Computational Competence on Basic Calculus of STEM Students through Mathematical Games

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Abstract - *This research study deallt mainly on the use of mathematical games, Damaths the Integrals and Snakes and Ladderivatives, in learning the different topics in Basic Calculus. This study used pre-test-post-test quasi experimental research design which utilized t-test and descriptive statistics in analyzing the data. Maximum variation purposive sampling was used to determine the respondents of this study and devised a self-made tests/questionnaires which were subjected to test of validity and reliability. The pre-test scores of the groups signify that the students' computational competence in Basic Calculus is low. The post-test scores of the groups significantly differ resulting to higher scores for the experimental group. It means that the computational competence of experimental group is superior compared to the control group. This was the result of exposure of both groups to different strategies and intervention programs. It could be concluded that mathematical games are effective in improving the computational competence of STEM students in Basic Calculus.*

Keywords: *Basic Calculus, Computational Competence, Mathematical Games*

INTRODUCTION

Learning concepts in mathematics, like any other subject, give numerous challenges for teachers and students. This subject is commonly associated as a tough and tiresome subject to learn [1]. Games that involve mathematical concepts have the capacity of undertaking these challenges. Interactive and engaging games can get students' attention for a long period of time while giving them with effective instruction and an attractive learning episode or experience. Games were widely used to improve the performance of the students in diverse areas or discipline including skills in algebra and its application, logical and calculated or strategic abilities, analytical geometry skills, and basic numerical or arithmetic approaches. Also, mathematical games have positive impact for teaching and influences the students' attitude towards mathematics compared to teaching the subject using other strategies. This strategy will boost the motivation and quicker understanding of the concepts and contents included in the subject. It emphasizes that mathematical games are effective on enhancing math skills and attitudes of the students [2]. The concept of integrating games to involve the students in the teaching and learning process is not new. There were lots of games that educators were already using and integrating in the curriculum to have a fun and interesting learning environment for the students. Although this strategy on using games can be very challenging and laborious, interactive, cooperative and competitive games lead to encourage the students and be motivated on the learning process [3]. According to Dewey, the model of experiential learning consists of a logical sequence which involves perceiving a problem, followed by its articulation, the formation of a hypothesis for finding a solution, experimentation to test the hypothesis, and finally giving reflective consideration to the consequences for society. Dewey believed that the meaning of a given experience is the result of the interaction between what the learner brings to the given situation and what happens there. For Dewey, continuity and interaction are the two fundamental criteria for determining the quality of experience and its implications for education. The learner should be able to connect aspects of the new experience to what he/she already knows, in addition to actively interact with his/her environment, testing out lessons developed in that environment [4].

According to Howard Gardner in his well-known book Frames of Mind: The Theory of Multiple Intelligences, in order to help all the students use their full thinking potential, it is necessary not only to teach them what a good mindset is, but to find ways to convince students of the value of using thinking strategies that may seem strange and uncomfortable at first. A good use of this approach includes both the type of activities and the tools that are most suitable for each of our students [5].

Meanwhile, Department of Education recognizes that the use of appropriate tools is necessary in teaching

mathematics. These include: manipulative objects, measuring devices, calculators and computers, smart phones and tablet PCs, and the Internet [6].

Article XIV, Section 2 of the 1987 Constitution of the Philippines states that the State shall establish, maintain and support a complete, adequate and integrated system relevant to the needs of the people and the society. This stipulation in the country's highest law is one of the legal bases of the Republic Act 10533, also known as the Enhanced Basic Education Act of 2013 which paved the way for upgrading the 10 – year basic education to a 12 – year program. It introduced Senior High School which is from Grade 11 to Grade 12 in the country [7].

Our educational system, perceiving the need for quality mathematics education to provide for the shape of the future, is now doing its best to prepare the next generation for effective living in a highly technological, complex world of tomorrow. Quality graduates who are products of highly educational standards is the premise of the Department of Education in defining the thrust of secondary education.

In Senior High School, STEM students are required to take Basic Calculus as part of the specialized subjects of the strand. Department of Education's Curriculum Guide lists down the following topics as the covered topics/content under Basic Calculus, namely limits and continuity; differential calculus; and integral calculus(DepEd). Many students have difficulty in learning Basic Calculus, the reason generally is that it primarily requires strong background in Algebra. This brought the challenge to the teachers of Science, Technology, Engineering and Mathematics (STEM) to think of different approaches to deal with this problem and to make learning more meaningful and interesting to the learners.

