

Students' Mathematical Creative Thinking Ability with Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure Model in New Normal

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Received May 27, 2021; Revised July 03, 2021; Accepted July 12, 2021

Abstract Students' creative thinking ability is essential to be developed in Mathematics because it can help students solve everyday life problems. This study aimed to determine the impact of the Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure model on developing students' creative thinking ability in mathematics in the new normal. The study was conducted at Diplahan National High School of the Division of Zamboanga Sibugay to Grade-11 students enrolled for the school year 2020-2021. The study employed a quasi-experimental pretest-posttest control group design. The experimental group was exposed to PEDE Productive Failure Model and the control group was exposed to the Conventional Method. Multiple solution tasks were used to measure students' level of creative thinking ability. A teacher-made test composed of 4-item open-ended questions with a rubric scale that measures mathematical creative thinking ability was the main instrument used in the study. The mean, standard deviation, and the analysis of covariance (ANCOVA) were used to analyze the data collected. The analysis revealed that students exposed to PEDE Productive Failure Model performed significantly better in terms of creative thinking ability posttest score. Researchers recommend that Mathematics teachers may use PEDE Productive Failure as a modular learning approach in the new normal to develop creative thinking ability in Mathematics. Teachers might also incorporate activities into their Mathematics modules that demand students to present various clearly defined solutions to foster students' creative potential.

Keywords: posing, exploring, doing, evaluating, productive failure, creative thinking ability in mathematics, new normal

Cite This Article: Pede I. Casing, and Dennis B. Roble, "Students' Mathematical Creative Thinking Ability with Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure Model in New Normal." *American Journal of Educational Research*, vol. 9, no. 7 (2021): 443-448. doi: 10.12691/education-9-7-8.

1. Introduction

Education in the new normal is a difficult undertaking in the Philippines, as the country struggles to push education forward in the face of a fatal pandemic caused by Coronavirus Diseases 2019 (COVID-19). The Department of Education (DepEd) and the Commission on Higher Education (CHED) adopted and implemented the flexible model of blended learning despite the resistance because of the risk to open classes due to the virus [1]. Education is a crucial factor in developing a human resource that is required for a country's development in all spheres. Education, in a wide sense, is any activity that has a substantial impact on an individual's ability to think creatively and fulfill his or her potential. Every human should acquire education which composed of various disciplines. Mathematics is one of the most established disciplines and is included in every curriculum worldwide [2].

While a student may be capable of thinking creatively, the ability remains a potential that must be fostered. In

mathematics, the ability to think creatively refers to the capacity to generate an original solution to a problem. Students' capacity to think creatively is critical for mathematics accomplishment because it enables students to address difficulties encountered in everyday life [3]. Some international achievement results such as Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) scores described the low ability of students' creative thinking in recent years. It is evident in the current results of the 2018 PISA. The Philippines scored 353 in Mathematics below the average of Organisation for Economic Cooperation and Development countries [4]. Grade 10 students' National Achievement Test (NAT) results from 2015 to 2018 were all below the Department of Education's (DepEd) 75 percent standard criterion for achievement level, which is the national target. These dismal outcomes might result in a lack of creativity, stifling of innovation, and a fear of failure. This paper uses the creative Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure model in the new normal.

The PEDE Productive Failure model is a guided discovery instructional design strategy that maximizes

modular learning by posing problems that are challenging enough to engage students' creative thinking abilities but not so difficult that they give up, exploring the central concept and procedures associated with problems where learners typically fail to generate the established solution, doing mathematical tasks and evaluating creative thinking ability. By failure, students will be unable to develop or uncover the proper solution(s) on their own. However, to the degree that students may use their existing knowledge to develop poor or even wrong answers to the problem, the process can be beneficial in preparing them to learn more effectively from the next lesson [5,6]. Productive Failure, in this way, combines the benefits of exploratory problem solving with the benefits of instruction, reducing the likelihood that students will not discover the correct concepts and processes on their own [7].

With these aforementioned views, this study aimed to investigate the influence of the Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure Model in the new normal on students' creative thinking ability in Mathematics.

The dependent variable of the study is students' mathematical creative thinking ability. It has three components, namely fluency, flexibility, and originality. Fluency refers to a student's ability to respond effectively and efficiently to several questions. Flexibility refers to students' ability to alter their thought patterns in response to a cognitive impediment. Finally, originality refers to a student's capacity to identify a solution path that is particularly distinct and rare among the group.

