Effects of Flipped Classroom in the Reduction of Learners' Errors in Differential Calculus

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Abstract

The focus of the study is to investigate the effects of the flipped classroom in the learners' errors in Differential Calculus tasks.
Two groups of students in the Technological Institute of the Philippines in Quezon City, Philippines were under investigation. The control group went through the traditional classroom method while the experimental group went through the flipped classroom strategy. Comparability of the two groups was ensured at the start of the semester through a test involving general mathematics topics. The students in each of the two groups were further divided into two—STEM and non-STEM which performed the same set of activities in their respective groups.
In the experimental group, lectures took place outside of the classroom with the aid of pre-recorded videos. The videos were personally created by the author. The average running time of the videos is 20 minutes. In cases that the topic needed more than the allotted time, the lecture was divided into segments. Classroom hours were used for more effective and creative activities and the teacher focused more on observing, guiding, and helping the students.
A pretest consisting of Differential Calculus concepts was administered at the start of the semester. Learners' errors per topic, by type of error, and by the group were determined through the pretest. Errors were classified into four namely: comprehension, transformation, procedural, and encoding.
Posttests were given at the end of the preliminary, midterm, and final periods. Posttest questions were similar to those in the pretest. Common errors of the students were noted and analyzed like the previous analysis.
The effectiveness of the flipped classroom in reducing the errors of the students was tested by comparing the errors of the students between the pretest and posttests of the two groups and the two tracks per topic. The number of correct answers and unanswered items was also recorded and included in the analysis.
In the end, the flipped classroom was found effective in the reduction of comprehension errors in functions, differentiation, and applications. In functions and the applications, the non-STEM track had a significantly greater difference in the frequencies of such errors, while in differentiation the two tracks both have remarkable contributions about the reduction. The grouping of the students only showed a significant effect in the reduction of such errors in functions and in the applications which meant that the students in the traditional classroom group performed almost at the same level as the students in the flipped classroom group in differentiation. The flipped classroom group also showed a significantly fewer transformation error in limits and continuity in the posttest which meant that the grouping of the students only mattered when it comes to learning the said topics.

Keywords: Flipped Classroom, Mathematics, Education, Calculus, Differential Calculus, Errors, Reduction of Errors

Introduction

Calculus concepts are extremely hard to learn. It is one of the most important branches of mathematics mainly because of its applicability to solve practical and theoretical problems in various disciplines. Many students struggle in Differential Calculus due to misconceptions on pre-calculus and calculus topics per se. These misconceptions lead to errors in performing the tasks in differentiation which then leads to disinterest in the subject matter, demotivation, and disengagement in the tasks. More often than not, underachievement of students in Differential Calculus stems from this reason. It is important to analyze students' errors so that teachers will be able to correct them and prevent these errors from recurring.
Learners develop misconceptions because they are not given sufficient experiences of a concept (Makonye, 2012). Learners must be given opportunities to experiment and conjecture results so that they prove for themselves what makes sense and does not. This is because teaching them by giving them quick-fix methods always leads to giving learners formulae which are second-hand knowledge (Littler, 2008). As second-hand knowledge, learners do not know how to flex it to match contexts different

from which it was learned (Boaler, 1993), mainly because formulae knowledge is specific to a particular context and cannot be generalized without understanding (Makonye, 2012).

Teachers are considered the primary partners of the Department of Education (DepEd) and Commission on Higher Education (CHED) in attaining their goal of producing students that are globally competitive and engaging in creative and critical thinking while imbibing Filipino values. To achieve these goals, teachers must aim to generate higher-order thinking skills among students. It is a teacher's role to discover and analyze students' weaknesses and errors that hinder them from achieving the said skills. Teachers must be creative in developing methods to reduce, if not eliminate, such errors. It is important that the method to be used adapts to the needs of the students and is suited to this modern-day and age.

The main goal of this study was to identify and analyze students' errors in Differential Calculus tasks and then compare the errors committed by students in the traditional classroom and the flipped classroom. The researcher was aware that millennial generation college students present a unique challenge to educators, requiring faculty to employ new teaching strategies to acquire and maintain their attention. There is an increasing number of teachers who are experimenting on new concepts to eradicate student errors. Active involvement increases responsiveness and challenges students to come to class prepared (Monterey, Walker, Sorensen, Kirkline, White, & Ross, 2013). As millennials are known to be fascinated with technology, an approach in teaching that involves any available technological tool seems to be more effective than the traditional way. In this dissertation, the author wanted to show how the injection of technology through the flipped classroom approach can reduce and correct students' errors in Differential Calculus, if not as much, preferably more than the traditional way can.