A mathematical game is a type of game that uses a set of guidelines or rules, aims at definite goal or outcome, and involves competition against other players or against barriers imposed by the nature of the game itself. A game is considered as a mathematical game if or when there is/are integration of mathematical concepts during the course of the game. These games may be used as introductory or drill activities to introduce concepts as a prelude to explicit teaching or practice skills or consolidate a concept after explicit teaching. Educational games do lead to improved learning [8].

Board games used for a number of educational purposes, as have been proven to help stimulate the minds of the students in a fun and informative way. Learning things like mathematics applications and higher mathematical computations can be difficult for the students, usually depending on their interest, motivation and the amount of attention they have received on the object. It has also been long proven that most students have a better time learning the skills when they are presented in a fun, interactive format, and giving educational math board games on which to make their stand.

Some researchers have evaluated the effectiveness of mathematical games and gave reasons for the use of games. Among them are the powerful motivation, involvement, and the development of positive attitudes in learning have long been recognized as being essential and necessary. Games are also valuable for encouraging social skill, for stimulating discussions, helping the development of understanding, for developing strategies for learning new concepts, reinforcing skills and concepts as an aid to symbolization and logic.

Considering the strategies, techniques, processes and methods used in teaching basic calculus which are sometimes laborious for the teachers and complicated for the students. For this reason, this research is made for science, technology, engineering and mathematics students, as well as the general reader to help them understand on the application of mathematical games in the field of calculus, specifically in differential and integral calculus. This research study will focus mainly on the application of mathematical games in improving the computational competence of the students in basic calculus. This study can also intensify learning on the part of the students taking up general physics subjects since basic calculus is a prerequisite of these subjects.

It may also serve as reference or guide to those students and teachers who will write or conduct studies related to this.

OBJECTIVES OF THE STUDY

Generally, this study aimed to integrate and verify the relevance of mathematical games in learning and acquiring knowledge and skills on the different topics of Basic Calculus.

Specifically, it intended to determine the computational skills of Science, Technology, Engineering and Mathematics students of the Schools Division of Calapan City, Philippines in Basic Calculus and compare the pre-tests and post-tests results of the control and experimental group. For the control group, the usual and suggested methods in teaching mathematics were used as intervention and for the experimental group, mathematical games/tools

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developed by the researcher were being implemented and utilized.

METHODS

This study used pre-test-post-test quasi experimental research design which utilized t-test and descriptive statistics in analyzing the data. For many true experimental designs, pretest-posttest designs are the preferred method to compare participant groups and measure the degree of change occurring as a result of treatments or interventions. Pretest-posttest designs are an expansion of the posttest only design with nonequivalent groups, one of the simplest methods of testing the effectiveness of an intervention [9].

Purposive sampling was used to determine the respondents of this study. The basic principle behind this sampling method is to determine a very specific group of students for reasons of feasibility or efficiency. This can help the researcher identify very specific eligibility criteria that are evident across the sample [10]. Science, Technology, Engineering and Mathematics students in Oriental Mindoro National High School and Holy Infant Academy for School Year 2017-2018 were considered, eighty four(84) students were considered as respondents of this study, each group had forty two(42) respondents.

The researcher personally administered a 40-item pre-test and post-test to secure information about the computational competence of senior high school in Basic Calculus. The devised questionnaire is a self-made test/questionnaire which was subjected to test of validity and reliability. It includes topics in differential and integral calculus. Before the tests was finalized, there were 60 items considered but trimmed down to 40 items after the test was subjected to content validation and test of reliability.

In content validation, the researcher asked the help of mathematics teachers of the Schools Division of Calapan City. All their comments and suggestions were considered. It was reviewed by the school principal of Oriental Mindoro National High School and approved by the Education Program Supervisor, in-charge of mathematics, of the division.

Reliability testing was done by administering the test to STEM students of the school who were not became part of this study. Cronbach Alpha were used to determine the reliability of the test. The alpha value of 0.71 means that the pre-test and post-test in Basic Calculus to determine the computational competence of the students was reliable.

