their next class. The students expressed that they felt the need to know what would happen next Killer Mega. One student was so

thoroughly engaged that he made it to the end of the game before class ended. There were some parts of the game where he was not able answer fully because of discovered scaffolding and lack of gaming information due to design issues. However, he was very upset when he did not win the battle against the big boss, *DarkHeart*. Rosas, Nussbaum, Cumsille, Marianov, Correa, and Flores (2003) coincides with these findings in that computer serves as an important motivational factor for learning mathematics. This also aligns with Ke's and Graboswki's (2007) findings in that playing computer games influence engagement, motivation, attitudes, and learning mathematics in students.

**Undergraduate students saw core mechanics such as internal economy, tactical maneuvering and other core mechanics as components that affect students' gameplay.**

Many of the students enjoyed the features. For instance, when Student #5 pressed the F key to launch the *fire-star* projectile to destroy a foe, he responded, "Woe," as he had a bedazzled look on his face while he stared at the computer screen. Student #6 and his classmates discussed some features such as social interactions with NPC, providing hints within the exercises in the game, and triggers, that may need to be redesigned. Student were impressed with Killer Mega's super jumping skills. They felt like they were flying across the screen at times because the adjustments and reinforced game physics provided by the game designer. Students were affected by the input semiotics because in one part of the stage they were unsure on what to do in the exercise or how to enter the solution into provided text field box. It left them with thoughts of uncertainty on what to do next in the game. Student believe that there should be triggers that create checkpoints and prompts to alert them that a question is coming up. This would alleviate the feeling that the questions came "out of nowhere." Students also thought it would be helpful to have a *cut-scene/storyline* before or in the middle of the game. This aligns with Adams' (2014) suggestion

on the need for the fourth element of core mechanics, which is *progression mechanisms* with the game world particularly with *progression in space* with a storyline. This aligns with Adams' (2014) statement that the use of storylines positions the player as he or she identifies with the characters and becomes interested in what happens to the characters to promote *gameplay tension*, where the player has gained a sense that something is at stake and desires to know what happens next.

### **Implications for Future Research**

There needs to be an increase in Digital Game Based Learning environments in higher education classrooms. Developing programs that help undergraduate professors incorporate technology in the classroom could assist professors that struggle in connecting with students on specific topics that may be difficult to teach to students. Using DGBL provides another form of differentiated instruction to improve the students understanding in learning certain concepts. This will also help us figure how to lower the DWF rate (students who receive “D”, “F”, or withdraw) crises that is taking place throughout the myriads of institutions across the country.

In addition, my views align with Gee (2013). He states, “Games have a place in teaching, as do a multitude of other tools. But, games are no silver bullet. Great teacher designing great experiences on the other hand can change the world” (p. 152). Adventures of Krystal Kingdom can be used as a great instructional tool with or without its updates from the game designer. However, it takes a great professor who cares about how knowledge is presented and dissected among young minds to provide those rewarding experiences so that students can actively learn. It is also important to add there should be more scaffolding techniques to help students with low mathematics knowledge to enhance and guide their performance in the game. Thus, methods to design effective scaffolding structures for the exercises throughout the game deserves further

exploration. Future research would find it beneficial to have worked examples and NPC to help the students improve their problem-solving skills, and NPCs in place to assist in scaffolding structures that will help redirect students when lost in a stage or exercises with a game. This is also reaffirmed by a Ke's statement. "The key issue that surround educational computer game is not whether or not to use the game, but how to better design an educational game or how to better apply game-based classroom instructional strategies" (Ke, 2008, p. 554). This study also suggests that there is a need for more computational thinking in K-12 and college mathematics. Delegating teachers and professors with responsibility to design and building a digital learning environment as alternative way to provided differentiated instruction. This could potentially lead the instructors being more confident in teaching because we have provided them with another way to do active learning through programming and software design, which have no limits an instructor's creativity in digital development. This will send a powerful message to K-12 teachers who are looking for ways to vary their pedagogic approaches in the classroom for the sake of successful student learning.

This study enlightens a portion of the gap in furthering the understanding of the impact of DBGL on undergraduate students in mathematics courses. There are currently no educational video games available to help students to deepen and personalize their understanding of the mathematical content in these advanced mathematics courses at the university. The study also brings new awareness for scholars at the university on how they can design DGBL environments to provide an active learning and fun instructional approach that engages the students to be more interactive in lessons or lectures that are discussed in the classroom.

In addition, the use of DGBL can be used to reverse students' negative self-perceptions and their emotional relationship with mathematics. There is an existing phenomenon among

students where students feel that they cannot do math (“Teaching maths – what does the evidence say actually work?”, 2016). These negative emotions are usually associated from bad experiences from learning mathematics in the classroom, around family or friends. After experiencing several sequences of these bad experiences such as receiving low performance scores, not knowing the answer when called on in class, or being labeled incompetent among their peers or adults, a student begins to believe that he himself is indeed incompetent or inadequate which leads to other negative thoughts such as lack of confidence, inadequacy, discouragement, insecurity, and so on. However, with these new innovative approaches to teaching with the use of digital learning using a DGBL environment, we can reverse these negative emotions to positive emotions. As a result, students will begin to bring their attention to the fun of learning in a digital world and gain back their self-confidence, which will lead us to see tremendous improvement in their academic progress and self-worth.

