Implementing a Flip-Flop Teaching Model in Thermal Physics for Engineering Students

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Emil C. Alcantara
Faculty, General Engineering Department, Batangas State University, Batangas City, Philippines
alcantara_emil0204@yahoo.com

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Abstract *– Implementing flip-flop teaching in a physics classroom allows students to learn concepts outside of the classroom and apply what they learn in the classroom, working with other students and getting immediate feedback from the instructor. The purpose of this study was to determine the effect of flip-flop teaching in the performance of engineering students in introductory physics particularly in thermal physics. The study employed descriptive and quasi-experimental method to describe and compare the performance of engineering students in thermal physics when grouped according to sex and types of instruction. Three physics classes consisting of 125 sophomore engineering students at the Batangas State University during the second semester of the SY 2013-2014 were handled by the researcher and selected purposively as participants of the study. It was found out that the variation in the performances of male and female students in the conceptual questions, in the problem solving questions, and overall performance in thermal physics are not significantly different. Male and female students have an overall satisfactory performance in thermal physics. The study also revealed that the variation in the performances of the students in the conceptual questions, in the problem solving questions, and overall performance in thermal physics when grouped according to the types of instruction are not significantly different. Engineering students taught in a traditional physics classroom, in a flipped physics classroom, and in an enhanced-flipped physics classroom are more likely to have similar performances in thermal physics.*

Keywords *– engineering students, flip-flop teaching, physics performance, sex, thermal physics*

INTRODUCTION

Flip-flop teaching, or reverse teaching, flipped classroom, flipped learning, and inverted learning, is an instructional strategy that commonly involves deliberately planning to introduce new information as homework instead of teaching it in class [1]. In reverse teaching, students learn new content at home (as homework) and class time is used for working on problems. A reverse classroom also provides a convenient way to correct homework. Teachers are often pressed to spend class time correcting homework because it squeezes out instruction time. Teachers need a certain amount of class time for instruction in order to move the class. Since a bulk of the instruction is moved outside of normal class time, there is less pressure to skip or minimize homework corrections.

The Flipped Classroom is one part of a larger inquiry or instruction cycle, not a panacea or stand-alone magic bullet for instruction. It overlaps with other instructional tools such as: Reverse Instruction, Inquiry Learning, Universal Design for Learning, Blended Learning, and Online Instruction through the use of podcasting or screencasting, Web 2.0 resources, and inquiry activities. Screencasts as instructional tools can be used in many different ways: pre-teaching, front-loading instruction, remediation, extension, providing students with feedback, student created content, etc.[2].

Some innovative teachers are turning the traditional classroom model on its head in an effort to make instruction more valuable to their students. This new teaching and learning style, often called “flipped” or “inverted” learning, makes the students the focus of the class, not the teacher, by having students watch a lecture at home and then apply the lesson with the teacher in the classroom [3]. With inverted learning, these forward-thinking educators say, students can absorb the material as homework and then practice what they have learned with guided help from the teacher if they need it. This new learning style not only makes class time more productive for both teachers and students, but also increases student engagement, increases achievement, and caters to all forms of personalized learning, say the teachers. Although this style of learning might be termed "inverted," perhaps it's the current style of learning with teachers as the "sage on the stage" that is backwards.

In the article of Saltman [4], the experience of a high school science teacher Shelley Wright in the implementation of flip-flop teaching were presented. Since the teacher began 'flipping' lectures and homework assignments, it was noticed that the number of students failing the course has dropped from the usual three to zero and the departmental exam scores are higher, too. The teacher introduces a topic in class through activities or groupwork, and then asks students to watch a related lecture from the not-for-profit tutorial creator or from the conference website for homework

In the article of Jac de Haan [5], several advantages of this model of teaching were presented. In flipped teaching an educator does not need to guess at what speed to deliver content – with students watching lectures at home, they can move at their own speed and review concepts as necessary and without large portions of classroom time spent lecturing. Also, educators can use that time to see students working through projects and assignments that would have previously been done in isolation at home: break-out sessions can occur spontaneously, students can work in mentor-based groupings, jigsaw opportunities, supplemental support, etc.