The flipped classroom is becoming a popular approach in teaching especially in other countries where technology is easily accessible. It is a pedagogical strategy where lecture and assignment elements of a course are reversed. Lectures are presented on videos that must be watched at home while assignments are done inside the classroom. Classroom hours are dedicated to the group and individual activities that may strengthen students' understanding of the lesson. Different variations have been developed over time. This model contrasts from the traditional model in which the students practiced the lowest levels of thinking—remembering and understanding in the classroom by listening to instructor's talk, while other levels were practiced outside the class such as doing homework or nothing (Zainuddin and Halili, 2016). Davies et al. (2013) conducted a study to explore how the use of technology in the flipped classroom might be utilized to effectively promote students' achievement.

One of the advantages of this approach is that students can work at their own pace. This means that students who are having difficulties in pre-calculus have time to study the concepts needed in Differential Calculus, those having difficulties with the terminologies being used have time to do more research, and those having difficulties in understanding the calculus lesson may replay the parts unclear to them. Other benefits of the flipped classroom strategy include increased time for engaging instruction (Milman, 2012); students can study at their own time and pace rather than listen to a lecture on a topic that they already understand and can view lectures on mobile devices whenever they are ready (Frydenberg, 2012; Steed, 2012); lectures can be viewed as often as needed to understand a topic, and recorded lectures are more time-efficient (Frydenberg, 2012). Milman (2012) suggests that the flipped classroom technique is good for teaching procedural knowledge, which is knowledge about how to do something, such as solving an accounting problem.

Phillips (2014) cautioned about the limitations and pitfalls of flipping the classroom. Such limitations may include: poor quality of video lectures compared with a face-to-face setting; student technology issues and conditions under which they might view the video (i.e., in front of the TV, distracting surroundings); students may not watch the video before class; instructor and peers are not available to answer questions during video viewing; and difficulties for second language learners or those with learning disabilities (Milman, 2012). Other pitfalls might include faculty initial preparation time; increased responsibility on students for their learning can leave some students feeling uncomfortable or abandoned; culture shock for students accustomed to rote, lecture-style learning; and student resistance to taking on the increased responsibility for learning (Talbert, 2012).

Despite these cautions and limitations, this teaching pedagogy has captured the curiosity and attention of the faculty and has been experimentally used at all levels of education since its discovery.

Flipped classroom approach, although not new and has shown positive results on those who have used it, has been used by very few teachers in the Philippines because of the lack of resources. Generally, students in the flipped classrooms performed better than students in traditional classrooms, although the performance gains were not high enough to be statistically significant but promised (Kadry & El Hami, 2014).

The author believed that although the said approach is effective to the students nowadays, it is significantly more important to identify the Differential Calculus concepts that most students are having difficulty understanding. Identifying the common mistakes that most students commit can guide the teachers on how they can teach the course better in the future. The author believed that reducing students' errors will lead to students' achievement.

The study also presumed improvements in students' motivation – one of the crucial elements of learning, and also students' engagement through the use of technology in the pedagogy. The author had the confidence that improvement in these aspects will also help in the reduction of errors of the students. Motivation is an inner power that pushes humans to take action or move toward a goal (Harmon-Jones, Harmon-Jones, & Price, 2013). Students' motivation is defined as a spirit, initiative, and willingness of students to attend and learn the material (Cole, Field, & Harris, 2004). Intrinsic motivation refers to those actions that individuals engage in as they are inherently interesting, fun, exciting, and enjoyable, while extrinsic motivation refers to individuals engaging in actions because they lead to reward or to avoid punishment (Deci & Ryan, 2002; Ryan & Deci, 2000).

Using technology, which the millennial students are fascinated with, the study aims to promote intrinsic motivation by capturing students' interest and making Differential Calculus more exciting and less difficult to learn. The analysis of Zainuddin and Halili (2016) showed that the flipped classroom has promoted students' empowerment, development, and ability to learn independently or at their own pace. On the other hand, students' engagement refers to students' active learning or students' desire to actively participate in a routine class activity such as submitting homework, listening to the topic, working on what the instructor asks them to do, and actively attending the class (Yang & Cheng, 2014). Likewise, Zepke, Leach, and Butler (2009) mentioned that students' engagement resulted from students' motivation. The term students' engagement is frequently used for students' active learning or students' desire to actively participate in a routine class activity such as submitting homework, listening to the topic, working on what the instructor asks to do, and actively attending the class (Delialioglu, 2012). Students can enhance their engagement in classroom activity, participate in discussions, exchange ideas, and solve problems with their peers (McLaughlin et al., 2013). Flipped classroom encourages student engagement. In contrast, students in traditional classrooms tend to be disengaged because the approach focuses on textbooks and lectures and students are not able to express their abilities. Another positive element of learning that can be enhanced by the flipped classroom approach is students' interaction with peers. Love et. al. (2014) mentioned that students had more opportunities to interact with one another and this helped them learn from other students which then leads to clarification of misconceptions among students.

