

Santos & Boyon, 2020

Volume 5 Issue 3, pp. 782-792

Date of Publication: 29<sup>th</sup> January 2020

DOI- <https://doi.org/10.20319/pijss.2020.53.782792>

This paper can be cited as: Santos, J. C. D., & Boyon, C. L., (2020). Effect of Inquiry-Based Lessons on Stem Students' Learning Competencies on Limits and Continuity. *PEOPLE: International Journal of Social Sciences*, 5(3), 782-792.

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## **EFFECT OF INQUIRY-BASED LESSONS ON STEM STUDENTS' LEARNING COMPETENCIES ON LIMITS AND CONTINUITY**

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### **Abstract**

*International test results, such as Trends in International Mathematics and Science Study Advanced, revealed that Filipino learners performed less well in Basic Calculus than other areas of Mathematics. This study developed inquiry-based lesson exemplars to enhance Grade 11 STEM students' learning competencies in Basic Calculus, particularly on Limits and Continuity; and investigated the effect of the developed inquiry-based lesson exemplars on students' learning competencies. A pre-experimental research design, specifically a single group pre-test and post test, was adopted for the study. A total of 98 grade 11 STEM students in the second semester of academic year 2018 – 2019 of a national high school in Philippines were tapped as study units. Ten inquiry-based lesson exemplars, adopting the 5E learning cycle, for 13 learning competencies on Limits and Continuity were developed and validated. Students' competency on Limits and Continuity was measured by their pretest-posttest scores. The findings revealed that the developed inquiry-based lessons positively enhanced students' mastery of Basic Calculus competencies on Limits and Continuity. These findings suggest that high school mathematics teachers may adopt/develop inquiry-based lessons or learning materials to improve their students' performance.*

## **Keywords**

Inquiry-based Lesson Exemplars, STEM Students, Limits and Continuity, 5E Learning Cycle, Math Competency

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## **1. Introduction**

One of the ways to determine the effectiveness of a country's educational system and curriculum is by means of assessing it. The Trends in International Mathematics and Science Study (TIMSS), a project of International Association for the Evaluation of Educational Achievement (IEA), is an international assessment test conducted to help countries examine how students perform and to identify educational areas for improvement. It aims to improve the teaching and learning of Mathematics and Science in school/educational systems around the world through a comparison of curricula and practice of different countries, and to relate this information to the performance of their students (Australian Council for Educational Research, n.d.).

In the 2003 TIMSS results, the Philippines ranked 34<sup>th</sup> out of 38 participating countries in Mathematics; and in 2008, even with only science high schools participating in TIMSS-Advanced Mathematics category, the Philippines ranked the lowest (DepEd, 2010). Results of TIMSS-Advanced showed that among ten (10) countries that participated in the study, the Philippines ranked 10<sup>th</sup>. These results revealed that Filipino students did relatively better in Geometry and relatively less well in Calculus; all types of science high schools demonstrated better performance in Geometry but weak performance in Calculus. The results further revealed that an item with the lowest correct response of Filipino students was in the subject Calculus, specifically on the content topic of Limits and Continuity; among 4,091 Filipino students who participated, only 2.5% had correct response on that item (Ogena, Laña, & Sasota, 2010). The findings affirmed the need to increase the country's performance in Mathematics, particularly in Calculus on Limits and Continuity.

According to many studies, one of the factors that affect students' learning or performance is teacher's teaching methods or approaches. The studies of Ely (2012) and Muema, Mulwa & Mailu (2018) found that teachers' methods or approaches in teaching have a direct correlation to students' achievement and academic performance. Saad, Adamu, & Sadiq (2014) support Ely's and Muema's et. al. statement that the poor teaching methods cause poor student performance in Mathematics. Therefore, once a teacher fails to prepare a facilitation plan and the best method in teaching a lesson, it is highly probable that his/her learners will also fail to understand the lesson. Hence, the need to

carefully design the lesson and to choose appropriate teaching methods and approaches properly is validated.

Theorists of education propose various teaching instructions to address poor academic performance of learners. One of these is the inquiry-based learning (IBL) approach which is a foundation of student-centered instruction. The IBL is a pedagogical approach that invites learners to explore academic content by posing, investigating, and answering questions. It develops and validates “habits of mind” that characterize a life-long learner (Center for Inspired Teaching, 2008); and according to Smith (2008), IBL approach is a pedagogy which best enables learners to experience the processes of knowledge creation. The studies of Witt and Ulmer (2010) and Smit (2016), established that IBL is effective in enhancing students’ academic performance. Smit further concluded that 21<sup>st</sup> century skills are positively promoted with inquiry-based task in mathematics education.