The implementation of flip-flop teaching model paved way for a better learning. The advantage of the flipped classroom is that the content, often the theoretical/lecture-based component of the lesson, becomes more easily accessed and controlled by the learner [6]. In this flipped model of instruction, some or most of direct instruction is delivered outside the group learning space using video or other modes of delivery. The shift is from a teacher-centered classroom to a student-centered learning environment. In the traditional teacher-centered model, the teacher is the main source of information. In the Flipped Learning model, there is a deliberate shift from a teacher-centered classroom to a student-centered approach, where in-class time is meant for exploring topics in greater depth and creating richer learning opportunities through various student-centered pedagogies. As a result, students are actively involved in knowledge formation through opportunities to participate in and evaluate their learning in a manner that is personally meaningful [7].

Recent advances in educational software and internet-based instruction have been exploited to develop inverted classrooms in engineering education. In 2009, Dollár and Steif [8] presented an inverted classroom model for engineering statics, delivered via the Open Learning Initiative (OLI). Inspired by this work, Papadopoulos [9] designed and implemented an inverted model for his sections of statics at the University of Puerto Rico, Mayagüez (UPRM) for Fall 2009. Excited by positive student feedback and his own impressions of its effectiveness, he continues to use the inverted method in statics (Spring 2010), and has also implemented an Inverted model to deliver a75-minute seminar in Engineering Ethics to UPRM freshman.

In the study of Warter-Perez and Dong [10,11], the freshman/sophomore introduction to digital engineering course are subjected to flipped teaching some of the time through Collaborative Project-Based Learning (CPBL). It was found out that less lecturing can actually lead to more effective learning, with the integration of various active learning components streamlined with class curriculum. It is important to balance between lectures and other learning components including in-class projects, discussions, real-time assessments, and interactive exercises. The structure of the revised curriculum presented in this paper has been classroom tested and can serve as a guideline to of how to effective integrate CPBL in freshman and sophomore level courses in other similar institutions.

In a new synthesis of past work, researchers found that women consistently score lower than men on common assessments of conceptual understanding of physics. However, when examining the factors that may account for these differences (such as student background and test-taking strategies), no clear pattern emerged [12]. Many changes have been made in college science instruction in the past decades. Numerous classrooms have shifted from a traditional lecture presentation to more interactive formats that aim to engage students in building their own knowledge. Physics has been a forerunner of this movement, in part because of early and ongoing research on how students grapple with key ideas in this difficult field. Comparisons of student understanding have been made possible through the development of "concept inventories" – multiple choice tests of student understanding, developed through years of research, enabling the same test to be given to students in a variety of classrooms. While there is a gender gap in performance on concept inventories, the performance of both men and women is improved when they experience an interactive classroom.

Based on the analysis of 26 published articles comparing the impact of 30 factors that could potentially influence the gender gap on concept inventories in physics, no single factor is sufficient to explain the gap[13]. Other factors such as gender differences in background preparation, scores on different kinds of assessment, and splits between how students respond to test questions do contribute to a difference between male and female responses. This was supported by other studies on gender differences in physics [14,15].

On the onset of the implementation of the outcome-based education in all engineering programs at the Batangas State University, it is imperative that students learn the thinking process that gets used in STEM(science, technology, engineering, mathematics) subjects. In this new era in which proficient problem solvers that can communicate and collaborate are absolutely crucial not only for our country, but also our world, students need guided practice in developing problem-solving skills. To prepare the teachers in this new classroom set-up, the General Engineering Department conducted series of seminar-workshop about outcome-based education.

Concerned for quality instruction and the experience of the researcher in teaching physics and mathematics among engineering students prompted the researcher to conduct an initial study about the implementation of flip-flop model of instruction at the Batangas State University. The results of this study can be used as initial data regarding the effect of the flip-flop model of teaching in the student's performance in introductory physics. The educational value of flipping the classroom is to allow the students to apply what they are learning, to engage them in the learning process, and to energize the classroom.