With the technology being flexible and appropriate for 21^{st}-century learning, it is time to change some traditional teaching methods which are not suitable anymore in this time and age. Adapting to the modernization is very important for teachers who want to reach out to their millennial students that are driven by technology.

I. Background of the Study

The millennial generation has garnered a tremendous amount of attention for their unique characteristics compared with previous generations. One of the main differences is that millennials were born into a world where technology is ubiquitous. This generation was noticed to give up very easily when performing tasks or even not try at all when tasks are found quite difficult in their perspective. The literature on millennials uniformly suggests that, as educators, we must understand this new generation of learners to educate them effectively (Phillips, 2014).

Adding to the present dilemma of the educators is the recent change in the curriculum in basic education in the country. A 13-year program was found to be the best period for learning under basic education. For this reason, the curriculum in basic education has been changed recently to K to 12, modeled internationally, adding kinder in the basic education, and two more years in high school. High school was divided into two—junior and senior. Separating students in senior high school by their preferred tracks and strands aim to prepare them for higher education suitable for the chosen track and strand. Unfortunately, in reality, a senior high school graduate may take any college program that they choose without considering their educational background.

Ideally, senior high school students who intend to pursue engineering programs must take the academic track and science, technology, engineering, and mathematics (STEM) strand where pre-calculus and introductory differentiation concepts are covered. STEM strand intends to build a concrete foundation for engineering mathematics. However, as we are still in the first few years of the transition from the old curriculum, problems in connecting the fragments of the concepts of pre-calculus and calculus were noticed. Engineering students are observed to be performing poorly particularly in mathematics and the success rate in Differential Calculus has dropped. In the Technological Institute of the Philippines (T.I.P.) in Quezon City, the Philippines the achievement rate of first-year engineering students in Differential Calculus significantly dropped from 84.54% to 62.04% in the last two first semesters of school years 2017 to 2018 and 2018 to 2019. These numbers were obtained before and after the effect of the K to 12 curricula at the college level.

In addition to the gap between STEM and engineering mathematics, other senior high school tracks and strands do not have pre-calculus subjects that may help them to perform the tasks in differentiation. A non-STEM graduate relatively does not know differentiation because their highest mathematics subject covers functions, logic, and business mathematics. Thus, non-STEM graduates are having more difficulties in understanding and succeeding in the course. With this problem, college instructors/professors are thinking of ways to resolve the problem emerging from the gap between senior high school and engineering mathematics which affects the students' performance that is caused by errors in the tasks in Differential Calculus. Bridging programs do not show much improvement in students' performance nor significantly decrease student errors in the course since very limited time is dedicated to too many topics. To mitigate, if not eradicate the problem, teachers must develop new ideas on how the students can cope with the fast-paced instruction in the college education which then results in an increasing variety of student errors.

Since the flipped classroom approach gives the students a little more freedom on following the pacing of the discussion, it is very suitable for those students who are non-STEM graduates as they have more time to prepare and have the required minimum competency for each lesson. Furthermore, students who are having problems with coping can always replay some parts of the discussion that were not clear to them because the lesson is recorded.

Fulton (2012) showed how the flipped classroom approach increased students' achievement, interest, and engagement in higher-level mathematics. Figure 1 shows how the achievement of the students in calculus in a school in southern Minnesota was raised using the flipped classroom.

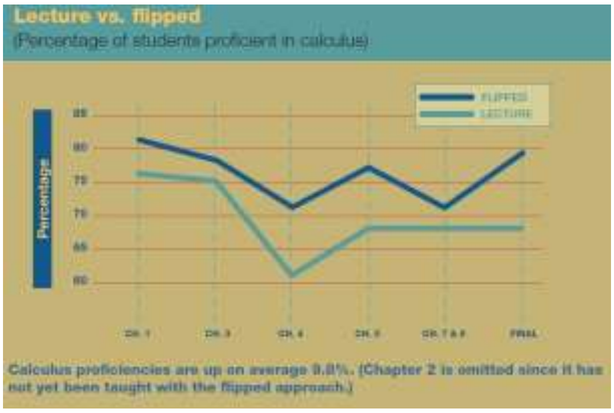

Figure 1. Lecture vs. Flipped Classroom in Calculus

As in any problem-solving situation, it is always important to know and understand how the problem existed. It is not enough to infer. Solving a problem must always begin with finding its root cause. The problem solver would know how to best attack the problem with it known. In this case, solving the problem on the declining students' achievement in Differential Calculus must begin with knowing and understanding the students' mistakes and misconceptions and then reducing these using a solution involving a tool that the students nowadays are very accustomed to.

