Flipped classroom and students' academic achievement in mathematics

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Abstract- Flipped classroom is one of the models that utilizes technology to provide instructional materials to students prior to the classroom sessions and uses class time to participate in meaningful learning activities. The present study primarily focuses on assessing and identifying the effectiveness of the flipped classroom approach in the academic performance of students in the subject of Mathematics in the Modern World. The experimental research design using the true control group pretest-posttest true-control group is adopted in this study. This study's participants are selected BSIT students from Quezon City University during the first semester of the 2019-2020 academic year, who are divided into two groups: the control group (50 students) and the experimental group (50 students). In determining the actual operation of the flipped classroom approach, selected faculty members of Quezon City University were asked to assess the effectiveness of the approach using the survey questionnaire. Results revealed that the flipped classroom approach in actual operations is highly effective, and there is a significant difference in the performance of the control and experimental groups after the conduct of the study. Based on the findings and conclusions of this study, it is recommended to adopt the flipped classroom approach as an alternative modality of teaching and learning.

Index Terms- Flipped classroom, Mathematics Education, Mathematics in the Modern World, Student Achievement

I. INTRODUCTION

Numerous scholars have suggested integrating technology into the curriculum due to the quick progress of educational technology and the good effects it has on students' ability to learn and comprehend concepts. To engage and inspire children to study mathematics in a more meaningful way, researchers and educators have been looking into new methodologies and teaching techniques. One of these options is the flipped classroom (Strelan, Osborn, & Palmer, 2020).

Many researchers define the flipped classroom model as one in which teachers use the time in the classroom to engage students in meaningful learning discussion activities and instructor-guided problem-solving instructions rather than having students watch lectures on video, read handouts, or watch online video lectures (Humrickhouse, 2021; Latorre-Cosculluela, et al. 2021; Wei, et al. 2020). Additionally, flipped classrooms provide students the freedom to learn at their own speed (Sosa Díaz, Guerra Antequera, & Cerezo Pizarro, 2021). As a result, the paradigm shifts from a teacher-centered to a student-centered approach occurs.

The amount of time allotted to each topic in traditional schools is the same for every student, however in flipped classrooms, a mastery learning approach is used, which requires that each student grasp a topic before moving on to the next (Strelan, Osborn, & Palmer, 2020).

Numerous scientific publications provide extensive research data on the utility of flipped classrooms in teaching and learning across a variety of disciplines, including statistics (Price & Walker, 2021), chemistry (Pienta, 2019), English (Seema & İrfana, 2019), nursing (Li, et al. 2020), and engineering (Bhat, et al. 2020). Studies, however, appear to be few when it comes to using the flipped classroom technique for Mathematics teaching and learning. As an example, as of right now, no such study has been carried out at the local university level.

Since the implementation of the New General Education Curriculum for tertiary level is now in place as instructed by the Commission on Higher Education in the Philippines, local studies that focus on the effects of flipped classrooms, specifically in learning mathematics, are found to be limited. To fill this gap, the present study examined the effects of flipped classroom models on the academic achievement of students taking mathematics courses, particularly at a local university in the Philippines.

This study may not seem so new, but it was able to provide concrete data and ideas on the effective teaching strategies in teaching mathematics to higher education, particularly in a local university like Quezon City University. It also paved the way for the researcher to explore the effects of a flipped classroom on students' achievement in mathematics, which is also a good topic for future research.

Generally, the study focuses on assessing and determining the effectiveness of the flipped classroom approach in the academic performance of students in the subject of Mathematics in the Modern World. In particular, it sought answers to the following research questions: (1) how effective is

the flipped classroom as used in the actual operation of the study in terms of objectives, learning content, presentation, usefulness, and student performance; and (2) how do students in the experimental and control groups perform in the post-test after the conduct of the study?

Considering the objectives of this study, the researcher hypothesizes that there is no significant difference between the post-test scores of the students between the experimental and control groups after the conduct of the study.