### **Recommendation for Future Research**

While the findings from this research study are promising and have possible implications for practice, the results may not be generalizable from this case study to the larger population of undergraduate students. Some of the identifiable limitations of this study include small sample size, a limited number of interviews, and specificity of one university. These will all contribute to the lack of generalizability (Locke, Silverman, & Spirduso, 2010).

It also recommended that a similar study should be done using Csikszentmihalyi’s Flow Theory. He defines flow as an optimal state of being that people experience while engaged in an activity where people remain in an enjoyable state of peak productivity and lose awareness of time and space (Csikszentmihalyi’s, 1991). The Flow State Scale, which was derived from Csikszentmihalyi’s Flow Theory, contains eight components: challenge, goal, feedback,



playability, concentration, time distortion, rewarding experience, loss of consciousness, and a sense of control (Kiili & Lainema, 2008). The data provided from the questionnaire will give us greater insight on what should be redesigned in the game so that it can reach an optimal performance level for teaching and learning.

To continue to expand on the effect of mathematics computer game on student learning and motivation, the following issues should be considered. First, it is beneficial to see and analyze the effects of the same game in this study with a different population. Second, various findings for the effectiveness of the game in this study, suggest that further investigation is needed to better identify the cause of the game effects on learning and motivation. In addition, constructing a study that ensures that students are provided with sufficient time and opportunity to reach mastery experience in the form of using DGBL environments would be beneficial.

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APPENDICES

APPENDIX A: INSTRUMENTS

This appendix includes the following sections:

- Demographic Survey
- Motivation Survey
- Pre/Post-test
- Game Performance Test #1
- Game Performance Test #2
- Mathematical Modeling Worksheet
- Interviews Protocol and Questions

## Demographic Survey

### Video Game Experience (Demographic Survey)

Age: \_\_\_\_\_

Major: \_\_\_\_\_

**Directions:** Please circle the best answer for each of the following questions, or write your answer in the space marked "other."

1. Are you male or female?

- A. Male
- B. Female

2. What is your ethnicity?

- A. Caucasian
- B. African American
- C. Hispanic
- D. Asian
- E. Other (Please Specify) \_\_\_\_\_

3. List the last three math courses you have taken? (Be sure to list the semester and year.)

- A. \_\_\_\_\_
- B. \_\_\_\_\_
- C. \_\_\_\_\_

4. What languages is spoken in your home (Circle all that apply.)?

- A. English
- B. Spanish
- C. French

Other (Please Specify) \_\_\_\_\_

5. Do you like to play video/ or computer games?

- A. Never Played
- B. Very Much
- C. Somewhat
- D. Not Really
- E. Not at all

a. If your answer was D or E to the question 3 above, why don't you play video games?

- a. Cost
- b. Not Interested
- c. Lack of Skill
- d. Not allowed
- e. Other (Please specify) \_\_\_\_\_

6. How did you get started playing video games; who or what motivated you to play?

- A. Self-Interest
- B. Other female/s
- C. Other Male/s
- D. Advertisements (magazines, TV, newspaper)
- E. The internet
- F. Other (Please Specify) \_\_\_\_\_

7. What types of games do you play? (Circle all that apply)

- A. Action (Ex: Doom, Street Fighter)
- B. Adventure (Ex: King's Quest, Myst, Return York, Ultima)
- C. Simulation (Ex: Flight Simulator, Rebel Assault)
- D. Sports (Ex: NBA Jam, Ken Griffey's MLB, NHL'94)
- E. Strategy/Puzzle (Ex: Sim City, Tetris, CandyCrush)

8. Why do you play the games (Choose at most 3)

- A. I like the graphics/realism
- B. Relaxation/recreation/escapism
- C. It improves my hand-eye coordination
- D. It challenges my mind
- E. It's such a great feeling to master or finish a game
- F. I'll play anything when I'm bored.
- G. Other (Please specify) \_\_\_\_\_

9. Where do you usually play video/computer games?

- A. Arcade
- B. On a system (Ex: Sega, Nintendo, etc.)
- C. On a computer (Ex: IBM, MAC, etc.)
- D. Other (Please specify) \_\_\_\_\_

10. Do you still find time to play when you're busy (e.g., during midterms)?

- A. Yes (can't stay away)
- B. No (school come first!)

11. What don't you like about video game playing? (Choose at most 3)

- A. It takes up too much time.
- B. It's frustrating.
- C. It's lonely.

