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Comparing the Effect of Explicit Mathematics Instruction with Rigorous Mathematical Thinking Approach and 5E's Instructional Model on Students' Mathematics Achievement

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Abstract This study investigated the effect of explicit mathematics instruction with rigorous mathematical thinking (EMI-RMT) approach and 5E's instructional model in mathematics achievement. It utilized the quasi-experimental pretest-posttest non-equivalent control group research design to gather the data. The researchers made use of the teacher-made test with a Cronbach alpha reliability coefficient of .74. Two intact classes of freshmen education students enrolled in the school year 2018-2019 at the University of Science and Technology of Southern Philippines, Cagayan de Oro City participated in this study. One section was taught using EMI-RMT approach in discussing the concept of the plane and spherical trigonometry while the other group was taught using the 5E's instructional model. The analysis of covariance (ANCOVA) with posttest as the dependent variable and pretest as the covariate, yielded $F(1,60)=.068$, $p=.796$, which is not significant at .05 level. This implies that the achievement of students taught with EMI-RMT is comparable with the achievement of students taught with 5E's instructional model. Since many studies showed that 5E's instructional model is effective, the researchers recommend that mathematics teachers may also employ the EMI-RMT approach in their classes to improve their students' achievement in mathematics.

Keywords: *explicit mathematics instruction, rigorous mathematical thinking, mathematics achievement, problem solving, 5e learning model*

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1. Introduction

Explicit mathematics instruction is widely recognized for many years due to its sequential organization of the lesson through a step-by-step process. Explicit mathematics instruction utilized a series of questions which scaffolds students' learning process with clear statements about the purpose for learning the new skill. It displays clear explanations, demonstrations of the instructional target, and supported practice with feedback until independent mastery has been achieved [1]. It contains elements particularly suited to support crucial working-memory processing needed for learning [2]. It is ideal for students who need a deep and lasting understanding of the lesson [3]. However, EMI approach focuses only on increasing students' procedural knowledge. Thus, it may not promote conceptual understanding and critical analysis.

Another teaching method that has been growing of interest for the past years is the rigorous mathematical thinking (RMT). This method composed of series of thought provoking questions and mathematical discourse. Discourse has been considered of considerable importance in teaching and learning as a means to elicit thinking processes in general and mathematical thinking in particular [4]. In developing students' mathematical thinking, communicating through questions encourage students to explain how they obtained their answer by describing their thinking process, create new solution, modify existing solution and present varied solutions [5]. However, as observed by the teacher-researchers, too much emphasis on student to student discourse the non-mathematically inclined students become confused and frustrated. In order to maximize the learning of the students, the researchers combined the explicit mathematics instruction (EMI) and the rigorous mathematical thinking (RMT) approach as one instructional model, which is the Explicit Mathematics Instruction with Rigorous Mathematical Thinking (EMI-RMT) to improve their performance and communication of mathematical concepts both oral and written.

In the EMI-RMT approach, the teacher discussed the step-by-step procedure of at least three examples. In the first example, the teacher throws questions to let students provide background concept of the lesson. For the second example, the teacher throws questions to lead the students to the process of the solution. The third example, only the students were required to solve the problem completely. In every example the students were guided by the teacher with the corresponding questions for every step. After the third example, the students were given more problems on real-life situation. The process was repeated until all topics were discussed.

Moreover, many studies proved that 5E's instructional model have improved students' achievement and interest [6]. This instructional model was designed by Rodger Bybee [7]. It has five phases such as engage, explore, explain, elaborate, and evaluate. In the first phase, engage, the students were given an activity to ignite their interest. In the second phase, explore, the students were given a group activity that allowed them to discover new ideas. In the third phase, the explanation, the teacher discussed the lesson. In the fourth phase, elaborate, each group was given a problem-solving task. Finally, in the last phase, evaluate, the students were given a quiz about the lesson learned. Under this approach, the students are given opportunities to implement their own thoughts [8] because the learning tasks were self-directed [9]. Hence, it supports deep conceptual learning [10]. Due to these findings, the Department of Education (DepEd) is optimistic about this approach [11]. Nevertheless, the 5E's instructional model was popular only to science educators. Most of the studies conducted about 5E's model were done in science classes.