The foregoing are reasons why this research developed inquiry-based lesson exemplars to enhance Grade 11 STEM students’ learning competencies in Basic Calculus, particularly on Limits and Continuity, and investigated the effect of the developed inquiry-based lesson exemplars on students’ learning competencies on Limits and Continuity.

### **1.1 5E’s Learning Cycle**

Along with IBL approach is the 5E’s learning cycle which is based on the constructivist approach of teaching-learning. 5E’s learning cycle allows learners to build or construct new ideas on top of their old ideas and it is suitable for students of all age’s even adults (Enhancing Education, 2002). Lemence (2017) cites in his lecture, “Why ask? A brief introduction to IBL,” the following are the 5E’s learning cycle in lesson exemplar making and its corresponding purpose: (1) Engagement – question for investigation is developed, prior knowledge is activated, and procedures, rules and safety precautions are outlined; (2) Exploration – imitates guided discovery, students manipulate the materials, make discoveries and share their findings with classmates and teachers, provides concrete experiences from which student learning and knowledge can be built; (3) Explanation – teachers invite students to share their discoveries and explanations. Based on descriptions provided by students, teachers introduce relevant principles and/or theories. Students and teachers utilize the concept and experiences to describe and explain the phenomenon and answer the initial question; (4) Elaboration – allows students to create connection between new concepts, principles, theories, and real world experiences by applying them to a new situation. Small group and classroom discussion continue to play a vital role in the learning process by allowing students to share and defend their understanding and explanation. (5) Evaluation – encourages learners to assess their understanding and abilities and

lets teachers evaluate students' understanding of key concepts and skills development. Through the inquiry-based exemplar lessons, in 5E's learning cycle or model format, students are expected to master Limits and Continuity learning competencies.

## **2. Methodology**

### **2.1 Research Design**

This study employed the pre-experimental research design, specifically the single group pre-test-post test study. The pre-test determined the baseline status of the learners' competencies on Limits and Continuity. The developed inquiry-based lesson exemplars were employed as both learning and teaching tools referred to as treatment. After the implementation of the treatment, post test was given to determine treatment effects on Grade 11 STEM students' Limits and Continuity learning competencies.

### **2.2 Respondents**

The respondents of this study were three sections of Grade 11 STEM students of a Philippine national high school in A.Y. 2018 – 2019. The school was purposively chosen because it has a good representation of qualified STEM strand students. In fact, this school has qualifying examination for the STEM strand which a student needs to pass and obtain a grade of 85 or better in Mathematics. Among the three sections, 98 randomly chosen students were the study units for the refined data analysis.

### **2.3 Research Instrument**

The main instrument used to determine the effect of inquiry-based lessons on students' learning competencies was a researcher-made pre-test-post test. This test is composed of 50 multiple choice items where each question has one right answer and three distractors. To assure that the developed test is appropriate for the research subjects, its validity, objectivity, practicability, utility, and consistency of the test items to the learning competencies were evaluated by nine validators. Its computed reliability (using KR21 test of reliability) was 0.78 interpreted as a good classroom assessment or test.

### **2.4 Procedures**

Prior to the conduct of the study, the researcher prepared a test covering all the lessons on Limits and Continuity. This test was evaluated by a total of nine validators and the results of validators' evaluation provided refinements to its final form. The researcher-made test was then pilot tested to Grade 12 STEM students of a science high school. The results of the pilot test were subjected

to test reliability with difficulty and discrimination indices analyzed; the good items were included in the final test.

The developed inquiry-based lesson exemplars were also validated by the same test validators. It was evaluated under its instructional objectives, use of 5E's learning cycle, prior knowledge/connection, and use of inquiry-based teaching-learning instruction. Validators' comments and suggestions served as guide to modify the developed lessons to make them more interesting and more applicable to the study units.

Implementation of the study started with the pre-test to determine the baseline performance of Grade 11 STEM students on Limits and Continuity. The students were then exposed to the validated inquiry-based lessons. After the execution of all inquiry-based exemplar lessons, post test was administered. The resulting data were analyzed and interpreted to come up with necessary recommendations.