OBJECTIVES OF THE STUDY

This initial study aimed to determine the effect of flip-flop teaching in the performance of engineering students in introductory physics particularly in thermal physics.

Specifically, it sought to determine the performance of male and female students in terms of conceptual thermal physics test; problem solving thermal physics test and thermal physics as a whole; to determine the performance of the students in thermal physics under the following types of instruction: traditional, flipped and enhanced-flipped; to determine the significant difference between the students' performance in thermal physics when grouped according to sex and types of instruction.

MATERIALS AND METHODS

This is a descriptive and quasi-experimental study seeking to determine and compare engineering students' performance in a calculus-based physics course particularly in the topics of thermal physics. It particularly identify differences of students' performances in conceptual thermal physics test, performances in problem solving thermal physics test, overall performances in thermal physics, when grouped according to sex (male or female) and types of instruction.

The study made use of purposive sampling. Prior to the selection of the participants in the inverted classrooms, the researcher conducted a survey among his classes to determine those students with internet access. Three physics sections of 125 sophomore engineering students at the Batangas State University in the main campus were used as participants of the study. Section 1 consisting of 42 students was handled using the traditional instruction which served as the control group. Section 2 consisting of 42 students was handled using the flipped classroom instruction. Section 3 consisting of 41 students was handled using the enhanced-flipped classroom instruction.

The students' performances in the conceptual thermal physics test and in the problem solving thermal physics test were determined from their scores in the midterm examination in Physics-2. The overall performance in thermal physics was determined from the students' midterm grade calculated from midterm examination, quizzes, homework exercises, and laboratory performance. Only the students' grades were available as a measure of their physics performance and used as the dependent variable. At the Batangas State University, all engineering students were regarded as having similar science and mathematics background. The participants were taught by the same physics professor and hence they were assessed using the same tests. In this study, the students' performances which were based from scores and grades were transmuted to numerical grade point and were given a corresponding equivalent score as follows: a numerical grade of 1.0 is given an equivalent of 1; grades of 1.25, 1.5, and 1.75 are given an equivalent of 2; grades of 2.0, 2.25, 2.5 are given equivalent of 3; grades of 2.75 and 3.0 are given an equivalent of 4; and grades of 5.0 is given an equivalent of 5. The mean of the students' performances were interpreted as follows: 1.0 – 1.79=Outstanding; 1.80 – 2.59 = Very Satisfactory; 2.60 – 3.39 = Satisfactory; 3.40 – 4.19 = Fair; and 4.20 – 5.0=Poor.

At the Batangas State University, traditional engineering physics classes were handled by an instructor/professor using lecture method for 4 hours per week and 3 laboratory hours per week. Quizzes were given to test the conceptual understanding of the students per chapter. Problem sets per chapter consisting of 10 conceptual questions and 5 problem solving type of questions were given as homework exercises which were due a week after. The traditional physics instruction was implemented in section 1. In this study, the researcher asked the permission from the dean to implement a flip-flop teaching of thermal physics. Two variations of this type of instruction were implemented. The first one is the flipped physics classroom which flip-flop the instruction. The lectures were sent to the students of section 2 via email two days before the actual schedule while the problem sets were discussed in class. The second variation of flip-flop teaching was named as enhanced-flipped physics classroom which was implemented in section 3. This type of instruction was inspired by Dollár and Steif's presentation at the 2009 ASEE Conference [8]. They designed and implemented a new Inverted Classroom with the following three basic components: (1) Pre-Lecture Modules, consisting of PowerPoint slides accompanied by Exercises (usually online and graded), delivered via email and completed prior to Lecture; (2) Lecture, focused discussion and activities leveraging the prior exposure gained in the pre-lecture Modules and Exercises;(3) Post-Lecture Problem-Solving Session after each Lecture (twice per week), encouraging students to initiate homework and related help-seeking activities.

Data were analyzed using SPSS 18 statistical analysis program. Means and standard deviations were determined. The t-test and ANOVA among the means were conducted.