II. METHODOLOGY

2.1 Research Design

The study utilized an experimental research design utilizing the true control group pre-test-post-test true-control group design to determine the effects of the flipped classroom approach on students' learning in the subject Mathematics in the Modern World. The Pretest-Posttest Design was used to determine the performance of students after exposing students to the flipped classroom approach and it was used to measure or observe two groups before and after being exposed to a treatment (Fraenkel, Wallen, & Hyun, 2012). This design is far better than a one-shot case study because the researcher at least knows whether any change occurred.

The study was conducted at Quezon City University, a local university in Metro Manila, Philippines, during the Academic Year 2019–2020.

The content of the flipped classroom method for mathematics in the modern world was validated by mathematics professors and education experts at Quezon City University (QCU). In developing the content of the flipped classroom method, the instructional problem was clarified by analyzing prior knowledge of the students, followed by establishing instructional goals and objectives and the learning environment. After careful analysis, the researcher, together with the I.T specialist, creates and assembles the content assets that will be used in the experiment.

Prior to the experimental procedure, the researcher secured a letter of approval from the Department Head of the QCU Mathematics Department to conduct the study, and after the approval, the experimental procedure was conducted.

The researcher administered a pre-test to the students in the control and experimental groups to determine students' prior knowledge of the subject Mathematics in the Modern World before the start of the first semester and prior to the use of the method. After the pre-test, topics in Mathematics in the Modern World were taught based on the OBE Syllabus for the subject. The control group was exposed to a normal classroom lecture-discussion method, while students in the experimental group were exposed to a flipped classroom method.

In the flipped classroom method, the researcher provides learning materials (ex. lecture hand-outs, activity sheets, problem sets, reading materials, video lectures, and related online games) to the students prior to the discussion using the agreed online learning group (ex. Facebook Learning Group and Google Classroom). In the actual classroom meeting, the researcher conducts a short discussion that focuses on the difficulties and challenges faced by the students in doing the prior assigned task. The class hours were spent checking students' output, clarifying issues, and correcting misconceptions.

The method was utilized by the teacher throughout her lessons in Mathematics in the Modern World within the semester and was done regularly throughout the experimental period. After the experimental period, a post-test was given to the control and experimental groups to determine their performances in the class.

Respondents of the Study

The general population of this study refers to all students who are officially enrolled in Quezon City University taking up Bachelor of Science in Information Technology (BSIT) during the 1st Semester of the Academic Year 2019-2020 and under the direct supervision of the researcher.

The control group consists of fifty (50) students under SBIT01, while the experimental group will also consist of fifty (50) students under SBIT02. Moreover, student respondents should satisfy the following criteria: he or she should be a bona fide student at Quezon City University (QCU) and officially enrolled in the subject Mathematics in the Modern World during the first semester of the school year 2019-2020.

To determine the actual operation of the flipped classroom approach, a total of fifteen (15) faculty members from the Mathematics and Science Department of Quezon City University were asked to assess the effectiveness of the approach using the survey questionnaire.

Research Instrument

The study utilized pre-test and post-test instruments and a researcher-made survey questionnaire to answer the research questions posed in this study.

The pre-test and post-test used in the study adopted the 50-item achievement test used by the Mathematics and Science Department of Quezon City University (QCU) for the General Mathematics course and is composed of fifty (50) multiple-choice questions, each worth one (1) point. Most of the questions in the pre-test consist of problems requiring an understanding of basic definitions, concepts, and the use of single equations, while others may be more complex. The test covered the topics in General Mathematics based on the Curriculum Guide set by the Commission on Higher Education (CHED). A similar set of questions will be given to students after the exposure to the flipped classroom method, which will serve as the post-test.

To ensure the validity of the test questionnaire, the researcher asked for the help of her adviser to evaluate the content of the survey questionnaire in terms of its format, language used, and questions measuring the desired objectives. Suggestions and comments from the thesis adviser were properly documented and reflected in the second version of the survey questionnaire. In terms of reliability, a total of twenty-five (25) randomly selected students who will not be part of this study will be asked to answer the second version of the survey questionnaire. Using SPSS version 22, Cronbach's alpha test will be administered to determine the test's acceptability and reliability.