The newest generation of learners is fluent with and intimately reliant upon technology in their daily lives; therefore, the use of technology in the classroom meets their needs (Monterey, Walker, Sorensen, Kirkline, White, & Ross, 2013). Although the flipped classroom approach is not a panacea for all educational ills in this age, it seems to promote active learning which requires students to solve problems using what they had learned before class. In the present review, no evidence flipped classroom approach negatively impacts student learning in K to 12 education. At best, this instructional approach can help students perform significantly overall better than students in traditional classrooms (Lo and Hew, 2017).

II. Statement of the Problem

The study aimed to measure the effects of the flipped classroom in the reduction of learners' errors of the first-year engineering students of T.I.P., Quezon City, the Philippines in Differential Calculus tasks between those who underwent the traditional method of teaching and those who used technology through flipped classroom approach.

The study aimed to answer the following questions:

1. What are the identified learners' errors in Differential Calculus in the pretest and posttest per topic?
2. How do the errors in Differential Calculus compare between the pretest and posttest in each of the grading periods?
3. How do the errors of the STEM and non-STEM in the posttest of the control and experimental groups compare?
4. How does the difference in the pretest and posttest compare between:
   4.1. a traditional and flipped classroom
   4.2. STEM and non-STEM
5. How effective is the flipped classroom in the reduction of errors of first-year engineering students of T.I.P. Quezon City in Differential Calculus?

Material and Methods

I. Methods of Research

The focus of the study was to investigate the effects of the flipped classroom in the learner errors in Differential Calculus tasks. This paper analyzed and compared engineering students' errors in Differential Calculus tasks between the group of students in the traditional classroom (control group) and the flipped classroom (experimental group). The study also compared the number of errors committed by the STEM and non-STEM students in the two aforementioned groups.

The study utilized descriptive and experimental methods. The descriptive method was used to identify the errors of the students in Differential Calculus. The experimental method determined the effects of the flipped classroom in the learners' errors in the said course.

To ensure that the two groups were comparable, a test was administered at the start of the semester. The fifty-item test consisted of topics from senior high school general mathematics topics such as functions and their graphs, business mathematics, and logic.

The control group underwent the traditional way of learning, that is, lectures took place in the classroom and was solely delivered by the teacher. Homework was done individually at home.

In the experimental group, students were taught using the flipped classroom approach where the lecture took place outside of the classroom with the aid of pre-recorded videos that were personally created by the teacher. McLeod et al. (2003) reported that cognitive processing could be overloaded if instruction exceeds 20 minutes, hence each lecture video did not exceed such time. In cases a topic needed more time, the lecture was divided into segments. Classroom hours were used for more effective and creative activities and the teacher focused more on observing, guiding, and helping students. The classroom activities were done by groups to encourage students' interaction and engagement. Questions were also encouraged during and after the activities.

To determine and analyze students' errors, a pretest was administered at the start of the semester and then posttests in the form of summative tests were administered at the end of the preliminary, midterm, and final periods. Each error was categorized as either comprehension, transformation, procedural, or encoding. Items left blank were included in the analysis.

Table 1 served as a guide for the researcher in the classification of errors.

Table 1. Guide for Error Detection

Type of Error	Topics	Rules
Comprehension Error	Functions	The learner is unable to identify what is required in the problem e.g. unable to show knowledge on domain and range or on proving that a function is one-to-one, etc.
	Limits and Continuity	The learner is unable to identify that the problem is asking to evaluate limits
	Differentiation	The learner is unable to show knowledge on differentiation
	Applications	The learner is unable to identify what the problem is asking
Transformation Error	Functions	The learner is unable to identify the correct rule or formula to applied e.g. using multiplication instead of the concept of composition of functions
	Limits and Continuity	The learner is unable to identify the correct theorem in evaluating limits
	Differentiation	The learner is unable to identify the correct differentiation formula e.g. unable to use chain rule when required
	Applications	The learner is unable to transform the problem into mathematical symbols such as writing the correct function
Procedural Error	Functions	Learner incorrectly applies the procedure or answers incompletely using the correct rule or procedure such as finding domain and range, applying a composition of function; may include errors involving some algebraic manipulations
	Limits and Continuity	The learner can identify the correct theorem but fails to apply it correctly or the solution is incomplete
	Differentiation	The learner can identify the correct differentiation formula needed but fails to apply it correctly or the solution is incomplete
	Applications	The learner can write the correct function but there are incorrect and missing steps
Encoding Error	Functions	The learner does not write the final answer as instructed
	Limits and Continuity	The learner does not write the final answer as instructed and may include arithmetic errors while applying the correct procedure throughout the solution
	Differentiation	The learner does not write the final answer as instructed
	Applications	The learner does not write the answer as instructed

To lessen subjectivity in the classification of errors, two mathematics experts were asked to help the researcher in the task. These experts have been teaching mathematics for more than a decade. The analysis of errors was done independently by the researcher and the two experts. A discussion was done among the three in cases where there were conflicts in the judgment.