- D. Too many rules to learn
- E. It costs too much
- F. It's boring
- G. My friends don't play
- H. It's pointless
- I. Other (Please specify) \_\_\_\_\_

12. Approximately how often do you play entertaining video games each week?

- A. Every Day
- B. 3-5 times per week
- C. 1-2 times per week
- D. Not very often
- E. Not at all
- F. Other (Please Specify) \_\_\_\_\_

**Video Game Genres (for #13)**

- |                                    |  |
|------------------------------------|--|
| Action                             | Economic simulation games                  |
| Fighting                           | City-building games                        |
| First-person shooter               | Adventure                                  |
| Role-playing                       | Arcade                                     |
| Massively Multiplayer Online Games | Educational                                |
| Simulators                         | Maze                                       |
| Flight                             | Music                                      |
| Racing                             | Pinball                                    |
| Military                           | Puzzle                                     |
| Space                              | Stealth                                    |
| Strategy                           | Puzzle                                     |
| Strategy wargames                  | Survival horror                            |
| Real-time strategy and turn-based  | Vehicular combat                           |
| Strategy games                     | Real-time tactical and turn-based tactical |
| God Games                          | Other (Please Specify)                     |

13. What are your Top 3 (in order) genres, or video games categories, that you enjoy to play (Choose from the list above, or add your own).

#1. \_\_\_\_\_

#2. \_\_\_\_\_

#3. \_\_\_\_\_

14. List your Top 5 educational videos games/video games/apps that you have played and select how often you played.

|    | Game Title | All of it | Most of it | Some of it | Very Little | Have not Play |
|----|------------|-----------|------------|------------|-------------|---------------|
| 1. |            | A         | B          | C          | D           | E             |
| 2. |            | A         | B          | C          | D           | E             |
| 3. |            | A         | B          | C          | D           | E             |
| 4. |            | A         | B          | C          | D           | E             |
| 5. |            | A         | B          | C          | D           | E             |

15. Based on your Top 3 and Top 5, what attracts you to these games?

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16. How good do you feel you are at playing video games?

- A. Very Good
- B. Moderately Good
- C. Not Very Skilled
- D. No Skill

17. Would you be interested in playing an educational video game that corresponds to this course in the future?

- A. Yes
- B. No

18. What type of marketing attracts you, or would attract you, to play video games?

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19. What you like to see in a game made just for YOU?

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20. Do you have a computer connected to the Internet at home?

- A. Yes
- B. No

21. Approximately how often do you use the computer to do school work at home?

- A. Every day
- B. 4-6 time per week
- C. 1-3 times per week
- D. Not very often
- E. Not at all

22. When you were in high-school was there a computer in your home?

- A. Yes
- B. No

23. 23. What do you think of mathematics?

Hate it    1    2    3    4    5    Love it

24. How would rate your computer skills (NOT considering game playing skills)?

- A. Awesome, power user
- B. Proficient, regular user
- C. Novice, infrequent user
- D. Beginning, just started user
- E. Non-user

25. What grade do you expect in this class?

- A. A
- B. B
- C. C
- D. D
- E. F

## Motivation Survey

### Instructions

There are 20 statements in this questionnaire. Please think about each statement in relation to the mathematics class that you are about participate in and indicate how true the statements are using the scale provided after each statement. Give the answer that truly applies to you and not what you would like to be true, or what you think others want to hear.

Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements.

Circle the number that best indicates your response, and follow any additional instructions that may be provided in regard to the answer sheet that is being used with this survey. Be sure to circle a number. DO NOT circle any space between the numbers.

### Scale for Your Responses

1 (or A) = Not true

2 (or B) = Slightly true

3 (or C) = Moderately true

4 (or D) = Mostly true

5 (or E) = Very true

## Course Motivation Survey (CMS)

### Instructions

1. There are 20 statements in this questionnaire. Please think about each statement in relation to the mathematics class that you are about to participate in and indicate how true the statements are using the scale provided after each statement. Give the answer that truly applies to you and not what you would like to be true, or what you think others want to hear.
2. Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements.
3. Circle the number that best indicates your response, and follow any additional instructions that may be provided in regard to the answer sheet that is being used with this survey. Be sure to circle a number. DO NOT circle any space between the numbers.

### Scale for Your Responses

1 (or A) = Not true

2 (or B) = Slightly true

3 (or C) = Moderately true

4 (or D) = Mostly true

5 (or E) = Very true

## Course Motivation Survey (CMS)

Name: \_\_\_\_\_ Teacher: \_\_\_\_\_ Class: \_\_\_\_\_

Please remember to circle a number. DO NOT circle any space between numbers.

1. I think this mathematics class will be challenging, but neither too easy, nor too hard for me.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

2. There is something interesting about this mathematics class that will capture my attention.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

3. This mathematics class seems more difficult than I would like for it to be.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

4. I believe that completing this mathematics class will give me a feeling of satisfaction.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

5. It is clear to me how this mathematics class is related to things I already know.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

6. I believe this mathematics class will gain and sustain my interest.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

7. I believe that the information contained in this mathematics class will be important to me.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

8. As I learn more about this mathematics class, I am confident that I could learn the content.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

9. I believe that I will enjoy this mathematics class so much that I would like to know more about this topic.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

10. The mathematics class seems dry and unappealing.

1-----2-----3-----4-----5

Not true      Slightly true      Moderately true      Mostly true      Very true

11. The mathematics class is relevant to my interests.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

12. It is apparent to me how people use the information in this mathematics class.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

13. I will really enjoy completing assignments for this mathematics class.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

14. After working on this mathematics class for awhile, I believe that I will be confident in my ability to successfully complete all class assignments and requirements.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

15. I think that the variety of materials, exercises, illustration, etc., will help keep my attention on this mathematics class.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

16. The technology that will be used to deliver this mathematics class may be frustrating/irritating.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

17. It will feel good to successfully complete this mathematics class.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

18. The contents of this mathematics class does not include information that will useful to me.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

19. I do NOT think that I will be able to really understand the information in this mathematics class.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

20. I do not think that this course will be worth my time and effort.

1-----2-----3-----4-----5  
Not true      Slightly true      Moderately true      Mostly true      Very true

Pre/Post-test

Name \_\_\_\_\_ Date \_\_\_\_\_

Pre/Post-Test

Directions: Circle the correct answer.