On the other hand, the researcher-made survey questionnaire was used to describe the actual operation of the flipped classroom approach. The survey questionnaire was based on the survey questionnaire by Tabunda (2018), which was validated through the Content Validity Index (CVI) involving five content experts and modified by the researcher to suit the sub-problems presented in this study. It consists of twenty-five (25) items which aim to determine the effectiveness of the flipped classroom method in terms of objectives, learning content, presentation, usefulness, and effects on students' performances as seen by the mathematics teachers at Quezon City University. Options for the response are presented in a Likert format where there are five choices provided for every question or statement, which represents the degree of agreement that each respondent had on the given question (5 – Very Highly Effective, 4 – Highly Effective, 3 – Effective, 2 – Moderately Effective, and 1 – Least Effective).

Data Processing and Statistical Treatment

After the retrieval of the survey questionnaires, the responses of the respondents will be tallied, tabulated, and analyzed. To further interpret the study's findings, collected data were processed using statistical software known as IBM SPSS Statistics version 22. The researcher utilized descriptive statistical tools such as frequency and central tendency to describe the distribution of the responses of the respondents to each question found in the survey questionnaire and the most common response of the respondents towards the effectiveness of the flipped classroom method in terms of objectives, learning content, presentation, usefulness, and effects on students' performances. And to determine if a significant difference exists between the scores of the students, the independent-sample t-test was used.

III. RESULTS AND DISCUSSION

Views on the actual operation of the flipped classroom approach to the subject Mathematics in the Modern World

The following tables show how mathematics and science faculty members of Quezon City University viewed the effectiveness of the flipped classroom method in the actual operation.

Table 1

Effectiveness of the Flipped Classroom Method in the Actual Operation in terms of Objectives

Criteria	Mean	V.I
1. Learning objectives are clearly stated in each lesson and is aligned to the New General Education Curriculum Guide.	4.00	Highly Effective
2. Learning objectives can change students' behavior and develop students to become 21st century life-long learners.	4.07	Highly Effective
3. Learning objectives provides learning opportunities and experiences.	4.13	Highly Effective
4. Learning objectives are appropriate within the student's level and can be achieved within a given timeframe.	4.20	Highly Effective
5. Learning objectives are complete and sufficient to improve students' performances and achievements in the Mathematics in the Modern World.	3.87	Highly Effective
Over-all Weighted Mean	**4.05**	**Highly Effective**

In terms of objectives, Table 1 shows that Mathematics and Science faculty members of Quezon City University view that the flipped classroom method is highly effective with a computed over-all weighted mean value of 4.05

In addition, Table 1 revealed that the teacher respondents viewed that the learning objectives of the lesson in the flipped classroom approach are appropriate within the student's level and can be achieved within a given timeframe are highly effective with a computed mean value of 4.20, the highest mean as far as the effectiveness of the flipped classroom method in the actual operation in terms of objectives is concerned. As Wei, et al (2020) states, the main feature of the flipped classroom involves moving the "transmission of knowledge" to outside the classroom and moving the "application of knowledge" into the classroom. An effective "flip" requires careful preparation by the educator; selecting appropriate learning goals and objectives (Humrickhouse, 2021); and an understanding of existing and emerging tools that are available to help support the out-of-class portion of courses (Sosa Díaz, et al. 2021).

Table 2

Effectiveness of the Flipped Classroom Method in the Actual Operation in terms of Learning Content

Criteria	Mean	V.I
1. Learning contents are sufficient and complete covering the topics based on the New General Education Curriculum Guide for the subject Mathematics in the Modern World.	4.13	Highly Effective
2. Learning contents provide opportunities and experiences to improve students' cognitive, psychomotor, and affective skills.	4.00	Highly Effective
3. Material consists of appropriate and relevant diagrams to enhance students' understanding and problem-solving skills.	4.40	Highly Effective
4. Material provides variety of activities that are suited to students' individual needs.	4.33	Highly Effective
5. Online material/s utilized are sufficient, properly presented and/or labelled, and relevant to the lesson or topic.	4.73	Very Highly Effective
Over-all Weighted Mean	**4.32**	**Highly Effective**