With this end, the researchers employ 5E's instructional model to provide an empirical evidence on its effect on mathematics achievement. Specifically, this study compared the effectiveness of 5E's instructional model and EMI-RMT.

2. Method

2.1. Research Design

This study used a quasi-experimental pretest-posttest non-equivalent control group research design. It is a quantitative method which was used to examine the students' mathematics achievement on plane and spherical trigonometry. The design of this study is illustrated as shown:

$$\begin{array}{ccc} O_1 & X_1 & O_2 \\ \hdashline O_1 & X_2 & O_2 \end{array}$$

The two groups were separated by the horizontal broken line, broken line because the two group are non-equivalent. O_1 represents the pretest which was given to both groups at the start of the experiment. The X_1 and X_2 represent the treatment or the instructional approach. X_1 is the EMI-RMT approach while X_2 is the 5E's instructional model. These treatments were employed immediately after the pretest until the lessons under study were covered. Then, the posttest was administered to both groups, which is represented by O_2.

2.2. Participants

The study was conducted at University of Science and Technology of Southern Philippines, one of the known state universities in the Philippines, located in the northern part of Mindanao, Philippines. The participants were the two intact classes of first year college education students enrolled in school year 2018-2019. The two classes were randomly assigned with the type of instructional approach.

The academic abilities of the participants in each group was assumed to be heterogeneous as it is a policy of the school to have each class a heterogeneous group of students. Some of them were graduates from private secondary school while others were from public secondary school. Some of them are honors while others are not. On the other hand, the participants were assumed to bear similar characteristics in regional or ethnic groups as they are all Filipinos by birth.

The group taught with EMI-RMT was composed of 29 participants, 13 males and 16 females while the control group was composed of 34 participants, 14 males and 20 females. These groups were handled by the researcher.

2.3. Research Instrument

The 25-item researcher-made, mathematics achievement test was used to collect data to determine the effects of the model. This instrument was subjected to content validity and reliability. It is composed of a 20-item two-tiered multiple choice test and a 5-item problem solving.

At first, the researchers made a 40-item, 30-item two-tiered multiple choice test and 10-item problem solving, mathematics test on plane and spherical trigonometry based on the table of specification (TOS). A panel of experts examined each item of this test for face and content validity. The experts made some corrections and suggestions. After which, the researchers modified the instrument and administered the revised test to the graduating college students of this same school. An item analysis was done and reliability coefficient was determined using Cronbach Alpha=0.74.

Since the test is open-ended, two mathematics teachers with master's degree in mathematics were requested to rate the students' responses. Inter-rater results were computed and have a reliability coefficient r = 0.701. The average score of the researcher and the two raters were the final score of the students. Students' responses on the open-ended problem solving were scored using the holistic rubrics as shown below:

1. if it does not interpret, translate, convert, express textual mathematical information into diagrams, charts, or illustrations, and no use of mathematical concepts, language, and symbols; no corrections made; solution is not stated and is incorrect.
2. if it attempted to interpret, translate, convert, express textual mathematical information into diagrams, charts or illustrations but with incomplete and inappropriate presentation, but does not use mathematical concepts, language and symbols correctly; tries to make connections; incorrect solution is stated.
3. if it can interpret, translate, convert, express textual mathematical information into an appropriate diagram,

charts or illustrations but not complete and clear, and use of correct mathematical concepts, language and symbols with minor errors; fairly makes connections; correct solution is stated with minor flaws.

4. if it can interpret, translate, convert, express textual mathematical information into a complete, clear and appropriate diagrams, charts or illustrations, and use of correct mathematical concepts, language and symbols; makes connections by applying previous and new concepts in solving the problem; correct solution is stated.

While the second-tier test was scored using the rubric as shown below:

0. if it shows no understanding of the question/problem, mathematical concepts and principles.
1. if it shows very limited understanding of the question/problem, mathematical concepts and principles; does not make connections and explanations; answer the question incorrectly.
2. if it shows understanding of the question/problem, mathematical concepts and principles, attempts to make connections and explanations, answer the question but not completely.
3. if it shows nearly complete understanding of the question/problem, mathematical concepts and principles, makes a little connection and give reasonable explanations; answer the question correctly with some minor flaws.
4. if it shows complete understanding of the question/problem, mathematical concepts and principles, cites connections and give accurate explanations; answer the question correctly.

