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Assess-Practice-Present-Reflect (APPR) Model in Flexible Learning on Students' Mathematical Creativity

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Abstract Every Mathematics educator has undertaken the challenge of developing students' mathematical creativity. However, this has been a more difficult task in flexible learning amidst the transition to the new normal. Hence, this study aimed to determine the efficacy of an Assess-Practice-Present-Reflect (APPR) e-module in flexible learning on students' mathematical creativity in tertiary education. The study used a quasi-experimental pretest-posttest non-equivalent control group design. The experimental group is exposed to APPR e-module while the control group is exposed to the conventional method. Multiple solution problems were used to assess students' mathematical creativity. Mean, standard deviation, and MANCOVA were used to analyze the data. According to the findings, there was a similar effect in the mathematical creativity between students exposed to the APPR e-module in flexible learning and students exposed to the conventional method. Furthermore, mathematical fluency and elaboration show good gains in the indicators of mathematical creativity using the APPR e-module, but flexibility and originality require further development in the approaches.

Keywords: *fluency, flexibility, originality, elaboration, mathematical creativity, flexible learning, and APPR e-module*

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1. Introduction

Development of students' mathematical creativity has been the subject of research in Mathematics education. Essentially, the rationale behind these endeavors is grounded on the principle that teaching Mathematics without providing for creativity denies all students the opportunity to fully develop their potential [1]. However, developing creativity in Mathematics amongst students has been noted as a challenging endeavor. This entails more than just learning the fundamentals [2].

Yet, a worst-case scenario happens to all students and Mathematics educators locally and globally aiming to develop mathematical creativity. Due to COVID-19 pandemic, a sudden shift in the education paradigm is embraced to ensure learning amidst ongoing health issues through online learning. To ensure the continuum of education in the country, schools embrace flexible learning modality approaches. Flexible learning is a pedagogical approach that promotes self-paced learning among learners at their convenient time, place, and audience but is not solely focused on the use of technology [3]. This learning modality can be reinforced with self-learning modules (SLM) addressing the learner's unique needs in terms of place, pace, process, and learning. However, teaching practices during the transition from face-to-face to flexible learning modality mostly focus on knowledge transfer such as practice, memorization, and demonstration of procedures which leads to students imitating the way their teachers solve problems [4]. These practices restrict the students' ability to comprehend mathematical concepts, thus limiting their ability to develop mathematical creativity [5,6] and problem solving skills [7]. Although flexible learning is advantageous in the development of mathematical skills since it encourages self-paced learning [8,9], it is not without its drawbacks. There is a need for Mathematics educators who have not yet been engaged in remote learning to acclimate to this learning modality transition, particularly with the use of technology to foster innovative practices in the teaching-learning process [10]. Moreover, students are also not prepared to embrace such innovations as they still have low confidence in accessing online materials [8].

Thus, these scenarios have prompted the researchers to innovate the flexible learning modality by integrating interactive e-module which can be accessed offline as interactive learning brought positive results in students' academic achievements [11]. In fact, a study showed that integrating the e-content module improved students' achievement in Mathematics more than the conventional method of teaching [12] but its efficacy in flexible learning modality while developing students' mathematical creativity has yet to be established. Thus, the researchers initiated the development of an e-module following the Assess-Practice-Present-Reflect (APPR) model embedded in flexible learning. Hence, an interactive e-module is designed based on the APPR model following the framework of productive failure [13,14]. Failure or struggle in learning mathematics is an integral component of students' cognitive development that induced deep learning of mathematical concepts with understanding [15,16]. To do this, the interactive APPR e-module begins with assessment, followed by practice, presentation, and reflection to foster students' creativity in Mathematics.

Hence, this study is primarily aimed at determining the effect of APPR-infused e-module methods in flexible learning modalities on the students' mathematical creativity.

2. Methodology

The study used a quasi-experimental design utilizing a pretest-posttest control group to determine the effects of APPR e-modules in flexible learning on students' mathematical creativity. It utilized two intact randomly assigned control group and experimental group sections of Mathematics in the Modern World course for first-year students of the College of Education and College of Business Administration and Accountancy of St. Michael's College, Iligan City during the first semester of the academic year 2021 – 2022.