RESULTS AND DISCUSSION

As shown in Table 1, the male performance in conceptual thermal physics test has a mean of 3.66 with standard deviation of 1.416. This indicates that male students have a fair performance in conceptual thermal physics test. The female performance in conceptual thermal physics test has a mean of 3.98 with standard deviation of 1.350. This indicates that female students have a fair performance in conceptual thermal physics test. As a whole, the engineering students' performance in conceptual thermal physics test has a composite mean of 3.79 with standard deviation of 1.393 which indicates that they performed fairly. The fair performance of the students can be attributed to their misconceptions of some terms in thermal physics like heat, thermal energy and temperature.

Table 1. Students' Performances in Thermal Physics When Grouped According to Sex

Aspects	Sex	Mean	SD	VI
Conceptual Test	Male	3.66	1.416	Fair
	Female	3.98	1.350	Fair
	Composite	3.79	1.393	Fair
Problem Solving Test	Male	3.34	0.961	Satisfactory
	Female	3.50	0.918	Fair
	Composite	3.41	0.943	Fair
Thermal Physics (overall)	Male	3.27	1.071	Satisfactory
	Female	3.37	1.030	Satisfactory
	Composite	3.31	1.050	Satisfactory

In terms of problem solving thermal physics test, Table 1 shows the male performance has a mean of 3.34 with standard deviation of 0.961. This indicates that male students have a satisfactory performance. The female performance in problem solving thermal physics test has a mean of 3.50 with standard deviation of 0.918. This indicates that female students have a fair performance. As a whole, the engineering students' performance in problem solving thermal physics test has a composite mean of 3.41 with standard deviation of 0.943 which indicates that they have a fair performance. The relatively fair performance of the students in problem solving can be attributed to the students' conceptual understanding of thermal physics problem and their mathematics background.

For the overall thermal physics performance, Table 1 shows that the male students' overall performance has a mean of 3.27 with standard deviation of 0.961. This indicates that male students have an overall satisfactory performance. The female students' overall performance in thermal physics has a mean of 3.37 with standard deviation of 1.030. This indicates that female students have an overall satisfactory performance. As a whole, the engineering students' overall performance in thermal physics has a composite mean of 3.31 with standard deviation of 1.050 which indicates that they have an overall satisfactory performance.

Table 2. Students' Performances in Thermal Physics When Grouped According to Types of Instruction

Aspects	Types of Instruction	Mean	SD	VI
Conceptual test	Traditional	3.48	1.401	Fair
	Flipped	3.79	1.457	Fair
	Enhanced	4.12	1.269	Fair
	Composite	3.79	1.393	Fair
Problem Solving Test	Traditional	3.21	0.842	Satisfactory
	Flipped	3.45	1.041	Fair
	Enhanced	3.56	0.923	Fair
	Composite	3.41	0.943	Fair
Thermal Physics (overall)	Traditional	2.98	0.975	Satisfactory
	Flipped	3.45	1.131	Fair
	Enhanced	3.51	0.978	Fair
	Composite	3.31	1.050	Satisfactory

As shown in Table 2, the students attending the traditional physics classroom has a mean performance of 3.48 with standard deviation of 1.401 which indicates a fair performance in conceptual thermal physics test. The students attending a flipped physics classroom has a mean performance of 3.79 with standard deviation of 1.457 which indicates a fair performance in conceptual thermal physics test. The students attending an enhanced-flipped physics classroom has a mean performance of 4.12 with standard deviation of 1.269 which indicates a fair performance in conceptual thermal physics test. As a whole, the engineering students' performance in conceptual thermal physics test has a composite mean of 3.79 with standard deviation of 1.393 which indicates that they have a fair performance.

In terms of the students' performances in problem solving test, Table 2 shows that the students attending the traditional physics classroom has a mean performance of 3.21 with standard deviation of 0.842 which indicates a satisfactory performance in problem solving thermal physics test. The students attending a flipped physics classroom has a mean performance of 3.45 with standard deviation of 1.041 which indicates a fair performance in problem solving thermal physics test. The students attending an enhanced-flipped physics classroom has a mean performance of 3.56 with standard deviation of 0.923 which indicates a fair performance in problem solving thermal physics test. As a whole, the engineering students' performance in problem solving thermal physics test has a composite mean of 3.41 with standard deviation of 0.943 which indicates that they have a fair performance.