## **2.5 Data Analysis**

The data were examined by descriptive statistics, gain scores, and paired t-test. The performance level of students was analyzed using the score interpretation of National Educational Testing and Research Center (NETRC) presented in Table 1. These approaches were used to establish the effect of inquiry-based lessons on STEM students' learning competencies on Limits and Continuity.

**Table 1: NETRC Standard Score Interpretation**

<b>Percentage</b>	<b>Descriptive Equivalent</b>
96% - 100%	Mastered
86% - 95%	Closely Approximating Mastery
66% - 85%	Moving Towards Mastery
<b>Percentage</b>	<b>Descriptive Equivalent</b>
35% - 65%	Average Mastery
16% - 34%	Low Mastery
5% - 15%	Very Low Mastery
0% - 4%	Absolutely No Mastery

### **3. Results and Discussion**

#### **3.1 Development of Inquiry-based Lesson Exemplars**

A total of 10 inquiry-based lesson exemplars on Limits and Continuity were developed. While designing the lessons, great importance was placed on the learning material so as to incorporate all 13 learning competencies of Limits and Continuity which are based on the curriculum guide of the Department of Education (DepEd); and to conform with all the phases of inquiry-based teaching and learning. The developed inquiry-based lessons are composed of five main parts: learning objective and lesson outline, materials, learning resources, lesson proper, and assignment. The lesson proper is divided into two parts: the introduction and the delivery. Under introduction part, students are given various tasks that aim to prepare them for learning. In the delivery part, the 5E's learning cycle or model format which consists of Engagement, Exploration (with inquiry-based activities), Explanation, Elaboration, and Evaluation was adapted. The designed lessons were subjected to evaluation/validation by six secondary Basic Calculus teachers, two university professors, and one Education Program Supervisor in Mathematics whose recommendations were considered to improve said lesson exemplars. The validators evaluated the inquiry-based lesson exemplars based on the following criteria: (1) alignment of the instructional objectives and assessment, (2) use of 5E's learning cycle, (3) activation of prior knowledge/connection, and (4) use of inquiry-based teaching-learning instruction. Each of these aspects has sub-indicators to better assess the lesson exemplars using a 7-point Likert scale: (7) excellent, (6) very satisfactory, (5) satisfactory, (4) moderately satisfactory, (3) poor, (2) very poor, and (1) needs major improvement. The developed inquiry-based lesson exemplars have an overall rating of excellent which affirmed the appropriateness of all exemplar lessons for use for learning the 13 competencies in Grade 11 Limits and Continuity lessons.

#### **3.2 Effect of the Developed Inquiry-based Lesson Exemplars on Students' Learning Competencies**

Table 2 presents the statistical data from the pre-test and post test results of Grade 11 STEM students. The learning competencies on Limits and Continuity are presented to highlight areas where learners' competencies were enhanced or diminished.

**Table 2: Pre-test and Post test Results Summary Statistic**

Parameters	Pre-test			Post test		
	Mean scores	PL		Mean scores	PL	
		%	DE		%	DE
1. Illustrate limit of the function using a table of values and the graph of the function	0.419	8.37	VLM	4.235	84.69	MTM
2. Distinguish between $\lim_{x \rightarrow c} f(x)$ and $f(c)$	0.357	7.14	VLM	4.164	83.27	MTM
3. Illustrate the limit laws	0.602	12.04	VLM	4.317	86.33	CAM
4. Apply limit laws in evaluating the limit of algebraic functions	0.388	7.76	VLM	3.776	75.51	MTM
5. Compute the limits of exponential, logarithmic, and trigonometric functions using tables of values and graphs of the functions	0.327	6.53	VLM	4.041	80.82	MTM
6. Evaluate the limits involving the expressions $\frac{\sin t}{t}$ , $\frac{1-\cos t}{t}$ , and $\frac{e^t-1}{t}$ using tables of values	0.09	3	ANM	2.525	84.18	MTM
7. Evaluate the limits of expressions resulting in the indeterminate form " $\frac{0}{0}$ "	0.047	2.33	ANM	1.163	58.16	AM
8. Illustrate continuity of a function at a number	0.285	9.5	VLM	2.908	96.94	M
9. Determine whether a function is continuous at a number or not	0.067	3.33	ANM	1.667	83.33	MTM
Parameters	Pre-test			Post test		
	Mean Scores	PL		Mean Scores	PL	
		%	DE		%	DE
10. Illustrate continuity of a function on interval	0.34	11.33	VLM	2.725	90.82	CAM
11. Determine whether a function is continuous on an interval or not	0.2	10	VLM	1.898	94.9	CAM