The study aimed to determine the significant impact of the Posing-Exposing-Doing-Evaluating (PEDE) Productive Failure model on developing students' creative thinking ability in mathematics in the new normal.

2. Literature Review

How might we define or characterize "creative thinking ability"? Numerous specialists from a variety of disciplines offer varying accounts of it. "Creative thinking ability" is a highly complex phenomenon that, to some, appears incompatible with mathematics education [8]. Creative minds are renowned for their capacity to notice details and distinctions that others miss. Thus, when generating and solving problems, the level of students' domain-general creative thinking has influenced their domain-specific creative thinking [9].

The capacity to think creatively is one of the keys to success in today's growing global economy and is also a crucial skill required for the twenty-first century. Additionally, creativity or the ability to think creatively is critical in mathematics because creativity is an inherent aspect of mathematics [10,11]. However, restricting classroom creativity limits mathematics to a set of skills to acquire and rules to memorize. As a result, many children's inherent curiosity and excitement for mathematics fade as they grow older, posing a significant challenge for mathematics instructors attempting to foster these qualities. To study the rise in student awareness of their creativity when solving arithmetic problems through the use of a task similar to PISA's Question, qualitative research emphasizing holistic description was done. They employed a formative evaluation approach to construct

mathematical challenges similar to those found in PISA that has the potential to foster students' mathematical creativity [12]. Nurulsari Novinta & Suyatna [13] conducted ten elementary school pupils in Palembang's sixth grade who participated in the research. They deemed the assignment they were given to be extremely difficult and piqued their interest. The outcome demonstrated that activities such as the PISA question can motivate pupils to be more innovative in mathematics.

The value of creative thinking ability has increased in recent years as a result of our fast-changing world and the need to adapt to on-going technical and scientific advancements. Mathematics requires a great deal of creativity. Mathematics is believed to be defined by its ability to think creatively [14]. In mathematics, creative thinking is defined as mental activity directed toward the formation of new mathematical relationships beyond those already known to students, and these new relationships reflect two types of verbal fluency and intellectual ability, namely flexibility, originality, and the ability to explain [15].

Moreover, creative thinking capacity can be regarded as a person's cognitive ability to solve difficulties through the generation of novel ideas. The issues underlying students' poor arithmetic accomplishment levels are mathematics presented as a finished product, ready for application, abstract, and mechanistically taught. This situation may contribute to the lack of creativity among less-developed students, as they are not permitted to think and use their ideas when solving mathematical problems [16].

A successful teacher fosters, supports, and assists students in developing their creative thinking, instructional methods, and democratic environment. These will enhance students' ability to think creatively, as previous research has demonstrated that a moderate school environment results in the availability of creative characteristics such as extroversion, enthusiasm, the instructor's emotional equilibrium, and the ability to enhance students' ability to think creatively. The importance of mathematics teachers in fostering creative thinking abilities linked with fluency, originality, flexibility, and explanations is limited to high school mathematics teachers [17,18].

Moreover, learning from failure has become a popular concept in education in recent years, owing in part to the fact that it makes intuitive sense to many individuals. In general, the concept of getting oneself up after a fall has existed in American society, as well as in many other regions of the world, for a long period. Teachers hope that by instilling this concept in their students, the little, everyday setbacks associated with acquiring new skills would become less emotionally charged for pupils, who will instead view them as a necessary part of the journey toward greater comprehension and ultimate success [19,20,21].

Productive Failure engages students in problem-solving activities that need previously unlearned concepts, followed by consolidation and teaching on the target idea. Failure simply refers to students' inability to produce or discover the correct solution(s) on their own. However, to the degree that students can develop poor or even wrong answers to the problem, the process can be beneficial in preparing them to learn more effectively from the ensuing instruction [5]. Furthermore, Productive Failure is an instructional strategy that requires learners to struggle while they attempt to solve issues before receiving direct

instruction on a particular idea, rather than later. Numerous studies suggest that productive failure helps students prepare for later acquisition of related knowledge [6]. This is related to the present study because the students are asked to work on the activities in their modules and would be given feedback using productive failure.

3. Methods

The study used a quasi-experimental design utilizing a pretest-posttest control group. The study was conducted in Diplahan National High School in Diplahan, Zamboanga Sibugay. The study involved Grade 11 General Academic Strand (GAS) and Humanities and Social Sciences (HUMSS) senior high school students who were officially enrolled in the MATH11 – Statistics and Probability subject for the third quarter of the school year 2020-2021. Due to a small number of populations, universal sampling was used. There were 50 Humanities and Social Sciences students and 50 General Academic Strand students. A total of 100 senior high school students participated in the study.