Finally, the number of errors committed by the students were compared between the control and experimental groups as a whole and between STEM and non-STEM, and within the control and experimental groups between STEM and non-STEM.

II. Research Instruments

In this study, the researcher used an achievement test to determine the comparability of the two groups. The test consisted of 50 questions regarding general mathematics topics, 25 of which will be about functions, 13 about business mathematics, and 12 about logic.

Pretest and posttests were developed covering the topics in Differential Calculus for the whole semester. The pretest, which was administered at the beginning of the semester, is a forty-nine-item problem-solving type test, 15 of which were about functions, limits, and continuity, another 21 were about differentiation rules, higher differentiation, and partial differentiation and the last 13 were about differentiation applications. The posttests were used at the end of each period and the questions were made similar to the pretest questions. These tests were used to determine learners' errors in the said course.

The researcher created and used lecture videos in the flipped classroom approach. These videos contained discussions on Differential Calculus topics and were solely created by the researcher.

III. Statistical Treatment of the Data

For comparability of the control and experimental groups, mean and standard deviation and independent t-test of the achievement test was used. Frequency and percentage were used on the types of errors. Statistical tests such as t-test and two-way ANOVA were employed to test the effectiveness of the flipped classroom in the reduction of errors in Differential Calculus.

Results and Discussion

Table 2. Learners' Errors in the Pretest of the Control Group

Topics	Comprehension		Transformation		Procedural		Encoding	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Functions	13	2.95	38	8.64	32	7.27	1	0.23
Limits and Continuity	2	0.91	21	9.55	17	7.73	6	2.73
Differentiation	83	8.98	104	11.26	20	2.16	1	0.11
Applications	2	0.35	18	3.15	0	0.00	0	0.00

*Percentage=frequency/((total number of items per topic)(number of students))

Table 2 shows the frequency and the relative frequency of the errors in the pretest of the 44 students in the traditional classroom. With the 10 items in functions, the researcher recorded 11 correct answers while some students failed to answer the other 345 items. Also, out of the 5 items about limits and continuity answered by the same number of students, there were 7 correct answers recorded and 167 items were left unanswered. Out of the 21 items in differentiation, 26 correct answers were documented and 690 were not answered by some students. In the 13 items in the applications, there were no correct answers recorded and 552 items were left unanswered. There were 49 questions in the pretest in total and the record showed that there were only 44 correct answers and 1754 items were left blank. Overall, 81.35% of the items were not answered.
The percentages of all four types of errors shown in table 2 were noticeably small and were not alarming without looking at the number of unanswered items and even the correct answers. With the number of unanswered items being taken into consideration, the reason for such small percentages was identified.

Table 3. Learners' Errors in the Pretest of the Experimental Group

Topics	Comprehension		Transformation		Procedural		Encoding	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Functions	36	7.20	91	18.20	53	10.60	7	1.40
Limits and Continuity	5	2.00	52	20.80	35	14.00	6	2.40
Differentiation	58	5.52	198	18.86	35	3.33	17	1.62
Applications	27	4.15	39	6.00	1	0.15	0	0.00

*Percentage=frequency/((total number of items per topic)(number of students))

Table 3 shows the frequency and the relative frequency of the errors of the 50 students in the pretest in the flipped classroom. In functions, there were 17 correct answers and 296 were not answered by some students. In limits and continuity, 27 were correct and 124 were left unanswered. In differentiation, 40 answers were correct and 702 were not answered by some students. In the applications, 2 were correct and 581 were not answered. There were totals of 87 correct answers and 1703 points that were left unanswered. Overall, 69.51% of the items were not answered.
Comparing the frequency of errors between the control and experimental groups, it can be noticed from tables 2 and 3 that most of the numbers in the experimental group are bigger except for the comprehension errors in differentiation and encoding errors in limits and continuity. This difference can be justified by the percentages of the unanswered items.

