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Development and Evaluation of Game-Based Learning System for Differential Calculus

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Abstract

One important task of every teacher is to help improve his/her student's ability of thinking and reasoning. The ability to think and reason out vigorously is one of the substantial learning that the student can achieve. Now, everybody is in the process of changing because of the advances in technology and as the technology continues to grow, the application of Mathematics to Science becomes superior. To reach the utmost potential of our students' mathematical skills, there are a lot of numerous ways we can do as teachers to achieve this and one of the methods or strategies that can be instigated is through game-based learning. As an educator, we always seek to determine first if the students are ready to learn the new topics that we are about to discuss and this is based on what they already know. Difficulty in coping with the topics is then experienced by the students if they lack the needed mathematical skills for a particular lesson.
In this study, the researcher developed a game-based diagnostic test and learning intervention for freshman engineering students for the course in Differential Calculus. The learning intervention was developed as a tool for mastery of topics for the course. The goal of the game-based learning system is for the students to bridge the gap of mastery in their Pre-Calculus most especially for the non-STEM students who were not able to take Pre-Calculus in their senior high school strand. The researcher also investigated if the game-based learning system eventually strengthened students' mathematical skills required in improving the performances in the course Differential Calculus. The researcher presented the acceptability of the game-based learning system, the comparison in the academic performance of the freshman engineering students who were exposed in traditional bridging with game-based learning intervention and those who were exposed with the purely traditional bridging program in the General Mathematics, Diagnostic Pretest and Posttest and Differential Calculus Final Grade.

Keywords: Game-based learning, mathematics, pre-calculus, differential calculus, intervention

Introduction

Proficiency with technology is not equivalent to competency in mathematics. Students need to be successful in meeting both objectives, but with the awareness that technology is a means of strengthening mathematical understanding.

Nowadays, technology has taken its place in society as most of the people are so into gadgets like computers, cellphones, and tablets where they can have easy access to any information. These advances in technology challenge educators to think of ways on how they can make use of these innovations to their advantage. As educators, they can utilize these technologies to induce learning, to capture the students' interests, and employ them as a positive motivation to enhance the mathematical skills of the learners.

Diaz (2006) stated that the goal of mathematics education is the mastery of the subject matter. Mathematics should be introduced and mastered at every level from kindergarten to the fourth year of high school. Progression should be in small increments of topics with the aim of depth, rather than breadth of understanding. One of the most vital goals of mathematics is to teach students the logical thinking needed in the 21st Century. The logic inherent in the study of Mathematics allows for applications to a broad range of situations in which answers to practical problems can be found with accuracy. This skill that we can acquire in learning mathematics is a cornerstone of success in this global world. It is an interconnected process. To reach this potential, there are a lot of numerous ways we can do as teachers to improve our student's mathematical skills, one of the methods or strategies that can be instigated is through game-based learning.

Game-based learning is an innovative learning approach derived from the use of computer games that possess educational value or different kinds of software applications that use games for learning and education purposes such as learning support, teaching enhancement, assessment, and evaluation of learners (Tang et al., 2009).

Seeking to determine first if the students are ready to learn the new topics that will be discussed must be anchored on what they already know. Difficulty in coping with the topics is then experienced by the students if they lack the needed mathematical skills

for a particular lesson. This is well supported by Sampang and Moseros (2016) who investigated redesigning diagnostic tests as developmental assessment instruments thereby finding out that mastery of prerequisite skills at a certain level prepares the learners to cope with the demands of more difficult concepts and applications in the succeeding level. Thus, reviewing the learners of the prerequisite skills could largely contribute to the overall learning of the students. When these skills are already mastered by the learners, forming new concepts and skills on the prerequisites and on what they already know would yield to full learning of the concepts. Firestone (2016) stated that when students are given the support they need while learning something new, they stand a better chance of using that knowledge independently and mastery and retention of the concepts and skills is assured.