Table 2 shows the overall weighted mean of the responses of the respondents towards the effectiveness of the flipped classroom in the actual operation in terms of learning content, and as we glean from the table, it shows that respondents agreed that it was highly effective with a computed over-all mean value of 4.32. In terms of learning content on the effectiveness of the flipped classroom method in the actual operation, online material/s utilized in the flipped classroom approach were sufficient, properly presented and/or labeled, and relevant to the lesson or topic according to the respondents, with the highest

computed mean value of 4.73 and interpreted as very highly effective. Similarly, the study of Stöhr, et al (2020) into the use of flipped classrooms found that it is important for educators to take care in developing learning content and materials that allow students to come to class prepared and be ready with some questions they wish to discuss.

Table 3

Effectiveness of the Flipped Classroom Method in the Actual Operation in terms of Presentation

Criteria	Mean	V.I
1. Topics are presented in sequential manner based on the General Education Curriculum Guide for the subject Mathematics in the Modern World.	4.47	Highly Effective
2. Topics are well-organized so that teachers and students can use it properly and independently.	4.07	Highly Effective
3. Parts consists of lesson title, learning objectives, introduction, content, evaluation, and application.	4.00	Highly Effective
4. Diagrams, animation, videos, and links utilized can motivate students' interests, curiosity, and awareness.	4.47	Highly Effective
5. Presentation of mathematical concepts is simple and clear.	4.40	Highly Effective
Over-all Weighted Mean	**4.28**	**Highly Effective**

Table 3 shows the computed over-all weighted mean of the responses made by the respondents towards the effectiveness of the flipped classroom approach in the actual operation in terms of presentation, which is 4.28 and considered to be highly effective. Topics are presented in a sequential manner based on the General Education Curriculum Guide for the subject Mathematics in the Modern World and the diagrams, animation, videos, and links utilized can motivate students' interests, curiosity, and awareness. They both have the highest computed mean of 4.47 in terms of presentation on the effectiveness of the flipped classroom method in the actual operations, which are highly effective.

The above results support the claims that to facilitate successful flipped classrooms, educators need to accommodate students using a familiar and safe learning environment in the presentation of the lessons (Tang, et al. 2020), with appropriate supporting technology (Wannapiroon & Petsangsri, 2020). Lecturers get to create their lectures then post them online, in the form of podcasts, PowerPoint with voice, videos, and so forth. Pre-class work by students also frees up more time for educators to focus on discussions, further reinforcing students' understanding and allowing them to provide more hands-on activities for students to be engaged in active, problem-solving-based learning (Strelan, Osborn, & Palmer, 2020).

In terms of usefulness, respondents viewed that the flipped classroom approach in the actual operation is highly effective, as shown in Table 4 with a computed over-all weighted mean value of 4.29.

Table 4

Effectiveness of the Flipped Classroom Method in the Actual Operation in terms of Usefulness

Criteria	Mean	V.I
1. The instructional material is very useful in developing students' cognitive, exploratory, and affective skills, and understanding of mathematics concepts and principles.	4.20	Highly Effective
2. The instructional material is very useful to improve students' achievement.	4.53	Very Highly Effective
3. The instructional material widens and deepens students' mathematical and logical ability.	4.13	Highly Effective
4. The material is activity-oriented so that the students can work and apply what they have learned in everyday life.	4.33	Highly Effective
5. The material is useful in applying various teaching strategies to meet students' needs and level of capabilities.	4.27	Highly Effective
Over-all Weighted Mean	**4.29**	**Highly Effective**

Similarly, the usefulness of the flipped classroom approach to students is that they can access class materials outside of class time at a time and location convenient to them (Pienta, 2019; Price & Walker, 2021). Thus, flipped classrooms allow students to take greater responsibility for their own learning in a space where they have greater independence and experimentation (Seema & İrfana, 2019). Flipped lectures enable students to review lessons in whole or in part, as many times as they want to grasp concepts (Li, et al 2020).