The researcher employed the Mathematical Creativity Test (MCT). It consists of six open-ended questions with multiple possible solutions for every item. MCT was originally developed by Kattou, Christou, & Pitta-Pantazi [17] and translated by Kroesbergen, & Schoevers [18]. Solutions of the students obtained from MCT were analyzed to determine the four components of mathematical creativity. These are fluency, flexibility, originality, and elaboration.

To determine the score for fluency, the number of correct solutions was counted and divided by the maximum number of correct solutions provided by one student in the group multiplied by 100% for each item.

To determine the flexibility score of the student, the number of different types or categories of correct solutions were counted in every question and divided by the maximum number of different types of the solution provided by one of the participants. This ratio is then multiplied by 100% for each item.

For originality, it was calculated by comparing the solution of each student with the solutions of all of the participants. The frequency of the categories of the participants' solutions was counted, and the least (*rare solution*) is divided by the total number of participants multiplied by 100%. The score 80, 60, 40, and 20 were given if the percentage belonged to 1% and 5%, 6% and 10%, 11% and 20%, and more than 10%, respectively.

For uniformity, all scores in fluency, flexibility, and originality will be transformed to a 5-point Likert scale. The table below shows the equivalent transformation of scores adopted from Asahid and Lomibao [19].

Table 1. Equivalent Transformation of Score to 5-Point Likert Scale

Range (%)	Scale	Scoring Scale	Descriptive Equivalent
81 – 100	5	4.20 – 5.00	*Excellent*
61 – 80	4	3.40 – 4.19	*Proficient*
41 – 60	3	2.60 – 3.39	*Approaching Proficiency*
21 – 40	2	1.80 – 2.59	*Developing*
1 - 20	1	1.00 – 1.79	*Beginning*

Elaboration scores ranged from 1 - to 5, a student was given the highest score if he can produce a detailed plan and generalized ideas or give in-depth reasoning behind a solution path.

Then, the mean score was calculated for each factor (fluency, flexibility, originality, and elaboration). The combination of the four factors represents the creativity level of the students. Table 2 below shows the mean intervals with equivalent descriptions.

Table 2. Mean Intervals for Sum of Scores in Mathematical Creativity

Mean Intervals	Description
16.20 – 20.00	*Emergent Creativity*
12.40 – 16.19	*Innovatively Creative*
8.60 – 12.39	*Inventive Creativity*
4.80 – 8.59	*Technically Creative*
1.00 – 4.79	*Expressive Creativity*

In the experimental group, participants were exposed to flexible learning utilizing the designed APPR e-module. The APPR e-module was designed through an interactive platform using Kotobee. The first part of the module is the assessment. It is composed of open-ended problem-solving questions, which may involve either many solutions or many answers. The next part is practice, the students were given time to answer the activities in the module, but they were not encouraged to answer all the activities. Only those items that they fail to show mastery during the assessment part. Mastered items were not given more emphasis in the practice part. The next part is the presentation of the concept. Finally, in the reflection part, the students reflected on what do they learned and evaluated their performance for the week.

The participants took a pre-test for mathematical creativity a week before the study began. Since the school implemented blended flexible learning, the classes were conducted in Google Meet every Mondays, Wednesdays and Fridays. The APPR e-module was disseminated gradually according to the phasing of the students. Moreover, they were given assessments every Mondays via the Google Form platform. This assessment was monitored synchronously. Based on the results of the assessment, the students were given the appropriate next part of the module. Only those who mastered questions corresponding to a topic were given the presentation part. Others were given the first practice activity. They were given the presentation part only after they mastered their practice activity. Tuesday to Thursday were set for their practice, study the presentation of the concept of the lesson, and explore the activities given in the module. Wednesdays were scheduled to accommodate students who have questions and clarifications synchronously via Google Meet conferencing. Especially those who were not able to answer a particular item in the assessment part. Every Friday was set for reflection on their learning for the week. Again, the reflection was monitored via Google Meet. This was done in a weekly cycle.