In terms of the overall students' performance in thermal physics, Table 2 shows that the students attending the traditional physics classroom have an overall mean performance of 2.98 with standard deviation of 0.978 which indicates an overall satisfactory performance in thermal physics. Students attending a flipped physics classroom have an overall mean performance of 3.45 with standard deviation of 1.131 which indicates a fair performance in thermal physics. Students attending an enhanced-flipped physics classroom have an overall mean performance of 3.51 with standard deviation of 0.978 which indicates an overall fair performance in thermal physics. As a whole, the engineering students' overall performance in thermal physics has a composite mean of 3.31 with standard deviation of 1.050 which indicates that they have an overall satisfactory performance.

Table 3. T-test Analysis of the Difference Between the Students' Performances in Thermal Physics When Grouped According to Sex

Aspects	t-value	p-value	Decision Ho	Interpretation
Conceptual Test	-1.282	0.202	Do not Reject	Not Significant
Problem Solving Test	-0.920	0.359	Do not Reject	Not Significant
Thermal Physics (overall)	-0.478	0.633	Do not Reject	Not Significant

$\alpha = 0.05$ level of significance

In terms of the conceptual test, Table 3 shows that the computed t-value of -1.282 with a p-value of 0.202 ($p>0.05$) indicates that the null hypothesis is not rejected. Male and female engineering students are more likely to have similar performance in conceptual thermal physics test.

In terms of problem solving test, Table 3 shows the mean performance of male students is 3.34 (satisfactory) while that of the female students is 3.50 (fair). The table also shows that the computed t-value of -0.920 with a p-value of 0.359 ($p>0.05$) indicates that the null hypothesis is not rejected. Male and female engineering students are more likely to have similar performance in problem solving thermal physics test.

In terms of the overall thermal physics performance, Table 3 shows the mean performance of male students is 3.27 (satisfactory) while that of the female students is 3.37 (satisfactory). The table also shows that the computed t-value of -0.478 with a p-value of 0.633 (p>0.05) indicates that the null hypothesis is not rejected. Male and female engineering students are more likely to have similar overall performance in thermal physics. The non-significant difference between the male and female students' performances in thermal physics is consistent with the findings of the previous study [16] indicating that gender difference does not exist in terms of students' achievement in critical thinking test in physics.

Table 4. Difference Among the Students' Performances in Thermal Physics When Grouped According to Types of Instruction

Aspects	F-value	p-value	Decision	Interpretation
Conceptual Test	2.276	0.107	Do not Reject Ho	Not Significant
Problem Solving Test	1.485	0.231	Do not Reject Ho	Not Significant
Thermal Physics (overall)	3.392	0.057	Do not Reject Ho	Not Significant

$\alpha = 0.05$ level of significance

As seen in Table 4, the computed F-value of 2.276 with a p-value of 0.107 (p>0.05) indicates that the null hypothesis is not rejected. Students taught under a traditional physics classroom, under a flipped physics classroom, and under an enhanced-flipped physics classroom are more likely to have similar performance in conceptual thermal physics test. Implementing an inverted classroom or flipping the classroom can be an alternative to traditional classroom in teaching concepts about thermal physics among engineering students.

In terms of problem solving test, Table 4 shows the computed F-value of 1.485 with a p-value of 0.231 (p>0.05) which indicates that the null hypothesis is not rejected. Students taught under a traditional physics classroom, under a flipped physics classroom, and under an enhanced-flipped physics classroom are more likely to have similar performance in problem solving thermal physics test. Implementing an inverted classroom or flipping the classroom can be an alternative to traditional classroom in handling problem solving sessions in thermal physics among engineering students.