Strelan, Osborn, and Palmer (2020) in their meta-analysis study note that students learn best when they are given the opportunity to expand on knowledge acquired through flipped lectures in in-class activities that promote greater creative and higher-level thinking. Students who have difficulties with activities in-class can also benefit from peer support and allow lecturers to gain a better insight into which students require assistance.

Table 5

Effectiveness of the Flipped Classroom Method in the Actual Operation in terms of Effects to Students' Performance

Criteria	Mean	V.I
1. Content and evaluation are sufficient to determine if transfer of learning occurs.	4.53	Very Highly Effective
2. Develop enthusiasm among learners.	4.60	Very Highly Effective
3. Improved students' academic performance in the subject.	4.60	Very Highly Effective
4. Motivates the learner to explore more and develop self-confidence and inquiry.	4.67	Very Highly Effective
5. Allow students to become creative and critical thinker.	4.33	Highly Effective
Over-all Weighted Mean	**4.55**	**Very Highly Effective**

In terms of the effects on students, respondents agreed that the flipped classroom approach is very highly effective, as revealed by the over-all weighted mean of their responses shown in Table 5, and the computed over-all mean is 4.55. Specifically, respondents agreed that the flipped classroom approach is very effective in motivating learners to explore more and develop self-confidence and inquiry (Mean, 4.67). In addition, respondents agreed that the flipped classroom approach is very highly effective in developing enthusiasm among learners and in improving students' academic performance in the subject (Mean, 4.60).

Table 5 also revealed that respondents agreed that the flipped classroom approach is very highly effective when it comes to completeness and appropriateness of the content and evaluation in determining the occurrence of transfer of learning among learners, with a computed mean value of 4.53. Lastly, respondents agreed that the flipped classroom approach is highly effective (Mean, 4.33) in allowing students to become creative and critical thinkers.

The above results contribute to the many benefits (yet potential challenges) of flipped classrooms for lecturers and students in that, if implemented effectively, flipped classrooms can bring a degree of authenticity to students' learning through real-life examples used and worked through by the lecturer and students in in-class activities. Authentic learning allows students' learning to be defined in terms of real-world relevance as well as provide a greater purpose and motivation to learn (Strelan, Osborn, & Palmer, 2020). Authentic learning that is facilitated using authentic contexts enables knowledge to be applied to real-life problems.

Humrickhouse (2021) argues that flipped classrooms should provide students with in-class activities that involve the use of specific techniques applied to new problems. Doing hands-on activities provided opportunities for students to reflect on the relevance of the course content to their professional goals, while group activities enable students to work in teams to develop teamwork and oral communication skills, which also become additional assets for employability and career success (Seema & İrfana, 2019).

As a result, students in the flipped classroom approach were able to devote much of the class time to problem-solving, allowing them to present their solutions to solve problems; as a result, students in the flipped classroom group performed as well as or better on all problems, and performed better on problems involving designs than their traditional lecture group peers.

Table 6

Summary of the Effectiveness of the Flipped Classroom Method in the Actual Operation in teaching the subject Mathematics in the Modern World

Criteria	Mean	V.I
Objectives	4.05	Highly Effective
Learning Content	4.32	Highly Effective
Presentation	4.28	Highly Effective
Usefulness	4.29	Highly Effective
Effects to Students' Performance	4.55	Very Highly Effective
Over-all Weighted Mean	**4.30**	**Highly Effective**

Table 6 revealed that the views of the respondents towards the effectiveness of the flipped classroom approach in teaching Mathematics in the Modern World and in actual operations is highly effective in terms of objectives, learning content, presentation, usefulness, and effects to students' performance with computed over-all weighted mean of 4.30.

The table reveals that in terms of the effects of the flipped classroom approach on the performances of the students in the actual operations and teaching the subject Mathematics in the Modern World, the respondents agreed that it was very highly effective with a computed mean value of 4.55. On the other hand, in terms of learning content (Mean, 4.32), usefulness (Mean, 4.29), presentation (Mean, 4.28), and objectives (Mean, 4.05), the flipped classroom approach is highly effective, according to the faculty members of the Mathematics and Science Department at Quezon City University.