On the other hand, in the control group participants were exposed to flexible learning utilizing the designed conventional e-module. This e-module was crafted in line with the institution's pedagogical framework. A week prior to the conduct of the study, the participants answered the pre-test for mathematical creativity. During the implementation of the treatment, the researcher designed and implement asynchronous supplemental activities and assessments that were integrated into the e-module. Students attended the online class every Mondays, Wednesdays, and Fridays while utilizing the e-modules for the rest of the days.

The contents in the APPR and conventional e-modules were the same with parallel practice problems and formative assessment. The only difference is the arrangement of the e-module sections according to assessment, practice, present, and reflect. The dissemination of these sections varied accordingly in both control and experimental groups. After the conduct of the study, the participants answered the same set of questionnaires, the MCT as their post-test. The duration of the study was the entire period of coverage of the prelim and midterm examinations.

3. Results and Discussion

Presented in Table 3 is the analysis of the mean scores and standard deviation of the students' mathematical fluency, flexibility, originality, and elaboration as indicators of their mathematical creativity.

Results revealed that before the start of the experiment, the experimental group obtained a little higher pre-test mean scores in fluency, flexibility, and elaboration than the control group. However, in originality, both the experimental and control groups had nearly similar originality mean scores. They also showed similar variations in scores, as evidenced by their standard deviations. This means that before the implementation of the treatments, both groups exhibited a comparable beginning level of mathematical fluency, originality, and elaboration, but at an early stage of developing level for flexibility as exhibited in their problem-solving solutions. This implies that students in both groups lack a grasp of conceiving alternative solutions, and lack of initiative to provide in-depth reasoning or details of a given solution. Hence, they were unable to provide unique solutions [20]. However, they can present diverse solutions in problem solving but not at an exceptional level of producing varied solutions in different categories.

After the treatment, both groups showed a relative improvement in mathematical fluency, flexibility, and elaboration. However, students in the experimental group had relatively higher scores in mathematical fluency, flexibility, and elaboration than students in the control group. This indicates that students exposed to the APPR model e-module in flexible learning relatively improved their mathematical fluency at approaching proficiency level, while mathematical flexibility and elaboration at the developing level. Noteworthily, after the treatments, only the students in the control group showed improvement in mathematical originality compared to the experimental group although these mean scores are at the same beginning level of originality before the treatments.

To determine if the difference in flexibility, fluency, originality, and elaboration between the experimental and control group, a multivariate analysis of covariance (MANCOVA) was performed on four dependent variables: fluency, flexibility, originality, and elaboration as indicators of mathematical creativity of students, after controlling for pretest scores. The independent variable is the treatment group (experimental and control groups). Results of evaluation assumptions of normality, homogeneity of variance-covariance matrices (The Box's M of 19.04 indicates that the homogeneity of covariance matrices across groups is assumed $F(10, 17039.66) = 1.77$, $p = .06$), linearity, and multicollinearity were satisfactory.

With the use of Wilks' criterion, the combined dependent variables were significantly different between the treatment group, Wilk's $\lambda = .63$, $F(4, 53) = 7.81$, $p < .01$, partial $\eta^2 = .37$, after controlling for their levels of fluency, flexibility, originality, and elaboration before treatment. This means that there was a significant effect of the treatment on the participants' post-tests scores in the mathematical creativity indicators. This showed a large effect on the participants who were exposed to different treatments. To investigate the impact of each effect on the individual dependent variables, a univariate F-test using Bonferroni correction [21] alpha level criterion of .0125 was performed. This criterion was based on the fact that there are four (4) dependent variables, hence, the level of significance at 0.05 is divided by four. That is. .05/4 = .0125. The effect of the treatment on dependent variables is based on the adjustment of the covariates.