Table 4. Learners' Errors in the Posttest of the Control Group

Topics	Comprehension		Transformation		Procedural		Encoding	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Functions	19	4.32	70	15.91	63	14.32	13	2.95
Limits and Continuity	1	0.45	81	36.82	30	13.64	19	8.64
Differentiation	11	1.19	314	33.98	104	11.26	26	2.81
Applications	0	0.00	93	16.26	33	5.77	23	4.02

*Percentage=frequency/((total number of items per topic)(number of students))

Table 4 shows the frequency and the relative frequency of the errors of the 44 students in the posttest in the traditional classroom. With the 10 items in functions, there were 87 recorded correct answers while the other 188 were not answered by some students. Also, in limits and continuity, there were 65 correct answers and 25 unanswered items. Out of the 21 items in this differentiation, 96 correct answers were documented and 373 were not answered. In the applications, there were 60 correct answers recorded and 363 were not answered by some students. There were totals of 308 correct answers and 949 points that were left unanswered. Only the comprehension error decreased in frequency from pretest to posttest, the other types of errors increased in terms of frequency. Despite this fact, the data shows a 12% increase in the correct answers and a 37% decrease in unanswered items. This meant that some unanswered items in the pretest became either a correct answer or an error. These percentages support the underlying reason why the frequencies of the errors increased from the pretest to the posttest.

Table 5. Learners' Errors Posttest of the Experimental Group

Topics	Comprehension		Transformation		Procedural		Encoding	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Functions	13	2.60	92	18.40	98	19.60	20	4.00
Limits and Continuity	1	0.40	43	17.20	54	21.60	10	4.00
Differentiation	0	0.00	267	25.43	165	15.71	71	6.76
Applications	0	0.00	105	16.15	56	8.62	18	2.77

*Percentage=frequency/((total number of items per topic)(number of students))

Table 5 shows the frequency and the relative frequency of the errors of the 50 students in the posttest in the flipped classroom. In functions, there were 135 correct answers and 142 were not answered by some students. In limits and continuity, 84 were correct and 58 were left unanswered. In differentiation, 302 answers were correct and 245 were not answered. In the applications, 164 were correct and 307 were not left unanswered. There were totals of 685 correct answers and 752 points that were counted as unanswered. Only the comprehension error decreased in frequency from pretest to posttest, the other types of errors increased in terms of frequency. Despite this fact, the data shows a 24% increase in the correct answers and a 39% decrease in unanswered items. Similarly, these percentages support the underlying reason why the frequencies of the errors increased from the pretest to the posttest.

Significant differences and negative means were also found in the flipped classroom group in the number of comprehension errors between the pretest and the posttest in functions where the non-STEM students greatly contributed, in differentiation where both the STEM and non-STEM students substantially contributed, and in the applications, where the performance of the non-STEM students remarkably impacted. Also, there were very significant differences in the number of correct items and the number of unanswered items in all topics in the same group. On the other hand, only the difference in the comprehension errors between the pretest and posttest in differentiation was found significant in the traditional classroom group.

The group and track did not have significant effects in the number of any of the four types of errors of the students in the posttest in functions but the flipped classroom group has fewer unanswered items in the posttest than the traditional classroom group by 13%.

Table 6. Learners' Errors Between the Pretest and Posttest of All the Students in the Flipped Classroom

		Mean	S.D.	t-value	p-value	Sig.
Functions	Comprehension	-.05	.12	2.75	p=.01<0.05	S
	Transformation	-.00	.22	-.07	p=.95>0.05	NS
	Procedural	.09	.15	-4.28	p=.00<0.05	S
	Encoding	.03	.09	-2.16	p=.04<0.05	S
	Correct Answer	.24	.21	-7.96	p=.00<0.05	S
	No Answer	-.31	.32	6.74	p=.00<0.05	S
Limits and Continuity	Comprehension	-.02	.14	.78	p=.44>0.05	NS
	Transformation	-.04	.24	1.04	p=.30>0.05	NS
	Procedural	.08	.21	-2.56	p=.01<0.05	S
	Encoding	.02	.12	-.94	p=.35>0.05	NS
	Correct Answer	.22	.26	-6.15	p=.00<0.05	S
	No Answer	-.26	.38	4.94	p=.00<0.05	S
Differentiation	Comprehension	-.06	.08	4.89	p=.00<0.05	S
	Transformation	.07	.28	-1.67	p=.10>0.05	NS
	Procedural	.12	.15	-5.78	p=.00<0.05	S
	Encoding	.05	.07	-5.39	p=.00<0.05	S
	Correct Answer	.25	.25	-6.99	p=.00<0.05	S
	No Answer	-.43	.34	9.05	p=.00<0.05	S
Applications	Comprehension	-.04	.10	2.86	p=.01<0.05	S
	Transformation	.10	.15	-4.95	p=.00<0.05	S
	Procedural	.08	.09	-6.83	p=.00<0.05	S
	Encoding	.03	.05	-4.32	p=.00<0.05	S
	Correct Answer	.25	.26	-6.83	p=.00<0.05	S
	No Answer	-.42	.29	10.21	p=.00<0.05	S