For mathematical games, the board games Snakes and Ladderivatives and Damaths the Integrals, developed and innovated by the researcher were considered and used in this study. These instruments were tried and tested by the students and mathematics teachers and validated and approved by the mathematics supervisor.

These instruments were used in the experimental group in imparting the learning competencies within the duration of the experiment. Traditional and usual approaches, techniques, methods and strategies were used in teaching the lesson to the control group. DepED curriculum guide in Basic Calculus was the basis in considering content standards and learning competencies included in these study

After the administration of pre-test, the researcher tabulated and computed the mean scores of the test to determine if there were difference on the computational competence of the two groups of students, the mean scores of control and experimental groups were 15.22 and 15.95 respectively. These mean scores showed that the computational competence of the two groups of students were almost the same before the treatment were being applied. These scores served as a go signal for the researcher to pursue with the study.

The researcher presented and explained the innovative mathematical games to the teachers and students of Basic Calculus. Mechanics and guidelines were discussed for them to be guided on how to use and play the games using their knowledge in differential and integral calculus. Post-test was administered after two(2) weeks of utilization of the instructional materials.

After the retrieval of the questionnaires as the main instrument of the study, the researcher tabulated and processed the data manually. Through documentary analysis, results were analyzed and interpreted.

The data and information obtained from the pre-test and post-test was treated in the following manner:

1. To determine the mean score of pre-test and post-test of the control and experimental groups, the data was subjected to the computation of the mean and standard deviation.

2. The mean and standard deviation was used to give each score equal weight in determining the central tendency in terms of the scores in pre-test and post-test of the control and experimental groups. .

3. t-test was used to find if there are significant differences that might exist between variables.

The researcher observed fairness in choosing the respondents of this by using sampling techniques. The goals of this research were made clear before

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administering the questionnaires. This guaranteed that the data gathered were correct and accurate through validation. The researcher personally gathered the instruments and validate the results from teachers' records and the names of the respondents were kept confidential. Acknowledgement of the sources was considered through proper citation. Credits to the sources were seen in the reference list.

The researcher made it sure that research design and tools were appropriate to the data gathered as experts in the field of research and statistics were consulted.

RESULTS AND DISCUSSION

Shown in Table 1 is the mean of pre-test score of the students in the control group and experimental group. It shows the mean score of control and experimental groups of 15.22 and 15.95 respectively. There is a slight difference of 0.73 which might not possibly affect the results of the study.

The standard deviations' results of 2.24 and 3.10 are not that big which signify that both classes are less variable; it means that the students were of differing level of intelligence. This is indeed a good baseline since the results suggest that the two groups included in the study are almost the same that the scores are scattered.

In terms of the mean percentage score (MPS), control group has 31.25 percent while experimental group has 32.64 percent both interpreted as low mastery. These scores are good indicators to test the possible impact of the instruments/materials on the computational competence of the students.

Aloraini [11] claimed that the analysis result of the pre test showed no statistically-significant differences, which in turn proves the equivalence of the two groups.

Table 1. Mean of Pre-test Scores of the Control Group and Experimental Group

Test	Group	Mean	SD	MPS	Verbal Interpretation
Pre-test	Control	15.22	2.24	31.25	Low Mastery
	Experimental	15.95	3.10	32.64	Low Mastery

It could be gleaned in Table 2 that the mean score in post-test of the control group is 26.2 and the mean score of the experimental group is 31.25. There is a difference of 5.05 that indicates that the computational competence of the students under experimental group is higher than the control group after the intervention of the mathematical games, Snakes and Ladderivatives and Damaths the Integrals.

In terms of the mean percentage score (MPS), control group has 64.25 percent interpreted as average mastery while experimental group has 76.36 percent interpreted as moving towards mastery. These indicate increases and improvement on the computational competence of both groups in Basic Calculus after the application of different strategies to impart the different learning competencies of the subject. However, it was observed that there was a higher mean gain score in the experimental group than the control group. It implies that the mathematical game approach is superior or better than the traditional or conventional approach in improving the performance of the students in Basic Calculus.

The findings is supported by Chang's [12] study on mathematical games where the study was able to prove that mathematical games are effective based on the results that indicate that students in the game intervention group showed higher mathematics proficiency than those in the other group.