There were two groups of students that include one control group and one experimental group. The control group (CG) was taught using the conventional method which was exposed to modular learning with the use of Activity-Analysis-Abstraction-Application (4A's) model. The experimental group (EG) was exposed to Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure Model. This particular group was also encouraged to justify every step of their solutions or answers in any assessment or activities as what the teacher had been presenting the modular learning. Both the control group and the experimental group were given feedback; however, it is by the use of a productive failure model feedback in the experimental group. All of these two groups were taught using the modular learning created by the researcher to minimize the effect of the teacher factor as an intervening variable that may affect the results of the study. Likewise, the two sections were taught using modular learning delivery with the same reference books.

The researchers used the Mathematical Creative Thinking Ability Test, which consists of four open-ended

questions in the study that could have Multiple Solutions Tasks (MST). The MST was adopted from Roble [22]. Slight revisions were made to fit the current setting of the study. The four questions obtained a 0.77 reliability coefficient. The modules in Statistics and Probability were shown first to Master Teachers in mathematics and the Division Education Program Supervisor in Mathematics for content and face validity and obtained a Cronbach Alpha value of 0.84.

The researcher administered a pre-test of MST to determine the students' level of mathematical creativity upon entering the study. The students were pretested during the first week of modular classes. To avoid the Hawthorne effect, the students were not informed that they were participants of the study. Right after the pretest, experimental group was given the treatment. Students in experimental group were given modules patterned to Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure Model. This PEDE model was created by the researcher and followed by feedbacking which was the Productive Failure approach. The day after their pre-test, students in each experimental group were given the modules in their respective areas. Each student was asked to answer the modules on the whole third quarter (2 months). This group of students was asked to create solutions for the activities applying the concepts learned for that week's modules in Statistics and Probability. Each student was given module to show their work to the teacher. The students followed the procedure in receiving and submitting the answers of my modules following the safety protocols in the Barangay Office of their local areas. Monday was scheduled for answering the Posing activity. Tuesday was the schedule for feedback through Productive Failure. Wednesday was the schedule for the Exploring activity about the lessons. Thursday was the schedule for Doing and Friday for the Evaluating activity. At the end of the week, feedback through Productive Failure was given. For the controlled group, modular learning delivery was conducted through Activity-Analysis-Abstraction-Application (4A's) and was given feedback. To avoid bias on giving of scores to the works of the students, both the pre-test and post-test results of the students were forwarded and checked by a Mathematics teacher.

Table 1. Teacher and Students' Modular Activities in Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure Model

Teacher's Activities in the Modules to support PEDE Productive Failure	Students' Activities in the Modules during PEDE Productive Failure
Posing	
<ul style="list-style-type: none"> • The teacher poses problems or questions in the modules. • The teacher could ask questions that have no readily available answers and inform students that their answers will not be graded. 	<ul style="list-style-type: none"> • Students look for entry points into the task. • Students make intuitive guesses <i>Productive Failure or Feedback will be given through corrected modules.</i>
Exploring	
<ul style="list-style-type: none"> • The teacher provides opportunities for learners to engage in active exploration and interaction of the problem posed. The teacher presents the lessons using the simplified and interactive approach modules.	<ul style="list-style-type: none"> • Students have a sense of hope as they are struggling – they believe they can conquer the task through effort. • Students actively re-invent ideas, concepts, procedures, and relations in the sense of horizontal mathematization through interactive modules.
Doing	
<ul style="list-style-type: none"> • The teacher provides learners the modules with a thorough workout in the application of the basic principles of mathematics. 	<ul style="list-style-type: none"> • Students enjoy what they are doing in the modules. "Learning by doing" <i>Productive Failure or Feedback will be given through corrected modules.</i>
Evaluating	
<ul style="list-style-type: none"> • The teacher tests the creative thinking of the learners through hands-on problem-solving of the given modules. • The teacher evaluates learners' progress and mastery of the modular learning. 	<ul style="list-style-type: none"> • Students display creative thinking of the subject matter through hands-on problem-solving in the modules • Students improve their work and progress on their modular learning. <i>Productive Failure or Feedback will be given through corrected modules.</i>

To ascertain if there is a significant difference between the experimental and control groups in terms of mathematical creative thinking ability as influenced by teaching using PEDE Productive Failure Model or Conventional Method. The analysis of covariance (ANCOVA) was used to determine the effects of treatment because the samples were intact. The performance on students' creative thinking ability of both groups was described using the mean and standard deviation. In testing the hypotheses, alpha is set at a 0.05 level of significance. The most prevalent process in this study is the experimental method which is the PEDE Productive Failure Model in the new normal learning environment as shown in Table 1.