2.4 Data Collection

Before instruction started, both groups were given pretest on the researcher-made questionnaire to assess mathematics achievement. The test composed of 25 questions; 20 items were two-tiered multiple choice test containing moderately difficult problems, and 5-item problem solving which are difficult problems. The participants' responses were personally checked by the researcher and two other raters. Both groups were then taught by the researcher personally with their corresponding approaches but with observers to avoid bias.

One group, which was randomly chosen, was taught using 5E's Instructional model, while the other group was taught using Explicit Mathematics Instruction with Rigorous Mathematical Thinking (EMI-RMT) approach.

In the EMI-RMT approach, the students were first provided with an activity which consists of tasks with teacher-student discourse with well-tailored questions emphasizing the concepts of the new lesson. The teacher discussed the step-by-step procedure which was done with a teacher-student and student-student discourse of at least three examples. In the first example, the teacher throws questions to let students think and provide background concept of the lesson which would also lead for them to learn new terms, identify the given, the requirement, and translation of words to symbol to form mathematical sentences and solution. For the second example, the teacher throws questions to lead the students to the process of the solution to the problem and understand it in every step. The third example, only the students were required to solve the problem completely. Then a student was asked to explain, while the other students throws questions about the solution. The third example allowed the student-student discourse. In every example the students were guided with the logical steps shown by the teacher with the corresponding questions for every step in order for them to easily recall the steps of the solution. After the third example, the students were given more problems on real-life situation to let them think and analyze how to apply the steps they have learned in real-life problems. They were encouraged and allowed to show other method of solving. They were given extra credit in seatwork if they presented varied and many solutions in different situations. The process was repeated until all topics were discussed. In this method, the teacher provides both the step-by-step procedure and posed a series of challenging questions in the discourse to promote mathematical communication among students.

In the 5E's approach, students were given an activity that motivate their interest and focus their mind on the concept of the lesson, as the engagement phase. In the next step, students were given a group activity that allowed them to explore and discover new ideas through the activity, and this was the exploration phase. After this phase, the teacher discussed the lesson and had teacher-students discourse to share their ideas they have learned on the two phases while they interact with each other which was the explanation phase. Under the elaboration or extension phase, each group was given problem solving task that allowed the students to apply everything they learned, explored, and discovered. Lastly, in the evaluation phase where they were given quiz to assess on how far they have learned the lesson.

The 5E's instructional model and EMI-RMT approach were done within eight weeks. At the end of the 8^{th} week, a posttest of all the instruments were administered for both groups. After the posttest, the group taught with EMI-RMT was asked to answer the questionnaire about their perception on the EMI-RMT process. The results of the pretest and posttest were recorded and analyzed using analysis of covariance (ANCOVA) unequal n's.

2.5. Data Analysis

To determine the effect of EMI-RMT and 5E model on first year college students' mathematics achievement, the data were subjected to analyses. For descriptive analysis, mean and standard deviation of the pretests and posttests were computed for both groups. To determine if there is a significant difference of students' achievement as influenced by the two methods of teaching, the one-way analysis of covariance (ANCOVA) unequal n's was used, with the pretest as the covariate, since the participants were intact classes. In determining the students' level of achievement based on their mathematics achievement, the K-12 descriptive level was adopted. The mean score was interpreted using the rating scale as follows:

Table 1. Rating Scale for Students' Level of Achievement

Mean Score Range	Descriptive Level
108 – 120	Outstanding/Advanced
84 – 107	Proficient
60 – 83	Approaching Proficiency
36 – 59	Developing
35 and below	Beginning

3. Results and Discussion

Table 2 shows the pretest and posttest mean scores, standard deviation and descriptive level of students' achievement in Plane and Spherical Trigonometry.