- Suppose you start at the origin, move along the x-axis a distance of 8 units in the positive direction, and then move downward a distance of 1 units. What are the coordinates of your position?
  - (8, 0, 1)
  - (0, 8, 1)
  - (8, -1, 0)
  - (8, 0, -1)
  - (8, 1, 0)
- Find the midpoint of the line segment from P1(-10,10,5) to P2(2,8,3).
  - (-4, 9, 4)
  - (6, 0, -1)
  - (-6, 0, 1)
  - (4, -9, 4)
  - (1, 9, -4)
- Find the center and radius of the sphere:  $x^2 - 2x - 38 + y^2 + 8y + z^2 - 6z = 0$ .
  - C(1, -4, 3),  $r = 4$
  - C(4, -4, 3),  $r = 2\sqrt{2}$
  - C(1, 4, 3),  $r = \sqrt{2}$
  - C(1, -4, 2),  $r = 2$
  - None of these
- Find the values of  $x$  such that the vectors  $\langle 4x, x, 3 \rangle$  and  $\langle 2, x, 5 \rangle$  are orthogonal.
  - $x = -3, x = -5$
  - $x = -1, x = -5$
  - $x = 3, x = -3$
  - $x = 1, x = -1$
  - $x = 5, x = -5$
- Find the unit vectors that are parallel to the tangent line to the curve  $y = 2x^2$  at the point (1, 2).
  - $\pm \frac{i+2j}{\sqrt{17}}$
  - $\pm \frac{4i-j}{4}$
  - $\pm \frac{i-4j}{4}$
  - $\pm \frac{i+4j}{\sqrt{17}}$

- e.  $\pm \frac{i+j}{\sqrt{17}}$
6. Let  $\mathbf{v} = 7\mathbf{j}$  and let  $\mathbf{u}$  be a vector with length 5 that starts at the origin and rotates in the  $xy$ -plane. Find the maximum value of the length of the vector  $\|\mathbf{u} \times \mathbf{v}\|$ .
- $\|\mathbf{u} \times \mathbf{v}\| = 12$
  - $\|\mathbf{u} \times \mathbf{v}\| = 140$
  - $\|\mathbf{u} \times \mathbf{v}\| = 30$
  - $\|\mathbf{u} \times \mathbf{v}\| = 1$
  - $\|\mathbf{u} \times \mathbf{v}\| = 35$
7. Find the distance between the two planes.  $5x - 2y + z - 1 = 0$ ,  $5x - 2y + z + 4 = 0$ .
- $\frac{1}{6}$
  - $\frac{\sqrt{30}}{6}$
  - $\frac{5}{6}$
  - $\frac{\sqrt{30}}{6}$
  - $\frac{5\sqrt{30}}{6}$
8. Find the angle between the planes.  $x - z = 1$ ,  $x - y - 2z = 25$
- $30^\circ$
  - $60^\circ$
  - $50^\circ$
  - $116^\circ$
  - None of these
9. Determine whether the lines  $L_1: x = 3 + 2t, y = 4 - t, z = 1 + 3t$  and  $L_2: x = 1 + 4s, y = 3 - 2s, z = 4 + 5s$  are parallel, skew, or intersecting. If they intersect find the point of intersection.
- Parallel lines
  - Skewed lines
  - Intersecting lines at  $(1, -2, 5)$
  - Intersecting lines at  $(3, 2, 2)$
10. Find the general equation of the plane containing the points,  $P(1,0,0)$ ,  $Q(3, 2, 0)$ , and  $R(0, 2, 1)$ .
- $x - y - 2z - 25 = 0$
  - $x - y + z = 0$
  - $3x + 2y + 4z - 12 = 0$
  - $2x - 2y + 6z - 2 = 0$



11. Find the antiderivative of  $\mathbf{r}'(t) = t\mathbf{j} + 2t\mathbf{k}$  that satisfies the initial condition  $\mathbf{r}(0) = \mathbf{i} + 2\mathbf{j}$ .