According to Drigas [13], the use of the game had positive effect on the enhancement of mastery learning and mathematics performance. The game is attractive to use, as it creates competition among the students to achieve a high score. The study's findings showed that the mathematical game promotes fast calculation and motivates the students for learning mathematics.

Table 2. Mean of Post-test Scores of the Control Group and Experimental Group

Test	Group	Mean	SD	MPS	Verbal Interpretation
Post-test	Control	26.2	4.12	64.25	Average Mastery
	Experimental	31.25	3.42	76.36	Moving Toward Mastery

Results show that the p-value or significant value of 0.6510 is greater than the 0.05 level of significance with a degree of freedom of 82. Hence, the null hypothesis is accepted

The results indicate that the difference between the mean pre-test scores of the control and experimental groups is not significant.

This result is good since the baseline data prior to the use of mathematical games suggest that the students have similar computational competence which will be very crucial for trying out the experiment in the teaching approach. The data suggest that the groups are very ideal for the group since they possess similarities prior to the experiment.

This can also be attributed to the homogeneity of the respondents in terms of their computational skills and the strategies employed by the teachers of Basic

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Calculus. Also, they have equal knowledge and conception with regards to the subject.[14]

Table 3. Significant Difference between the Mean Pre-test of the Control Group and Experimental Group

Test	Group	Mean	df	t-value	P-value	Decision
Pre-test	Control	15.22	82	-2.45	**0.6510**	**Accept Ho**
	Exp'l	15.95				

The table reveals that from the computed t-value of -10.15 and degrees of freedom of 41, the obtained p-value or significant value is 0.00 which is less than the 0.05 level of significance. Hence, the null hypothesis is rejected.

The results indicate that the difference between the mean pre-test and post-test scores of the control group is significant.

The results also reveal that the traditional and conventional methods and approaches in teaching Calculus enhance students learning. But the increase or gain on the mean score is not quite large to say that the students have mastery on the subject matters or topics included in the study.

Table 4. Significant Difference between the Mean Pre-test and Post-test of the Students in Control Group

Group	Test	Mean	df	t-value	P-value	Decision
Control Group	Pre-test	15.22	41	-10.15	**0.00**	**Reject Ho**
	Post-test	26.2				

Table 5 shows that the obtained p-value or significant value of 0.00 is obtained from the computed t-value of -14.17 and is less than the 0.05 level of significance with a degree of freedom of 41. Hence, the null hypothesis is rejected.

The result indicates that the difference between the mean pre-test and post-test scores of the experimental group is significant.

The result also shows that mathematical games dramatically enhanced mathematical competence of the students. And that making use of other methods or approaches could improve or enhance the performance of the students. And with practice through the use of mathematical games, achievement level can be increased, control group improve their efficiency by doing practice[15].

Katmada[16] stated that game-based learning activities are suitable and enjoyed by the students. Also Ke[17] pointed out that cooperative games is an effective strategy to promote students' learning in mathematics, both cognitively and affectively. Another implication is that mathematical games conditions, beyond the games themselves, yield significant effects on mathematical performance of the students.

Table 5. Significant Difference between the Mean Pre-test and Post-test of the Students in Experimental Group

Group	Test	Mean	df	t-value	P-value	Decision
Experimental Group	Pre-test	15.95	41	-14.17	**0.00**	**Reject Ho**
	Post-test	31.25				

From the data, it is very clear that the difference in scores in the post-test favor the students in the experimental group which were subjected to intervention using mathematical games.

The results indicate that the difference between the mean post-test scores of the control group and experimental group is significant. It means that the group of students who were treated with mathematical games performed better than those students where the traditional approaches in teaching Calculus were used. This result simply implied that mathematical games could increase the performance of the students. Hence, it is valid to say that mathematical games is effective based on the data obtained.

Ezeugwu [18] stated that students taught using mathematical games performed higher than those taught using the conventional and traditional method.

In comparison to traditional teaching, game-based or mathematical games improves learning of the students. These games can be considered as an active learning method, in which students participate actively in the teaching and learning process. Therefore, learning could be acquired through games designed by the teacher [19].