While flipped classrooms can have many benefits for addressing the ways educators teach and the ways in which students learn, certain challenges are associated with the implementation of flipped classrooms.

The time-consuming nature of the set-up required for a flipped classroom and student frustration at being responsible for their own learning can all contribute toward less-than-successful cases of flipped learning (Strelan, Osborn, & Palmer, 2020). Nevertheless, with careful design and implementation, flipped classrooms can play a key role in modernizing education in the higher education sector by freeing up more time for lecturers to design learner-centered activities and, in turn, encourage students to become independent self-learners who are able to apply knowledge and skills to solve real-world problems in their future careers and lives.

Comparison between the post-test performances of the experimental and control groups

Table 7 shows the t-test results between the post-test scores of the control and experimental groups after the conduct of this study.

Table 7

t-test result of the Post-test scores of the Control and Experimental Groups

Group	N	$\bar{X}$	p-val.	t-val.	Interpretation	Decision
Control	50	24.26	0.00	3.27	Statistically	Reject
Experimental	50	27.16			Significant	the H_0

*Significant Level 0.05
*Degrees of Freedom 98

The mean score of each test signifies that the students' performances in the experimental group show a significant increase after the conduct of this study as compared with the performance of students in the control group.

It is important to note that after the conduct of this study and the implementation of the flipped classroom approach, the performance of the students in the experimental group shows a significant improvement in the subject Mathematics in the Modern World. The table shows that the control group obtained a mean score of 24.26, which is considered below the passing mark of the total number of correct items, while the mean score obtained by the experimental group, which is 27.16, indicates a score above the passing mark.

Table 7 shows that the group's computed t-value at the 0.05 level of significance is $t(98) = 3.27$, $p<.05$.By conventional criteria, the computed t-value is statistically significant. This means that the performance of the two groups in their post-test is not the same after the conduct of this study. Therefore, the results

of the independent sample t-test reject the null hypothesis of this study, stating that there is no significant difference in the performance of the students in their post-test scores prior to the conduct of the study.

The significant change, either positive or negative, in the performance of students before and after the experimental study denotes that the application of the treatment to the experimental group has a greater effect on the variables being measured (Fraenkel, Wallen, & Hyun, 2013).

IV. CONCLUSION

The study revealed that the views of the respondents towards the effectiveness of the flipped classroom approach in teaching Mathematics in the Modern World and in actual operations are highly effective in terms of objectives, learning content, presentation, usefulness, and effects on students' performance, with a computed over-all weighted mean of 4.30.

The mean score of the post-test signifies that the students' performances in the experimental group show a significant increase after the conduct of this study as compared with the performance of students in the control group. It is important to note that after the conduct of this study and the implementation of the flipped classroom approach, the performance of the students in the experimental group shows a significant improvement in the subject Mathematics in the Modern World. The group's computed t-value at the 0.05 level of significance is $t(98) = 3.27$, $p<.05$.By conventional criteria, the computed t-value is statistically significant. This means that the performance of the two groups in their post-test is not the same after the conduct of this study.

Based on the analysis of the performance of the students after the conduct of this study, the flipped classroom approach served as an effective alternative method in enhancing and developing students' cognitive skills and improving the teaching-learning process.

Specific implications drawn from the findings of this study are: (1) Objectives are achieved within the given time frame; (2) Simple technology; (3) Efficient and effective utilization of instructional material; (4) Motivate students to learn; (5) Management of the sequence and flow of the lecture; (6) Improve students' achievement; and (7) Motivate the learner to explore more and develop self-confidence and inquiry. Aside from the positive implications of the flipped classroom found in this study, there are several challenges that can be noted for the use of the flipped classroom approach, such as creating a digital divide among learners, dependence on preparation and trust, and an increase in the time in front of the computer screens instead of people and places.

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