- a.  $\mathbf{r}(t) = \mathbf{i} + \frac{1}{2}t^2\mathbf{j} + t^2\mathbf{k}$
- b.  $\mathbf{r}(t) = t\mathbf{i} + \frac{1}{2}t^2\mathbf{j} + \frac{t^3}{3}\mathbf{k}$
- c.  $\mathbf{r}(t) = \mathbf{i} + \left(\frac{t^2}{2} + 2\right)\mathbf{j} + t^2\mathbf{k}$
- d.  $\mathbf{r}(t) = \mathbf{i} + \left(\frac{t^2}{2} - t\right)\mathbf{j} + (t^2 - 2)\mathbf{k}$
- e. None of these

### Game Performance Test #1

1. The invisible Magical sorcerer starts from rest at point  $P(1,2,0)$  and moves with a velocity of  $\vec{v}(t) = t\mathbf{j} + 2t\mathbf{k}$  where  $\|\vec{v}(t)\|$  is measured in feet per second. Find the location of the sorcerer after  $t=2$  seconds to successfully launch a projectile to destroy him.
2. Killer Mega uses his powers of telepathy and senses a sorcerer near the surrounding coordinates  $(2,1,1)$ ,  $(0,4,1)$ , and  $(-2,1,4)$ . Determine the general plane of the region by determine the equation of the plane in general form so that he use telekinesis to destroy the sorcerer.
3. Two spacecrafts are coming from opposite directions on a diagonal path where spacecraft 1 travels along  $(1,-7, 2)$  to  $(7,8,-1)$  and spacecraft 2 travels along  $(1,11,4)$  to  $(5,9,1)$ . Will they intersect and explode, or will they miss each other? If they explode, enter the coordinates. If they don't, then typed SKEWED OR PARALLEL.

## Game Performance Test #2

1. The invisible Magical sorcerer starts from rest at point  $P(1,0,0)$  and moves with a velocity of  $\vec{v}(t) = -\cos(t)\mathbf{i} - \sin(t)\mathbf{j} + \mathbf{k}$  where  $\|\vec{v}(t)\|$  is measured in feet per second. Find the location of the sorcerer after  $t=2$  seconds to successfully launch a projectile to destroy him.
2. Killer Mega uses his powers of telepathy and senses a sorcerer near the surrounding coordinates  $(1,2,3)$ ,  $(3,2,1)$ , and  $(-1, -2,2)$ . Determine the general plane of the region by determine the equation of the plane in general form so that he use telekinesis to destroy the sorcerer.
3. Two spacecrafts are coming from opposite directions on a diagonal path where spacecraft 1 travels along  $(3, -2,1)$   $(3,-2, 1)$  to  $(9,13, -2)$  and spacecraft 2 travels along  $(5,9,1)$  to  $(1,11,5)$ . Will they intersect and explode, or will they miss each other? If they explode, enter the coordinates. If they don't, then typed SKEWED OR PARALLEL.

# Mathematical Modeling Worksheet

## Mathematical Modeling Cycle Solution Plan

|  |  |   |
|--|--|---|
| <p><b>Situation (Understanding the Task)</b><br/>Read the text precisely and imagine the situation clearly!, What is require from you? Discuss what you already understand and make a sketch if necessary!</p> | <p><b>Mathematical Model</b><br/>Look for data the data you need; if necessary make assumptions Look for mathematical relations, and use appropriate mathematical procedures! Discuss any mathematical tools and techniques that you plan to use to construct any mathematical model (formula). Use tools/techniques to construct the model.</p> | <p><b>Computer Model</b><br/>Write your final mathematical model exactly as you have typed it in computer input screen.</p> |
|--|--|---|

Name \_\_\_\_\_ Problem# \_\_\_\_\_

1

|  |  |  |
|--|--|--|
| <p><b>Computer Results</b><br/>Write the computer's response message to your solution!</p> | <p><b>Mathematical /Real Results</b><br/>Link your results to the task! is your results reasonable? if not, go back to step 1 (Situation)! if yes, write down your final answer!</p> | <p><b>Results</b><br/>Enter your final score and time below!</p> |
|--|--|--|

Name \_\_\_\_\_ Problem# \_\_\_\_\_

2

# Mathematical Modeling Worksheet

## Mathematical Modeling Cycle Solution Plan

**Situation (Understanding the Task)**  
Read the text precisely and imagine the situation clearly!, What is require from you? Discuss what you already understand and make a sketch if necessary!

**Mathematical Model**  
Look for data the data you need, if necessary make assumptions Look for mathematical relations, and use appropriate mathematical procedures! Discuss any mathematical tools and techniques that you plan to use to construct any mathematical model (formula). Use tools/techniques to construct the model.

**Computer Model**  
Write your final mathematical model exactly as you have typed it in computer input screen.

Name \_\_\_\_\_ Problem# \_\_\_\_\_

3

## Interview Protocol and Questions

The following information is to be used by the researcher before, during, and after the interview. The researchers follow these steps:

### **Before the interview**

- Schedule interview with student. Be sure to schedule a room on campus where we can meet.
- Request permission ahead of time to tape the interview.
- Assure the participant that results will be kept confidential
- Make sure to test recording equipment, including the microphone and volume.
- Have all materials organized and ready for the interview
- Take an extension cord or extra batteries for recording equipment
- Make sure to bring a recorder of high quality

### **During the interview**

- Before beginning the formal questions, the researcher records students' name and date.
- Ask the questions as written, but if the participants seems to misinterpret the question or to get "off track" with his/her response, ask probing questions to clarify his/her response.
- Try to avoid a dialogue during the interview – let the participant do the talking
- In conclusion, asks the participant if she/he have any questions or comments

### **After the interview**

- Write up (or verbally attach) a brief report as soon as possible after the interview. Make sure to clarify any unusual occurrence (such as an interruption in the interview), or her impressions of strange responses from the participant. (e.g. Were there any questions that he/she seemed to find offensive or threatening? Were there any questions that seemed unusually difficult to answer?)
- Supplement notes by defining any special terms or explanations used that might not be known by the other universities.
- Describe any insights that may not have registered through the audio medium any other unusual occurrences during the meeting.