Table 7. Learners' Errors Between the Pretest and Posttest of All the Students in the Traditional Classroom

		Mean	S.D.	t-value	p-value	Sig.
Functions	Comprehension	.01	.09	-1.02	p=.31>0.05	NS
	Transformation	.07	.15	-3.14	p=.00<0.05	S
	Procedural	.07	.14	-3.31	p=.00<0.05	S
	Encoding	.03	.05	-3.62	p=.00<0.05	S
	Correct Answer	.17	.23	-5.02	p=.00<0.05	S
	No Answer	-.36	.27	8.85	p=.00<0.05	S
Limits and Continuity	Comprehension	-.00	.05	.57	p=.57>0.05	NS
	Transformation	.27	.28	-6.39	p=.00<0.05	S
	Procedural	.06	.21	-1.83	p=.07>0.05	NS
	Encoding	.06	.16	-2.38	p=.02<0.05	S
	Correct Answer	.26	.29	-6.13	p=.00<0.05	S
	No Answer	-.65	.28	15.59	p=.00<0.05	S
Differentiation	Comprehension	-.08	.07	7.05	p=.00<0.05	S
	Transformation	.23	.27	-5.45	p=.00<0.05	S
	Procedural	.09	.10	-6.27	p=.00<0.05	S
	Encoding	.03	.05	-3.37	p=.00<0.05	S
	Correct Answer	.08	.18	-2.81	p=.01<0.05	S
	No Answer	-.34	.32	7.15	p=.00<0.05	S
Applications	Comprehension	-.00	.02	1.43	p=.16>0.05	NS
	Transformation	.13	.15	-5.87	p=.00<0.05	S
	Procedural	.06	.07	-5.48	p=.00<0.05	S
	Encoding	.04	.07	-4.13	p=.00<0.05	S
	Correct Answer	.11	.18	-3.84	p=.00<0.05	S
	No Answer	-.33	.26	8.42	p=.00<0.05	S

In the posttest in limits and continuity, however, the grouping of the students, in favor of the flipped classroom, showed an effect in the number of transformation errors incurred as shown in table 8, while in the grouping in favor of the traditional classroom showed an effect in the number of procedural errors incurred in the posttest as shown in table 9.

Table 8. Effects on Transformation Errors in the Posttest of Limits and Continuity

Source	df	Mean Square	F	p-Value	Sig.
GROUP	1	.96	21.30	p=.00<0.05	S
TRACK	1	.10	2.30	p=.13>0.05	NS
GROUP * TRACK	1	.08	1.73	p=.19>0.05	NS
Error	90	.05			

Table 9. Effects on Procedural Errors in the Posttest of Limits and Continuity

Source	df	Mean Square	F	p-Value	Sig.
GROUP	1	.20	5.56	p=.02<0.05	S
TRACK	1	.08	2.30	p=.13>0.05	NS
GROUP * TRACK	1	.06	1.74	p=.19>0.05	NS
Error	90	.04			

In the posttest in differentiation, the track of the students showed a significant effect on the transformation errors committed by the students as shown in table 10. The STEM students appeared to incur fewer of this type of error. Also as shown in tables 10 and 11, the students in the flipped classroom committed 5% more procedural and 4% encoding errors in the posttest but this was justified by the data of the correct and unanswered items. The students in this group have a substantial 19% correct answers and 17% fewer unanswered items during the posttest as compared to the students in the traditional classroom. Additionally, the STEM students were found to have contributed more to the number of correct answers in both groups.

The results in the posttest in applications were not much different from the other results as the data showed that the grouping of the students, in favor of the flipped classroom, has a significant effect on the numbers of correct items acquired and unanswered items incurred.

About the reduction of errors in functions, the group and the track of the students, in favor of the flipped classroom, and non-STEM, respectively, showed significant effects in the decrease of comprehension errors in the posttest as shown in table 10. Also in the same topic, the grouping was confirmed an important part in the reduction of transformation errors as shown in table 11. The number of correct answers for both groups was increased from the pretest to the posttest and although the numbers were not significantly different. The number of unanswered items was also reduced for both groups although the track of the students played a greater role in this reduction. There was a recorded significant difference in the number of unanswered items between the two tracks.