4. Results and Findings

The students' creative thinking ability scores in both groups in the modular learning delivery in the new normal were shown in the following table:

Table 2 shows the mean and standard deviation of the experimental and control groups of students' creative thinking ability which is the sum of their level of fluency, flexibility, and originality of solutions. Results revealed that before the start of the experiment both the experimental and control groups obtained scores which are described as at the fairly creative. This means that before the experiment, the mathematical creative thinking ability of the two groups of students has not been manifested and is functioning poorly, as evidenced by their pre-test scores. In the pre-test, the table displays a mean of 16.34 for the experimental group, while that of the control group, and shows a mean score of 13.70. The experimental group yields a slightly higher mean compared to that of the control group.

Table 2. Mean and Standard Deviation of Students' Mathematical Creative Thinking Ability

	Experimental Group N=50		Control Group N=50	
	Pretest	Posttest	Pretest	Posttest
Mean	16.34	39.14	13.70	36.80
SD	3.47	3.14	2.92	3.92

Legend: Mean intervals Description Perfect score is 48.
 37-48 Highly Creative
 25-36 Moderately Creative
 13-24 Fairly Creative
 1-12 Not Creative

This indicates that the experimental group shows a little bit of creative thinking ability than the control group. In terms of their creative thinking ability scores, the experimental group has shown more dispersed scores than that of the control group as manifested in the standard deviation results.

It can be observed further that after the treatment, the mean of the experimental group increases to 39.14 which is described as highly creative, while the control group reaches 36.80 which is describes as moderately creative. However, scores of the control group show to be more scattered compared to that of the experimental group as

shown in the result of their standard deviation. Additionally, the experimental group shows a higher increase in their post-test creative thinking ability scores as compared to that of the control group. This is evidence that the use of the method of Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure Model in the experimental group improved the students' creative thinking ability scores, pointing to the fact that they were given feedback about the mistakes they committed. The same is true for the control group who showed an increase in their creative thinking ability scores. Their exposure to the method Conventional Method, which is Activity-Analysis-Abstraction-Application (4A's) had helped the students improved their creative thinking ability scores. It goes to show that both methods used in this study helped the students to become more creative, especially if they continue to persevere in learning how to solve the mathematical problems despite the difficulties and also to focus on accuracy in carrying out the procedure. While it is true that some of the students were not able to come up with clearly defined solutions or provide a unique solution to a mathematical problem, this happened because they did not explore more on finding another solution to a problem that would help expedite the long and tedious process of the problem-solving. On the other hand, if they persisted or persevere, their level of creativity would have enhanced further.

Table 2 further shows the pre-test results of both groups on the variability of the mathematical creative thinking ability of both groups where the experimental group has obtained 3.47 and the control group, 2.92. This little difference indicates that the experimental group scores were more scattered compared to that of the control group. Moreover, the standard deviation of the scores of the experimental group in the post-test is 3.14 while that of the control group is 3.92. It means that the scores of students' mathematical creative thinking ability of the experimental group after the treatment became the closer to each other compared to that of the control group. Results reveal further that both groups developed their mathematical creative thinking ability by trying to come up with clearly defined solutions and originality of solutions, although most of the participants had a hard time when it comes to showing the novelty of solutions. However, as shown in the table, the experimental group performs better in terms of mathematical creative thinking ability. Findings are consistent with the report of Maulidia, et.al [16] that creative thinking capacity can be regarded as a person's cognitive ability to solve difficulties through the generation of novel ideas. The issues underlying students' poor arithmetic accomplishment levels are mathematics presented as a finished product, ready for application, abstract, and mechanistically taught. This situation may contribute to the lack of creativity among less-developed students, as they are not permitted to think and use their ideas when solving mathematical problems. It can be concluded that exposure to PEDE Productive Failure Model might have helped them to enhance students' creativity. Together with this is the observation that some got high scores and there were those whose scores remained relatively low.