## Interview Guide for Use by Researcher

Interviewer initials: \_\_\_\_\_ Date: \_\_\_\_\_ Time begin: \_\_\_\_\_ Time end: \_\_\_\_\_

### **Introduce yourself and the purpose of the interview:**

After I introduce myself and have the recorder started, I will read the following.

“ Thank you for allowing me to come in today to talk about the mathematics course. The purpose of our interview is not to grade or rank you, but to look at factors that affect you as a student when learning mathematics. The interview will run about 30 minutes. Please be assured that the information you provide will be kept in strict confidentiality. Do you have questions before we begin?”

### **Confidentiality:**

What you say will be confidential. I won't connect your name with anything you say.

Please say what you really think – it's not a test:

Please remember, there is no right or wrong answers. It's not a test.

You won't hurt my feeling, no matter what you say about it. So please feel free to say what you think.

### **For treatment and comparison groups**

1. Describe your learning experience in this class.
2. How do you see yourself in this class? Are you comfortable with the math concepts being introduced?
3. If you were lost on a topic, what would you do to overcome this difficulty in understanding concepts?
4. Do you recall any activities that you have done in class that attracted your attention?
5. What did you like about the course?
6. Did you or the instructor use any form of technology that influenced the way you understand the course content? If so, what was it?
7. What specific parts of your mathematics class catch and keep your attention?
8. What specific parts of your mathematics class do you think are important/relevant to your personal life and/or interests?
9. What specific parts of your mathematics class increased your confidence to do mathematics and do well in the mathematics class?
10. What specific parts of learning mathematics and of your mathematics class do you think are worth your time and effort?
11. What specific parts of your mathematics class do you think help you learn mathematics in general, and do well on the mathematics quizzes and exams?
12. What specific parts of your mathematics class either motivate you to learn or have a bad effect on your motivation to learn?

### **Treatment group only**

13. Compared to other forms of mathematics school work (e.g. worksheets, homework, assignments), do you like playing the game designers' mathematics game?

- a. 1 – a lot less
  - b. Less
  - c. About the same
  - d. More
  - e. A lot more
14. Compared to other entertaining video games, do you like playing the games designers' mathematics game?
- a. 1 – a lot less
  - b. Less
  - c. About the same
  - d. More
  - e. A lot more
15. What did you like or dislike about the game?
16. Do you feel that playing the mathematics video game helped you understand mathematics concepts and increase your mathematics skills?
- a. No, not at all
  - b. No
  - c. Somewhat
  - d. Yes
  - e. Yes, very much
17. Did any of the following effect your desire to play the mathematics games?
- a. Your Mathematics skills
    - i. No effect
    - ii. Little Effect
    - iii. Some effect
    - iv. Significant effect
    - v. Great effect
  - b. Your computer skills
    - i. No effect
    - ii. Little Effect
    - iii. Some effect
    - iv. Significant effect
    - v. Great effect
  - c. Your English skills
    - i. No effect
    - ii. Little Effect
    - iii. Some effect
    - iv. Significant effect
    - v. Great effect
18. Was it easy for you to learn how to play the mathematics game?
- a. No, they were very difficult to learn
  - b. No
  - c. Somewhat



- d. Yes
  - e. Yes, they were very easy to learn
19. What specific problems, if any, did you have in learning to play the game?
  20. What specific aspects of the game did you enjoy the most?
  21. What specific aspect of the game did you dislike the most?
  22. How would you improve the game?
  23. Do you have any questions or comments?

Thank you for the time and comments!

## APPENDIX B: GEORGIA STATE UNIVERSITY IRB APPROVAL LETTER

### INSTITUTIONAL REVIEW BOARD

**Mail:** P.O. Box 3999  
Atlanta, Georgia 30302-3999  
**Phone:** 404/413-3500  
**Fax:** 404/413-3504

**In Person:** Dahlberg Hall  
30 Courtland St, Suite 217



April 03, 2017

Principal Investigator: Iman Chahine

Key Personnel: Chahine, Iman; Devoe, Malcom W; Tinker Sachs, Gertrude, PhD

Study Department: GSU - Georgia State University, GSU - Middle & Secondary Education

Study Title: The Effects of Digital Game-Based Learning In Multivariate Analysis

Review Type: Expedited, 6,7

IRB Number: H17339

Reference Number: 339034

Approval Date:

04/03/2017

Expiration Date:

04/02/2018

The Georgia State University Institutional Review Board (IRB) reviewed and approved the above referenced study in accordance with 45 CFR 46.111. The IRB has reviewed and approved the study and any informed consent forms, recruitment materials, and other research materials that are marked as approved in the application. The approval period is listed above. Research that has been approved by the IRB may be subject to further appropriate review and approval or disapproval by officials of the Institution.