The Philippines emerged as the only country in Asia and one of the three countries in the world (the others were Angola and Djibouti) that had a 10-year basic education before it acknowledged the implementation of the K to 12 Program - a vision towards Philippine education's improved level of global competitiveness. One of its features is the new curriculum for the Senior High School (SHS) providing the students an opportunity to select among the four tracks namely Academic, Technical-Vocational-Livelihood, Sports, and Arts and Design. The Academic track includes four strands: Accountancy, Business and Management (ABM); Science, Technology, Engineering, and Mathematics (STEM); Humanities and Social Sciences (HUMSS); and General Academic Strand (GAS).

The said strands in SHS aim to prepare the students for higher in-depth learning on the specialization that they would like to pursue in the future. Ideally, the chosen track in SHS is designed to align the degree that the students might take in college. However, it has not been observed lately since an SHS graduate can take an academic program in college regardless of the track they took in SHS. For instance, non-STEM graduates may enter any engineering program in an educational institution notwithstanding his previous knowledge in the discipline they previously had in SHS. This is where the gap transpires. As for the Engineering program, the basic foundation of mathematics lies in Pre-Calculus which, inopportunely, the non-STEM students did not take in SHS. Having the core subject of General Mathematics in SHS is not adequate to pursue a course in Differential Calculus in higher education. This is the part where the researcher focused its study in giving the non-STEM students the chance to bridge the gap of learning the mathematical skills and concepts required for them in the course Differential Calculus through the development of the game-based learning system.

In this study, the researcher developed a game-based diagnostic test and learning intervention. To determine the effectiveness of the game-based learning system for the course Differential Calculus. The researcher sought to answer the following objectives:

1. test the acceptability of the game-based learning system
2. establish comparability between the control and the experimental groups based on the General Mathematics Achievement Test
3. compare the gain scores of the control and the experimental groups
4. compare the academic performance in Differential Calculus of the control and the experimental groups.

Methods of Research

The descriptive and experimental methods of research were used for this study. The descriptive method has been proven to be valuable in the collection and organization of research data to arrive at findings in conclusive form. Since this study sought to describe the performances of the freshman engineering students in the General Mathematics Achievement Test, Diagnostic Test in Pre-Calculus, and in Differential Calculus and evaluation of the game-based diagnostic test, the descriptive method was appropriate. Furthermore, since the study sought to determine the effectiveness of the game-based learning system in the academic performance of the non-STEM students in Differential Calculus, so experimental method was applied.

How the study was conducted is illustrated in Figures 1 and 2 which were the guide of the researcher.

Phase I: System Development

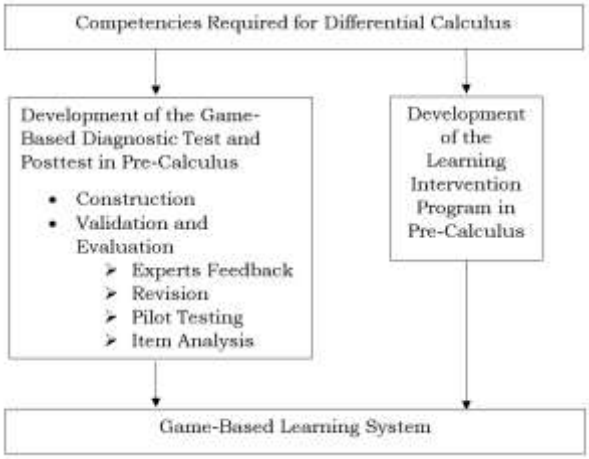

Figure 1. Research Paradigm Phase I

Phase II: Evaluation of the Game-Based Learning System

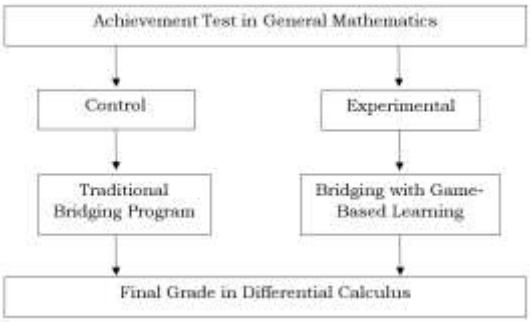

Figure 2. Research Paradigm Phase II

The control and experimental groups were both exposed in the game-based diagnostic test and posttest. The control group did not have access to the learning intervention while the experimental group had access to the learning intervention.