12. Illustrate different types of discontinuity (hole/removable, jump/essential, asymptotic/infinite)	0.245	4.9	ANM	4.327	86.53	CAM
13. Illustrate the Intermediate and Extreme Value Theorems	0.225	4.49	ANM	3.419	68.37	MTM
Mean	3.59	6.902	VLM	41.162	82.604	MTM
Standard Deviation	3.6246			4.1225		
Mean Gain	+37.572					
t Stat	70.62					
p value	0.00					
t critical value	1.98					
Significance	Significant ( $\alpha = 0.05$ )					

**Legend:** PL - Performance Level  
DE - Descriptive Equivalence  
ANM - Absolutely No Mastery  
VLM - Very Low Mastery  
AM - Average Mastery  
MTM - Moving Towards Mastery  
MTM - Closely Approximating Mastery  
M - Mastered

The table revealed that there is a significant increase from the pre-test and post test scores of Grade 11 STEM students in each learning competency on Limits and Continuity. In addition, the learners' scores became more varied after the implementation of the inquiry-based lesson exemplars. These results indicate that some student-respondent made significant progress while others did not, thus, extending the range of the test scores. The mean scores of the respondents increased from 3.59 to 41.162 (+37.572). The significant increase of the mean scores of the Grade 11 STEM students-respondents is attributed to the inquiry-based lesson exemplars used.

Based from the students' post test PL, of the 13 learning competencies on Limits and Continuity, they have a mastered PL in competency 8 only. This means that these students performed very well in illustrating continuity of a function at a point. In competencies 3, 10, 11, and 12, the students' PL ranges from 86.33 to 94.9 interpreted as closely approximating mastery. The achievement levels of students in seven competencies (i.e. 1, 2, 4, 5, 6, 9, and 13) are at moving towards mastery with PL ranges from 68.37 to 84.69. Comparing the students' performance in the 13 learning competencies, they performed less well in competency 7 with a PL of 58.16. This latter result reveals that Grade 11 STEM students, even with inquiry-based lessons, have difficulties in evaluating the limits of expressions resulting in the indeterminate form " $\frac{0}{0}$ ". For students to master this competency,

it is required that they have a strong understanding of the basic concepts of Mathematics (patterns and algebra), such as factoring and rationalizing expressions. This finding implies that intense review, drills and exercises including on patterns and algebra content of Mathematics must be given to Grade 11 STEM students; preferably junior high Mathematics should similarly address the quantitative skills and learning gaps to facilitate students' skills progression in handling Basic Calculus learning tasks.

The overall PL of Grade 11 STEM students on Limits and Continuity before the implementation of the inquiry-based lesson exemplars was 6.902 classified as very low mastery; after implementation of the treatment, the PL increased to 82.604 classified as moving towards mastery. This overall result evidences that the developed inquiry-based exemplar lessons helped significantly to increase students' performance on Limits and Continuity; t-tests results further confirmed the significant difference between students' pre-test and post test scores.

#### **4. Conclusion and Recommendation**

This research focused at investigating the effect of inquiry-based lessons on STEM students' learning competencies on Basic Calculus. Topics in Basic Calculus other than limits and continuity were not part of this study. The learning competencies in Basic Calculus outside the Teaching Guide or the Curriculum Guide provided by the Department of Education (DepEd) were not included in this study. Other strands were likewise excluded.

Based from the results and discussion of the study, it can be inferred that the developed inquiry-based lesson exemplars, in 5E's learning cycle or model format, are valid and effective learning resource. Furthermore, it can be concluded that inquiry-based lessons have positive effect in enhancing Grade 11 STEM students' mastery of Basic Calculus learning competencies on Limits and Continuity. This study offers results that support previously performed studies by other researchers (Jarrett, 1997; Witt & Ulmer, 2010; Ferguson, 2010; Kogan & Laursen, 2014; Gomez, Martinez, & Miranda, 2015; and Smit, 2016).

To further enhance learners' performance and learning competencies in Mathematics, it is suggested for curriculum implementers or educators to prepare effective lesson plans or exemplars applying the inquiry-based learning approach in 5E's learning cycle or model format. A future research should also be conducted to validate the effect of IBL in Basic Calculus particularly on the topics about Derivatives and Integration. It is likewise forwarded for future studies to address students' learning gaps by teaching the basics of Mathematics, particularly on the content area of patterns and algebra, intensively soonest.

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