Federal regulations require researchers to follow specific procedures in a timely manner. For the protection of all concerned, the IRB calls your attention to the following obligations that you have as Principal Investigator of this study.

1. For any changes to the study (except to protect the safety of participants), an Amendment Application must be submitted to the IRB. The Amendment Application must be reviewed and approved before any changes can take place
2. Any unanticipated/adverse events or problems occurring as a result of participation in this study must be reported immediately to the IRB using the Unanticipated/Adverse Event Form.
3. Principal investigators are responsible for ensuring that informed consent is properly documented in accordance with 45 CFR 46.116.
  - The Informed Consent Form (ICF) used must be the one reviewed and approved by the IRB with the approval dates stamped on each page.
4. For any research that is conducted beyond the approval period, a Renewal Application must be submitted at least 30 days prior to the expiration date. The Renewal Application must be approved by the IRB before the expiration date else automatic termination of this study will
5. When the study is completed, a Study Closure Report must be submitted to the IRB.

All of the above referenced forms are available online at <http://protocol.gsu.edu>. Please do not hesitate to contact the Office of Research Integrity (404-413-3500) if you have any questions or concerns.

Sincerely,

A handwritten signature in cursive script that reads "Ann Cole Kruger".

Ann Kruger, IRB Chair

## APPENDIX C: TEACHER INFORMED CONSENT

Dear Professor,

My name is Malcom Devoe and I am Ph. D. candidate at the Georgia State University. As part of my research, I am asking professors at the university to participate.

The purpose of this research study is to determine the effects of an educational video game and related instructional materials on students' mathematical achievement, mathematical anxiety, and mathematics course motivation. The researcher wants to document and write about the class and the effects the video game on everyone in the class. The results from the study will help institutions make informed decisions about using the game, as well as well help educators make better use of such instructional materials. The results will also help educational game designers like myself create better games supporting instructional materials for professors and students. You should feel good about assisting with this important research and sharing your successes!

With your consent, students in your course, specifically Multivariate Calculus, will be asked to volunteer for the study. Of those students who volunteer and sign a consent form, scores on gaming and institutional calculus II exams will be recorded. Participating students will be asked to complete a questionnaire regarding their mathematics anxiety and mathematics motivation at the beginning, and mid, and end of the semester. Two sections of this course will be studied. With your consent, I will like your section of the Multivariate Calculus course to be held in a classroom that contains working computers with internet access at each students' desk for the experimental group. The classes will be observed and recorded. The interviews will be held during non-instructional time and should be less than 30 minutes. Interviews will be recorded for transcription purposes only. Your participation and other subjects in this study will be kept confidential. All data including tapes, completed observation forms, mathematics achievement scores, and responses to mathematics anxiety and mathematics course questionnaires will be stored in a locked room in my research development laboratory.

Please Note: All data, including participating students' personal information, will also be given to the game designer who will also use the same basic procedure to secure the data and protect your right, as well as your students' name, email address, and online contact information. Names and email addresses will only be used for administrative purposes. The information will not be used for marketing the game designer's products or services in any manner.

Your name, the names of your students, and the name of your institution will be kept confidential and will not be used in any report, analysis, or publication by the researchers or the game designer. All identifying information will be replaced with alternate names or codes. In addition, the researcher is requesting your permission to access participating students' documents and school records such as those available in cumulative file, and students' grades.

There are no anticipated risks, compensation or other direct benefits to you as a participant in this interview. You are free to withdraw your consent to participate and may discontinue your participation in the interview at any time without consequence.

If you have questions about this research project, please contact me at (678) 768-4692 via email at [mdevoe1@gsu.edu](mailto:mdevoe1@gsu.edu) or [mdevoe@atlm.edu](mailto:mdevoe@atlm.edu). Research at the Georgia State University involving human participants will be carried out under the oversight of the Institutional Review Board (IRB). Questions and concerns about research participants' rights may be directed to the Institutional Review Board Office, Your help in this study will be very much appreciated!!

Sincerely,

Malcom

## APPENDIX D: STUDENT SCRIPT

### STUDENT SCRIPT

Good Day students! I am a graduate student with mathematics education department. I would like to ask you to participate in a research study to see if technology has any effect on your mathematics skills or mathematics attitudes.

The results of the study will also help us decide whether to pursue the use of innovative technology for the entire post-secondary mathematics for instructional use as well as guide future research and development.

Participation will not affect your grade in this course in any manner

If you do not want to participate, that's fine, just please let me know.

If you would like to participate, would please read and sign the Informed Consent form and return it to me today? It's essential that we have your approval or you cannot participate in the study. After reviewing and sign the form, I will hand a survey to complete. This survey must be returned to me once completed.

Thank you.

## APPENDIX E: STUDENT INFORMED CONSENT FORM

Georgia State University

Department of Mathematics Education

Informed Consent

**Title:** The Effects of Digital Game Based Learning with Applications of Multivariate Analysis

**Principal Investigator(s):** Dr. Iman Chahine ([ichahine@gsu.edu](mailto:ichahine@gsu.edu))

**Student Principal Investigator:** Malcom Devoe ([mdevoe1@gsu.edu](mailto:mdevoe1@gsu.edu))

**Purpose:** You are invited to participate in a research study. The current study aims to explore and determine the effects of student learning in role playing/platform educational video games and how these video games affect students' mathematics achievement, motivation and engagement. A total of 55 students will be recruited for this study. Participation requires 6.5 weeks of your time.