In terms of the overall thermal physics performance, Table 4 shows the computed F-value of 3.392 with a p-value of 0.057 (p>0.05) which indicates that the null hypothesis is not rejected. Students taught under a traditional physics classroom, under a flipped physics classroom, and under an enhanced-flipped physics classroom are more likely to have similar overall performance in thermal physics. Implementing an inverted classroom or flipping the classroom can be an alternative to traditional classroom in teaching thermal physics among engineering students.

In the implementation of the flip-flop classroom, students indicated some difficulty with taking notes in class because traditional lecturing was not done at the board. In addition, the instructor noticed that when exercises were given in the lecture session, too much time was consumed by students drawing or writing the problem before starting it. The instructor now provides some problem templates prior to lecture so that students can come to class with the problem already copied or printed. From an instructional viewpoint, the instructor observed an increase in student attention to the coursework compared with other courses taught in a more traditional manner. In addition, the flipped classroom allowed the instructor more time to provide activities during the class session compared with traditional settings. This allows a better implementation of the instructor's philosophies of structured problem-solving procedures and multiple-method problem solving (solving a given problem by more than one method and comparing the alternative methods). The instructor acknowledges spending a great amount of time to create the modules and exercises from scratch (probably 6-8 hours per week). It was only about 3 hours per week were required to update the modules, exercises, and homework assignments. Up to one additional hour per week is spent in reviewing student performance on the pre-lecture exercises.

Although the findings of the study showed that the student's overall performances in thermal physics when taught in a traditional classroom, in a flipped classroom, an in an enhanced-flipped classroom are not significantly different, the researcher recommends the enhanced-flipped classroom as an alternative class management strategy. All preparations for lecture are completed at least 48 hours in advance, save for a brief time spent reviewing the student performance immediately prior to lecture, and the instructor never has to cram to prepare notes just before class. The modules and exercises also allow for a clear way to deliver the course schedule and scaffold graded exercises.

CONCLUSION AND RECOMMENDATION

Engineering students have fair performance in conceptual test and in problem solving thermal physics test. The overall performance (which includes examinations, quizzes, problem sets, and laboratory output) of the engineering students in thermal physics is generally satisfactory. Male and female engineering students are more likely to have similar performance in conceptual thermal physics test, in problem solving thermal physics test, and in their overall performance in thermal physics. Engineering students taught under a traditional physics classroom, under a flipped physics classroom, and under an enhanced-flipped physics classroom are more likely to have similar performance in conceptual thermal physics test, in problem solving thermal physics test, and in their overall performance in thermal physics. Implementing an inverted classroom or flipping the classroom can be an alternative to traditional classroom in teaching thermal physics among engineering students.

The General Engineering Department of the Batangas State University manages the physics courses that are required for all baccalaureate engineering students. The department is beginning to conceive a common module approach to standardize the teaching of physics. As part of this development process, the flip-flop classroom model presented here will be evaluated by other teachers for use in delivering the common modules. The department plan to work with the IT staff to increase sophistication using Moodle. During the coming year, the department hopes to conduct a more thorough evaluation of both the implemented flip-flop system and that from other inverted classroom model, and ultimately determine which platform is most appropriate for use by physics teachers in the department. However, regardless of which system is used, there is a favorable impression of the inverted classroom model, and plan to continue its use with an appropriate platform. A follow-up study will be conducted to assess the effectiveness of this new platform.

There have been many similar studies investigating the gender gap in physics, yet there are still many open questions. It is still unknown why the gender gap increases from pre- to posttest in some courses and not others. It is not clear if these differences in gender gap result from characteristics of the teacher, e.g. the gender of the instructor or some kind of instructor gender bias. It is not well understood how the level of interactivity of the teaching method influences the gender gap and if it does, what specific aspects of the method are most important. Another open question is how the dynamics of student interactions and attitudes influences the gender gap. It is also unclear how stereotype threat influences female physics students and how can this effect be mitigated consistently. These questions should be investigated in future studies and the gender gap on concept inventories should not be considered a well understood or solved problem. The researcher call for other researchers to devote additional attention to investigating the underlying causes of this gender gap and possible interventions.

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