Table 10. Effects in the Reduction of Comprehension Errors in Functions

Source	df	Mean Square	F	p-Value	Sig.
GROUP	1	.12	11.14	p=.00<0.05	S
TRACK	1	.07	6.98	p=.01<0.05	S
GROUP * TRACK	1	.04	3.99	p=.05>0.05	NS
Error	90	.01			

Table 11. Effects in the Reduction of Transformation Errors in Functions

Source	df	Mean Square	F	p-Value	Sig.
GROUP	1	.20	6.00	p=.02<0.05	S
TRACK	1	.10	2.92	p=.09>0.05	NS
GROUP * TRACK	1	.19	5.70	p=.02<0.05	S
Error	90	.03			

Also about the reduction of errors in limits and continuity, the grouping of the students, in favor of the flipped classroom, showed a significant effect in the decrease of transformation errors as shown in table 12. It must be noted that the flipped classroom group remarkably reduced this type of error while the traditional classroom group, unfortunately, increased such errors in the posttest. Also, the number of correct items increased for both groups but the difference between the means of such increase was not remarkable. The grouping, again in favor of the flipped classroom, also showed a significant effect in the reduction of unanswered items in the said topic.

Table 12. Effects in the Reduction of Transformation Errors in Limits and Continuity

Source	df	Mean Square	F	p-Value	Sig.
GROUP	1	2.48	38.14	p=1.87E-8<0.05	S
TRACK	1	.25	3.84	p=.05>0.05	NS
GROUP * TRACK	1	.31	4.85	p=.03<0.05	S
Error	90	.06			

In differentiation, the students' track, in favor of the non-STEM, showed a significant effect on the reduction of comprehension errors as shown in table 13. Although there was a significant difference in the transformation errors between the two groups and the two tracks of the students, this type of errors was noted to have increased from the pretest to the posttest for both groups and tracks. Similarly for procedural errors, the significant effect of the track to this type of error was, in fact, an increase instead of a reduction. The increase in the number of correct answers, however, was very notable for the flipped classroom group and the reduction of unanswered items of the non-STEM students was also very remarkable.

Table 13. Effects in the Reduction of Comprehension Errors in Differentiation

Source	df	Mean Square	F	p-Value	Sig.
GROUP	1	.00	.62	p=.43>0.05	NS
TRACK	1	.08	15.31	p=.00<0.05	S
GROUP * TRACK	1	.03	5.84	p=.02<0.05	S
Error	90	.01			

Lastly, in the applications, the students' group and track were found to have significant effects in the reduction of comprehension errors as shown in table 14. The flipped classroom group showed a better performance about such a reduction. A significant interaction between the effects of the group and the track of the students was also found in comprehension errors which implies that the number of errors committed by the students in each track depended on the group they belong to. The grouping of the students did not show any effect in the reduction of the other types of errors in the applications but it has shown a significant effect in the increase of correct answers. With positive means for both groups, the flipped classroom revealed a larger difference in this increase. Moreover, even though the two groups showed a decrease in the number of unanswered items in the posttest, the numbers were not found to be significantly different from each other. Nevertheless, the students' track showed a significant effect in such reduction wherein the STEM students showed a remarkable decrease in such items.

Table 14. Effects in the Reduction of Comprehension Errors

Source	df	Mean Square	F	p-Value	Sig.
GROUP	1	.06	12.92	p=.00<0.05	S
TRACK	1	.06	12.77	p=.00<0.05	S
GROUP * TRACK	1	.05	11.92	p=.00<0.05	S
Error	90	.00			

Conclusion

The flipped classroom is effective in the reduction of comprehension errors in functions, differentiation, and applications. Comprehension errors were found to be reduced in functions and in the applications where the non-STEM track had a significantly greater difference in the frequencies, while in differentiation the two tracks both have remarkable contributions. Although flipped classroom was found to be effective in the reduction of the comprehension errors in functions, differentiation, and applications, this grouping of the students only showed a significant effect in the reduction of such errors in functions and in the applications which meant that the students in the traditional classroom group performed almost in the same level with the students in the flipped classroom group in differentiation. Also, the flipped classroom group showed a significantly fewer transformation error in limits and continuity in the posttest which meant that the grouping of the students mattered when it comes to learning the said topics.

The lecture videos presented to the students were purely about the topics in the said course. Comprehension and transformation errors can be identified by focusing on how the learner understands the problem and how the answer is going to be found. Hence, these two types of errors were addressed by the flipped classroom approach. Procedural and encoding errors, on the other hand, were focused on how the solutions and answers were presented and written and may often involve recalling some basic mathematical concepts such as performing arithmetic operations and doing different algebraic manipulations. Although part of most solutions, the videos did not focus much on such concepts. Hence, these two types of errors were not found to be reduced.

The increase in the number of correct items means that some types of errors were transformed to correct answers which imply that the students learned the correct way of doing while the decrease in the number of unanswered items means that the students learned from nothing and that more students were trying to answer based on what they have learned in the process.

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