**Procedures:** You will be gaming and exam scores will be recorded. You will also be asked to complete questionnaires regarding your mathematics motivations, computer and gaming skills. Your class will be observed at minimum of once a week. You may be selected to be interviewed by the researcher and/or a professor at Georgia State University. Classes will be videotaped. The interviews will be held on-campus during non-instructional time and should take less than 30 minutes. The interview will be recorded for transcription purposes only.

**Discomfort and Risks:** There are no risks associated with your participation in this study and we do not anticipate any discomfort.

**Benefits:** The researcher wants to document and write about the mathematics and the effects of the video game on everyone in the class. The results of the study will assist professors in making an informed decision about using the game, as well as help many educators to make use of such supplemental instructional materials. The results from this study will assist game designers to improve their game development approaches for students.

**Cost of Compensation:** Your participation in this study is strictly voluntary. There is no compensation with your participation in this study.

**Duration:** 6.5 Weeks

**Voluntary Participation and Withdrawal:**

Participation in research is voluntary. You do not have to be in this study. If you decide to be in the study and change your mind, you have the right to drop out at any time. Whatever you decide, you will not lose any benefits to which you are otherwise entitled

**Statement of Confidentiality:** Your participation in this study will be kept completely confidential. All data, including tapes, completed observation forms, mathematics achievement scores, responses to mathematics course motivation questionnaires will be stored in a locked room in student PI research development laboratory. All data, including participating students' personal information, will also be given to the game designers who will also use the same basic procedure to secure the data and protect your right to privacy. The personal information collected will include your name, email address, and online contact information. Names, email addresses and online contact information will only be used for administrative purposes. The information will not be used for marketing the game designers' products or services in any manner. By signing the consent form, you are also agreeing to allow us release the data to the game designers. Your name, and the name of the school will be kept confidential and will not be used in any report, analysis, or publication by the researchers or the games designers. All identifying information will be replaced with alternate names or codes. You are free to withdraw with your consent to participate and may discontinue your participation in the interview at any time without consequence.

**Contact Persons:**

If you have questions about this research project, please contact me at (678)-768-4692 or by email at [mdevoel@gsu.edu](mailto:mdevoel@gsu.edu). Research at Georgia State University involving human participants is carried out under the oversight of the Institutional Review Board 30 Courtland St., Room 218, Alumni Hall, Atlanta, GA 30303. The telephone number is 404-413-3505.

**Copy of Consent Form to Participant:**

Please sign and return this copy of the letter to me. A second copy is provided for your records. By signing this letter, you agree to participate in this research study.

Sincerely,

Malcom Devoe  
Mathematics Education

Georgia State University

\_\_\_\_\_ I have read the procedures described above for the research study

\_\_\_\_\_ I voluntarily agree to participate in the study

\_\_\_\_\_ I agree to be audio/video taped during the interview

\_\_\_\_\_ I give consent for the online collection and use by the game designers, and the disclosure of my personal information to the game designers for administrative purpose only.

\_\_\_\_\_/\_\_\_\_\_  
Participant Date

\_\_\_\_\_/\_\_\_\_\_  
Principal Investigator Date



## APPENDIX F: BOSS AND PLAYER SCRIPTS

```
Event: obj_Player_Step_1
Applies To:  Self  Other  Object

action
1 phy_speed_x = max(min(phy_speed_x,max_xspeed),-max_xspeed);
2 if (phy_speed_x > 0.1 || phy_speed_x < -0.1)
3 {
4     sprite_index = sprite15;
5     //image_xscale = 0.2;
6     image_yscale = 0.2;
7 }
8 else if( alarm[1] !=-1)
9 {sprite_index = spr_shooting_player;}
10 else {
11     sprite_index = sprite14;
12     image_xscale = 0.15;
13     image_yscale = 0.15;
14 }
15 //if (phy_speed_x < -.1) {obj_fireball.image_xscale =-1*obj_fireball.image_xscale;}
16 //if (alarm[1] == -1)
17 //{sprite_index = spr_shooting_player;}
18
19 image_speed = phy_speed_x/5;
20
```

```
Event: obj_main_enemy_Alarm 2_1
Applies To:  Self  Other  Object

action
1
2 //myvar =random(30);
3 // This event/function generates random attacks to the protoganist
4
5 if ((n%6) == 0 && alarm[2]<=0)
6 {sprite_index = spr_greenz; n +=3; alarm[2]=90;show_debug_message(" n = ");
7 show_debug_message(n);}
8 else if (((n%9)== 0 && alarm[2]<=0)
9 {sprite_index =enemy_special_move; n +=3; alarm[2]=90;show_debug_message(" n = ");
10 show_debug_message(n);}
11 else if ((n%3)== 0 && alarm[2]<=0)
12 {sprite_index = spr_enemy_shock; n +=3; alarm[2]=90;show_debug_message(" n = ");
13 show_debug_message(n);}
14
15
```