Table 6. Significant Difference between the Mean Post-test Score of the Students in Control and Experimental Group

Test	Group	Mean	df	t-value	P-value	Decision
Post-test	Control	26.2	82	-5.13	**0.000**	**Reject Ho**
	Experimental	31.25				

The results from this study indicated that those students who were taught Calculus concepts using mathematical games performed significantly better than those students taught applying the traditional or the conventional method. Putting it differently, the

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experimental group performed or produced higher mean achievement score than the control group in the post test.

The findings of this study agreed with the theories where this study is anchored such as Dewey's experiential learning who supported that mathematical games through quality and hands-on experiental learning that the learner should be able to connect aspects of the new experience to what he/she already knows. This is also connected to Gardner's Theory of Multiple intelligence where learning could take place when there is a good use of an approach or strategy and the tools that are most suitable for each of the students.

The findings of this study is not surprising since it is given that these games in mathematics encourage the learners the concepts patterns and systematic ideas. Through this, one can say that those students in the experimental group grasp or understand the concepts easily by applying game concepts in solving basic calculus problems.

Although the ultimate goal of this research is to show significant interaction between variables, that is showing the effectiveness and the role of mathematical games in improving the performance of the students in Basic Calculus. It can also be noted that any tool or strategy that can improve the performance of the students is effective and better in all dealings. But still appreciation to mathematical games should be given over the conventional way of teaching the subject.

CONCLUSION

The pre-test scores of the groups signifies that the students' computational competence in Basic Calculus is low.

The computational competence of the students in Basic Calculus who were under the experimental group increased from "low mastery" to "moving towards mastery" after the implementation and use of the mathematical games Snakes and Ladderivatives and Damaths the Integrals. There was also an increase in the computational competence of the students in control group from "low mastery" to "average mastery".

There is no significant difference between the mean pre-test score of students of the control group and experimental group. It means that the experimental and control group have almost the same computational competence in Basic Calculus before the intervention of mathematical games.

There is a significant difference between the mean pre-test and post test scores of the students in control group. This is because of the increase on the mean score of the group after using other strategies to enhance the performance of the students.

There is a significant improvement from pre-test to post-test scores of the students in the experimental group. It means that there is an increase or improvement on the computational competence of the students after the intervention to improve their performance in the subject. It also indicated that the instrument used for mathematical games are effective.

The post-test scores of the groups significantly differ resulting to higher scores for the experimental group. It means that the computational competence of experimental group is superior compared to the control group. This was the result of exposure of both groups to different strategies and intervention programs. It could be concluded that mathematical games is effective in improving the computational competence of STEM students in Basic Calculus.

This study being an experimental in nature, increases a number of opportunities for new researches related to this, in terms of teaching strategies in mathematics and content validation for the subject. The results of this study could be refined and further elaborate by future researches.

For many mathematics teachers, it is quite difficult to think and use different strategies in teaching mathematics subjects especially higher mathematics or senior high school mathematics. It is more often that they resort to traditional method in teaching the subject because they need to comply with the time constraints given on the curriculum guide.

The findings of this study suggest a positive connection between the learning environment and students' positive and active participation on the lesson through games that resulted to an improve performance in mathematic subject. These findings provide an avenue or basis for teachers to consider mathematical games in increasing students' participation and showing positive attitude towards mathematics. The results of this study also suggest that it is useful if mathematics teachers think of new strategies or device interactive games in order to improve performance in mathematics.

The results of this study cannot generalize to other population as this study dealt only a relatively small number of respondents. The number of samples could be the limiting factor of this study, as compared to a large number of possible population. It is therefore unclear whether the results would apply to other STEM students.

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RECOMMENDATION

Mathematics teachers can use mathematical games "Snakes and Ladderivatives" and "Damaths the Integrals" to improve the computational competence of the students in the subject. They develop interesting and challenging instructional materials for the students to gain mastery of the concepts and skills and modify approaches to make learning fun and enjoyable for students since students learn best when they find the activities engaging and useful.

Utilization of the intervention can be advised to other teachers experiencing parallel problem in this study.

Researchers may also use Snakes and Ladderivatives and Damaths the Integrals in other topics in Senior and Junior High School mathematics to generate more evidences on the effectiveness of the games in improving the performance of the students in mathematics subjects.

To further improve the extent of effectiveness of this study, it is recommended to test these mathematical games to other group of STEM students or to a large number of population. It is also suggested to examine whether the findings of the present study can be generalized to other schools or divisions.

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