Table 3. One-way ANCOVA Summary for students' Creative Thinking Ability Scores

Source	Adj. SS	DF	Mean Square	F-value	P-value
Treatment Within	147.632	1	147.632	11.683	0.001*
Error	1225.710	97	12.636		
Total	1374.910	99			

*significant at $p < 0.05$ alpha level.

Table 3 shows the analysis of covariance of pre-test and post-test scores of students' level of creativity in Mathematics. The analysis yields a computed probability value of 0.001 which is less than 0.05 level of significance. This led to the non-acceptance of the null hypothesis. This means that there is a significant difference in the students' creativity levels between the experimental and control groups.

With regards to students' creative thinking ability in mathematics, the study showed that creative thinking ability in mathematics is significantly higher when exposed to Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure Model than those who were exposed to Activity-Analysis-Abstraction-Application (4A's). This implies that the significant difference in their scores could be due to the students' exposure to the mathematics problems with feedbacking from which the students under treatment were actively engaged in different productive failure mathematics activities. This situation happened probably because the students were involved in activities that develop critical thinking that facilitates learning of important mathematical concepts and processes. The process allowed them to commit mistakes during the modular lesson and to check their failure after every solution they made. Moreover, based on the result of the analysis shown in the table, the experimental group performed better than the control group in terms of mathematical creative thinking ability because the students were able to solve problems and become productive with the failure they encountered. This further implies that solving mathematics problems with an emphasis on the modular learning of the same concept and having them feedback using the Productive Failure Model helped students' comprehension of procedural processes. This is also supported by Kapur [5] that Productive Failure engages students in problem-solving activities that need previously unlearned concepts, followed by consolidation and teaching on the target idea. Failure simply refers to students' inability to produce or discover the correct solutions on their own. However, to the degree that students can develop poor or even wrong answers to the problem, the process can be beneficial in preparing them to learn more effectively from the ensuing instruction. Thus, Productive Failure developed a more positive attitude towards Mathematics, allowed students to construct ideas in Mathematics that promote thinking, and illustrated an awareness of mathematical connections.

Furthermore, this implies that the method used in the experimental group helped a lot after treatment as evidenced in the correct solution to a given mathematics problem. This indicates also that both groups had a hard time providing novelty of solutions. But it is still evident that the experimental group performed better compared to the control group despite their little increased scores. This

implies further that the PEDE model was effective compared to the usual modules given to the students. The PEDE Productive Failure model maximized modular learning and feedback in the new normal and had helped the students in one way or another to solve the mathematical problems. The findings confirm the claims of Ombay and Roble [23] that creative thinking ability in problem-solving has a positive effect on the learners, and promotes student achievement and conceptual understanding. This is also supported by Ardiansyah, et al. [17] that a successful teacher fosters, supports, and assists students in developing their creative thinking, instructional methods, and democratic environment. These will enhance students' ability to think creatively, as previous research has demonstrated that a moderate school environment results in the availability of creative characteristics such as extroversion, enthusiasm, the instructor's emotional equilibrium, and the ability to enhance students' ability to think creatively.

5. Concluding Statements

Based on the analysis and findings of the study the researchers conclude that the Posing-Exploring-Doing-Evaluating (PEDE) Productive Failure is an effective method in the modular learning delivery in the new normal to improve students' creative thinking ability in mathematics. Hence, the researchers recommend that teachers may use PEDE Productive Failure Model as an approach in the new normal for mathematics modular learning to improve mathematical creative thinking ability. Moreover, teachers and researchers may use this method as a basis for future studies for more insights on instruction that use PEDE Productive Failure Model. Finally, further research may be conducted to the wider scope using different populations in different institutions for better generalizability of the method.

Acknowledgments

The researchers would like to express their sincere gratitude to Diplahan National High School, especially to the school principal, Mr. Salvador D. Arquilita for allowing the researchers to conduct the study in the said school. The Department of Education (DepEd) headed by the Schools Division Superintendent Dr. Jeanelyn A. Aleman in the division of Zamboanga Sibugay for approving this research study. The authors also wish to express their gratitude and appreciation to Dr. Laila S. Lomibao, the Dean of the College of Science and Technology Education of USTP, and Dr. Rosie G. Tan, the chair of the Department of Mathematics Education, for

their tireless support, professional guidance, countless supervision, encouraging comments and patience in reviewing the research works with special care and attention. Finally, the researchers would like to thank the Department of Science and Technology (DOST) for their professional and financial support to the main author.

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