An achievement test was constructed by the researcher to establish comparability within the respondents and the test consisted of fifty (50) multiple-choice items that covered the topics in the core subject General Mathematics: 25 items in functions, 13 items in business mathematics, and 12 items in logic. The researcher also developed a game-based diagnostic test and a game-based posttest which consisted of fifty (50) multiple-choice items that covered all the contents in Pre-Calculus: 21 items in analytic geometry, 7 items in series and mathematical induction, and 22 items in trigonometry. The general mathematics achievement test, game-based diagnostic test, and game-based posttest underwent item analysis whereby the difficulty index and the discrimination index were determined as a basis of retaining the item. The researcher also developed a learning intervention in the form of PowerPoint presentations based on the topics in Pre-Calculus which were embedded in the learning system. The instrument that was used for an expert evaluation on the game-based diagnostic test and learning intervention is Rubric for eLearning Tool Evaluation by Anstey and Watson (2018). This rubric has been designed for instructors and staff as a formative tool to evaluate eLearning tools in higher education. eLearning tools are defined as any digital technology, mediated through the use of computing devices, deliberately selected to support student learning. The rubric supports a multi-dimensional evaluation of functional, technical, and pedagogical aspects of eLearning tools.

In the analysis of data, the following statistical tools were applied:

To determine the performance of the students in the Achievement Test in General Mathematics, Diagnostic Test, Posttest, and in the Final Grade in Differential Calculus, the researcher employed the mean and standard deviation. The mean described the performance while the standard deviation determined the homogeneity/heterogeneity in the students' performance. Furthermore, the same statistical treatment was used to describe the evaluation of the user and the experts regarding the Game-Based Learning System.

In identifying the effectiveness of the Game-Based Learning System to the academic performance of the students in Differential Calculus, a paired t-test was employed.

Results and Discussion

After analyzing and interpreting the data gathered from the experiment, the following are the findings of the study:

1. In the acceptability of the game-based learning system, the system was evaluated and tested by the IT and Math experts. The assessment showed that in the Functionality category the learning system can be scaled to accommodate any size class with the flexibility to somehow create smaller sub-groups or communities of practice; the system has a user-friendly interface and it is easy for instructors and students to become skillful within a personalized and intuitive manner. In the Accessibility category, the learning system was designed to address the needs of diverse users, their various literacies, and capabilities, thereby widening opportunities for participation in learning; the system also exhibited that the proper use of the system does not require equipment beyond what is typically available to instructors and students (computer with built-in speakers and microphone, internet connection, etc.); the system at all aspects of the tool can be used free of charge; the learning system has a simple, intuitive interface with minimal clicks to access materials, little or no training needed to get started, and the look and feel is inviting. In technical, the learning system was evaluated excellent in this category. In this system, the users can effectively utilize the system with any standard, up-to-date operating system; the users do not need to download additional software or browser extensions. In Mobile Design, the tool can be accessed, either through the download of an app or via a mobile browser, regardless of the mobile operating system and device, design of the mobile tool fully takes into consideration the constraints of a smaller-sized screen; the system has a little to no functional difference between the mobile and the desktop version, regardless of the device used to access it; the system has no difference in functionality between apps designed for different mobile