Table 3. Unadjusted and Covariate Adjusted Descriptive Statistics for Students' Fluency, Flexibility, Originality and Elaboration as an Indicators of Mathematical Creativity

Dependent Variables	Group	Pretest		Posttest (unadjusted)		Posttest (adjusted)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Fluency	Control	1.61	0.40	2.16	0.48	2.23	0.39
	Experimental	1.78	0.53	2.69	0.68	2.62	0.39
Flexibility	Control	1.89	0.47	2.17	0.54	2.25	0.42
	Experimental	2.18	0.49	2.51	0.66	2.44	0.41
Originality	Control	1.24	0.24	1.32	0.22	1.32	0.13
	Experimental	1.24	0.23	1.17	0.17	1.17	0.13
Elaboration	Control	1.50	0.52	1.82	0.55	1.89	0.47
	Experimental	1.78	0.59	2.28	0.66	2.22	0.47

After adjusting for the difference on fluency pre-test, the results of the analysis yielded a significant main effect of the treatment on the participants' post-test mean score in fluency, $F(1{,}56) = 14.48$, $p < .05$, $\eta_p{}^2 = .21$, showing a large effect size. This means that the treatment implemented in the experimental group was more successful than the treatment implemented in the control group. Hence, it follows that using an interactive APPR e-module in flexible learning significantly developed the students' mathematical fluency than the conventional e-module.

This finding affirmed the hypothesized claim that students in the experimental group gradually acquired mathematical skills that prompted them to devise different ways of solving the problem [22]. It can be noted that these students were exposed to assessment first before the proper presentation of the lesson is given. Other than that, they failed in the assessment, they were exposed to different practice problems until they mastered the target learning outcomes. This scenario simulated the Humanistic Theory of Rogers [23] which highlighted the experiential learning of the students which actuated students' self-initiated learning is the most lasting and pervasive. Since they were assessed first and putting emphasis that it is not their score during this period that is significant, but rather their involvement with the challenges they encounter and how they can connect what they currently know to the new lesson.

Moreover, after adjusting the pre-test score of flexibility, univariate analysis showed that the main effect of the treatment on the participants' post-test mean score in flexibility was not significant, $F(1{,}56) = 2.76$, $p > .05$, $\eta_p{}^2 = .05$, which indicates a small effect size. This means that the effect of each treatment is comparable in both control and experimental groups. This implies that either integrating interactive APPR or the conventional e-modules has a similar effect on the students' flexibility in solving problems in Mathematics. Although net gain (*post-test – pre-test*) of the mean scores of flexibility in the experimental group of students was slightly higher than the control group but not statistically supported. Hence, it can be inferred that there is no inferiority nor superiority between both treatments in developing the mathematical flexibility of the students.

On the other hand, after adjusting for the difference on originality pre-test mean score, analysis revealed a significant main effect of the treatment on the participants' post-test mean score in originality, $F(1{,}56) = 20.06$, $p < .05$, $\eta_p{}^2 = .26$, showing a large effect size. This implies that the treatment implemented in the control group was more effective than the treatment implemented in the experimental group. This confirmed the posited claim as highlighted in the findings depicted in Table 3 that students who were exposed to interactive APPR e-module in flexible learning manifested improvement in producing many solutions as possible with more varied categories of solutions but failed to improve the novelty of their solutions [24]. This finding is not surprising attribution of the effect of the treatment using the conventional e-module. It can be recalled that this e-module was designed following the institution's pedagogical framework anchored on constructivism. The students were exposed to a developmental stage of cognitive learning through scaffolding as they progress in different learning content as designed in the e-module. In this process, they gradually develop their cognition and can see different patterns in solving problems in MCT. Students need guidance through scaffolding to connect their existing concepts to the given problem and how to solve it. The scaffolding method strengthened students' ability to explore other means of solving complex problems which led them to discover rare solutions [25].

In the same manner, the observed mean score difference of elaboration between control and experimental groups was further analyzed upon adjusting the covariates that control their prior knowledge. Analysis yielded a significant main effect of the treatment on the participants' post-test mean score in elaboration, $F(1{,}56) = 7.06$, $p < .05$, $\eta_p{}^2 = .11$, showing a medium effect size. This means that the treatment implemented in the experimental group was more effective than the treatment implemented in the control group. Thus, it can be deduced that using an interactive APPR e-module in flexible learning significantly improved the students' mathematical elaboration than the conventional e-module. Again, the findings confirmed the hypothesized claim as insights based on the findings reflected in Table 3.