Table 2. Mean Standard Deviation and Descriptive Level of Students' Mathematics Achievement Score

Time of Appraisal	Method of Teaching	n	Mean	SD	Level
Pretest	EMI-RMT	29	20.52	8.01	Beginning
	5E	34	15.55	9.39	Beginning
Posttest	EMI-RMT	29	82.59	16.49	Approaching Proficiency
	5E	34	79.41	13.44	Approaching Proficiency

It can be noted that the students in both groups have shown apparent improvement from beginning level at the start of the study to approaching proficiency level in the post test. In the pretest, the class taught with EMI-RMT got a mean of 20.52 and a standard deviation of 8.01 while the class taught with 5E's got a mean of 15.55 and a standard deviation of 9.39. It can be observed that EMI-RMT is a little higher. In the posttest, both groups have increased in the mean score with 82.59 for those exposed to EMI-RMT and 79.41 for those who underwent 5E's. Both groups have comparably increased. However, to determine if there is significant difference in the participants' achievement scores, the one-way analysis of covariance (ANCOVA) unequal n's was used.

The one-way analysis of covariance (ANCOVA) unequal n's, was calculated, the pretests were analyzed as covariates for the posttest. Table 3 displays the summary of one-way ANCOVA results.

Table 3. One-way ANCOVA Unequal N's Summary for Students' Mathematics Achievement Score

Source	DF	Adj SS	Adj MS	F	P
Treatment Effect	1	11.733	11.733	0.068	0.796
Error	60	10406.35	173.439		
Total	61	10418.08			

The analysis of covariance unequal n's with pretest as a covariate yielded an F-ratio, $F(1,60) = 0.068$, $p>.05$. This led the researchers not to reject the null hypothesis. This implies that there is no significant difference in the students' mathematics achievement scores between the groups taught with EMI-RMT approach and 5E's instructional model. This means EMI-RMT and 5E's have similar effects on the participants' achievement scores in plane and spherical trigonometry. This result confirms the findings of Jean Smith et. al. and Christian Doabler et. al. that supports EMI-RMT to promote deep and lasting understanding [2,3].

The result was evident in their posttest score which were having the same level as approaching proficiency. This implies that EMI-RMT approach and 5E's instructional model were comparably effective in improving student's mathematics achievement score. These students taught with EMI-RMT were able to improve their comprehension and interpretation because this class underwent discourse with thought provoking question and student-teacher interactions. This supports the study of Gleides Lopes-Rizzi, where the grade 3 students taught with more thought-provoking questions improved their reading comprehension and academic performance [12]. Comprehension and interpretation are the necessary ingredient to translate into mathematical sentence and, therefore enable students to solve mathematical problems [13]. Class interaction was available in class to provide learners with experiences that exposed them to opportunities for developing the mind and better understanding. In the study conducted by Natasha Gillette in relation to class interaction, her findings revealed that teacher-student interaction have a positive impact on the academic performance of Native American college students [14].

These results corroborate to the study of Genevieve Hartman on the principles of children's mathematical thinking. His findings suggest that when teachers focus on children's thinking, they continue to learn even after the professional development has ended [15].

On the other hand, the result supports the study of Ufuk Töman where using 5E model as classroom teaching approach can help increase students' achievement [16]. This study also shares the same result to the research conducted by Porandokht Fazelian, stating a positive influence of 5E's instructional model on enhancing student's retention and learning of the middle school students [17]. This is probably because in 5E's instructional model, the students actively participated the learning episodes where they acquire the knowledge through actual experiences in the real-world [18].

4. Conclusions and Recommendations

Based on the findings of the study, the researchers concluded that instructional approach using the EMI-RMT approach was comparably effective as the 5E's instructional model in raising the level of mathematics achievement among the first-year college education students. EMI-RMT have focused the students' mind to questions that led them to understand the concept better, that promote fluency and flexibility of thinking and communication of mathematical concepts orally and in writing necessary for teaching. Through continuous mathematics discourse under EMI-RMT, students continually keep their minds focus and active. The researchers recommend that mathematics teachers may use the EMI-RMT approach in discussing their lessons for students to improve performance and communicate mathematical concept with fluency and flexibility.

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