operating systems; the system offers an offline mode: core features of the tool can be accessed and utilized even when offline, maintaining functionality and content. In Privacy, Data Protection, and Rights, the learning system does not require the creation of an external account or additional login, such that no personal user information is collected and shared; the users maintain ownership and copyright of their intellectual property/data; the user can keep data private and decide if / how data is to be shared. In Social Presence, the system can support a community of learning through both asynchronous and synchronous opportunities for communication, interactivity, and transfer of meaning between users; the instructors can control learner anonymity; the system provides technical solutions for holding learners accountable for their actions; the learners' familiarity with the system is likely mixed, some will lack basic technical competence with its functions. In Teaching Presence, the system has easy-to-use features that would significantly improve an instructor's ability to be present with learners via active management, monitoring, engagement, and feedback; the system is adaptable to its environment: easily customized to suit the classroom context and targeted learning outcomes; the instructor can monitor learners' performance on a variety of responsive measures, these measures can be accessed through a user-friendly dashboard; the system has good tools that are provided and well documented, but the migrated material will need additional formatting. In Cognitive Presence, the learning system enhances engagement in a targeted cognitive task(s) that were once overly complex or inconceivable through other means; the use of the system easily facilitates learners to exercise higher-order thinking skills (given consideration to design, facilitation, and direction from instructor); it also, exhibited that through the system, learners can regularly receive formative feedback on learning (i.e. they can track their performance, monitor their improvement, test their knowledge); the system is more than a simple test generator, this system provides tools for creating assessments with multimedia, learning games, and other interactive tools; tests can provide immediate feedback with tips for remediation; the system provides a suite of tools for authoring media-rich content, importing content, drag-and-drop interfaces, as well as uploading rich content types such as podcasts, video clips, etc.; allows metadata creation for easier/better management. In Math Content, the learning system exhibited that the learning intervention fully and eloquently articulates mathematical concepts; and develops connections among mathematical concepts; explains mathematical procedures without difficulty and provides full explanations for why mathematical procedures are valid or appropriate; the system had well-chosen and well-sequenced examples; the representations are clear and appropriate, with explanations of significant elements; and clearly explains connections among mathematical representations; the learning intervention had sophisticated use of mathematical terminology and symbols; the presentation has a clearly defined structure with elegant transitions and an effective introduction and conclusion; the learning intervention communicates clearly and effectively; and legible and grammatically correct.

In general, the game-based learning system was indeed an acceptable learning system based on the evaluation of the IT and Math experts.

2. The mean grade in General Mathematics Achievement Test of the experimental group was slightly higher than that of the control group but based on the t-test result, it showed that the difference is not significant by the p-value of 0.123 which is greater than 0.05 level of significance. This implies that there is no significant difference in the academic performance of the students in the General Mathematics Achievement Test and that the experimental and control groups were comparable.

3. The mean grade in the Analytic Geometry of the experimental group was greatly higher than that of the control group. The t-test result showed that the difference is significant based on the p-value of 0.046 which is less than 0.05 level of significance. This infers that there is a significant difference between the gain scores of the two groups in Analytic Geometry. In Series and Mathematical Induction, the mean grade of the experimental group was significantly higher than that of the control group. Moreover, the mean gain scores of the control group were negative which implies that the students performed well in the pretest than in the posttest. The t-test result showed that the difference is not significant by the p-value of 0.053 which is greater than 0.05 level of significance. This exhibited that there is no significant difference between the gain scores of the two groups in Series and Mathematical Induction. The mean grade in Trigonometry of the experimental group was greatly higher than that of the control group. The results also revealed that the control group had higher scores in pretest than in the posttest. The t-test result showed that the difference is significant based on the p-value of 0.032 which is less than 0.05 level of significance. This revealed that there is a significant difference between the gain scores of the two groups in Trigonometry. In the course Pre-Calculus, the mean grade of the experimental group was greatly higher than that of the control group. The t-test result revealed that the difference is significant by the p-value of 0.023 which is less than 0.05 level of significance. This infers that there is a significant difference between the gain scores of the two groups in Pre-Calculus.

The results proved that the game-based learning system alleviated the students in the experimental group to improve their academic performance in Analytic Geometry, Trigonometry, and as a whole in Pre-Calculus. These results supported the learning system to be an effective tool for the students to learn the mathematical concepts and skills in Pre-Calculus.

4. The experimental group showed a slightly higher mean grade than that of the control group. The t-test result showed that the difference is not significant by the p-value of 0.059 which is greater than 0.05 level of significance. This indicates that there is a significant difference in the academic performance of the students in Differential Calculus when grouped by those who were exposed in the game-based learning system with bridging program and those who were in the traditional bridging program. The mean scores of the students exhibit that the Pre-Calculus course is not adequate to perform better in Differential Calculus.

Conclusions

Based on the findings, the following conclusions were drawn:

1. The developed game-based learning system was an acceptable tool for learning.
2. The experimental and control groups are comparable.
3. The game-based learning system was an effective tool to increase the performance of the students in Pre-Calculus.
4. The topics in Pre-Calculus is not sufficient enough to take a course in Differential Calculus, the students should also have a strong foundation in Algebra.

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