The treatment implemented in the experimental group follows the concept of productive struggle learning which simulates the conditions for students to persist in generating and exploring representations and solution methods for solving complex or novel problems [26]. Hence, students exposed to flexible learning with interactive APPR e-module persisted to solve the problems correctly so that they can proceed to the presentation of the lesson. Thus, nurtured the ability to solve problems with a detailed plan and able to give in-depth reasoning behind a solution path.

Table 4. Unadjusted and Covariate Adjusted Descriptive Statistics for Mathematical Creativity

Group	Pretest		Posttest (Unadjusted)		Posttest (Adjusted)	
	M	SD	M	SD	M	SD
Control	1.51	1.57	1.62	1.95	8.34	1.14
Experi-mental	6.24	7.47	6.99	8.66	7.81	1.14

Table 4 reveals the level of mathematical creativity of students which is based on the combination of the student's transmuted scores of fluency, flexibility, originality, and elaboration. It can be observed from the table that before the start of the experiment both the experimental ($M = 6.99$, $SD = 1.62$) and control ($M = 6.24$, $SD = 1.51$) groups obtained scores that are described as technically creative. This means that before the experiment, students' mathematical creativity in both groups was technically limited but not too expressive spontaneity [19]. This suggests that their capacity to identify gaps, obtain various solutions, and produce novel ideas in solving problems is limited [27].

After the treatments, students exposed to interactive APPR e-module in flexible learning exhibited higher mathematical creativity scores ($M = 8.66$, $SD = 1.95$) with a corresponding level of inventive creativity as compared to the students exposed to conventional APPR e-module ($M = 7.47$, $SD = 1.57$) whose creativity remains at the technically creative level. This development of students' mathematical creativity has brought an emphasis on their ability to combine limited technical concepts of solving problems to inventively make more varied solutions which they had not done before [19].

Table 5. One-Way ANCOVA Summary of Students' Mathematical Creativity

Source	df	SS	MS	F(1,59)	p-value	η^2
Treatment Between Groups	1	4.12	4.12	3.24	.08	.05
Error	59	74.92	1.27			
Total	62	4258.7				

Upon checking the necessary assumptions needed for Analysis of Covariance (ANCOVA), data exploratory analysis showed that the data fits the aforementioned statistical analysis to determine whether the observed mean score difference on the sum of scores in mathematical creativity was influenced due to the treatments implemented. ANCOVA yielded results showing that the main effect of the treatment on the participants' post-test mean score in mathematical creativity was not significant, $F(1,59) = 0.08$, $p > .05$, $\eta_p{}^2 = .05$, which indicates a small effect size. This means that the effect of each treatment is comparable in both control and experimental groups. This implies that either integrating interactive APPR or the conventional e-modules has a similar effect on the students' mathematical creativity. This seemingly same effect on the mathematical creativity of the students is attributed to the fact that the conventional e-module also brought a significant effect. In fact, the originality component of mathematical creativity was significantly influenced by using the conventional e-module in flexible learning anchored on constructivism. However, results showed that the post-test mean score of the students in the experimental group is higher than the post-test mean score of the students in the control group. This suggests that the level of mathematical creativity of the students in the experimental group is relatively higher than the control group after the treatment as exhibited in their respective levels. Hence, in overall, integrating an interactive APPR e-module brought a positive impact on the students' mathematical creativity.

4. Conclusion and Recommendation

Based on the empirical investigation and in-depth analysis of the data gathered, findings highlighted the fact that mathematical creativity of the students can be developed in flexible learning. Integrating interactive APPR e-module in flexible learning is more effective in developing students' mathematical creativity most particularly in fluency and elaboration components. Both interactive APPR and conventional e-module anchored on constructivism are with comparable effects on flexibility and mathematical creativity as the conventional e-module is more effective in developing originality of solutions. Students should still be encouraged to try different ways of solving more complex problems and come up with novel solutions.

Future studies could concentrate on improving students' mathematical flexibility and originality. This research can be utilized to generate additional ways and strategies to solve the problems identified by the findings.

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