Asia-Pacific Journal of Science and Technology: Volume: 23. Issue: 02. Article ID.: APST-23-02-01. Research Article

APST

Asia-Pacific Journal of Science and Technology

https://www.tci-thaijo.org/index.php/APST/index

Published by the Faculty of Engineering, Khon Kaen University, Thailand

Project based learning and team-based learning for freshmen physics at Southern Taiwan university of science and technology

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Abstract

Many technical universities in Taiwan face a challenge on students lacking interest in traditional classroom learning. This article presents the preliminary results of the course transformation for the freshmen Physics class at Southern Taiwan University of Science and Technology. The class STUST 2025 is a pilot class that aims to provide students with a more hands-on approach to acquire knowledge by performing team-based learning and project-based learning approach for various courses and project courses every semester. Participants for this special class included 50 students who were divided into 10 groups and assigned specific Physics topics as a guideline for their projects. Students are required to discuss and submit a proposal during the midterms and the final project and report at the end of the semester. Students are evaluated base from their performance in making the projects and the contents of the submitted documentation. The pilot course showed that although this course change breaks away from the student's traditional learning environment, they were able to learn to work in teams and learn from their respective projects. Learning includes the challenges of working with others in accomplishing a project together. It also provided students a deeper understanding of theories and its applications in actual settings through studying differences in the results of the theoretically calculated values and the actual experimental values. However, in order to have a more holistic learning approach, improvements on the current practice will be done such as providing additional homework and short quizzes. Eventually this kind of practice will be implemented university wide.

Keywords: Physics, Team-based learning (TBL), Project-based learning (PBL), Curriculum transformation

1.Introduction

The learning environment for technical universities in Taiwan is challenged by the need of a reform to adequately provide decent jobs to its graduates. However, increasing unemployment and lack of skilled laborers have been attributed to a steep decline in students interested in going to vocational schools [1]. This decline then directly affects the number of prospective students in the university level. Subsequently, it was found in recent years that a different pedagogic approach in the form of project based learning (PBL) makes passive learners become active learners because of the incessant need to acquire knowledge themselves [2]. It was also studied by Chuang et al. that hands-on or practical skill development for vocational school students enhances their learning, motivation and engagement [3]. Project based approach mixed with traditional "chalk and talk" showed promising results to approach engineering education especially in the early years. A good combination of teaching methods while ensuring the engineering fundamentals is necessary to better equip today's engineering students [4].

In a typical Physics lecture class student are required to sit down, open their text books, get their notebooks and listen to hours of lectures by the professor. These lectures would include PowerPoint presentations with the theory, examples and answers to the problems. This seemingly typical learning environment is conducive for those who have a strong passion and drive for the topic. However, students from technical high schools often has very few background on Physics due to various reasons that includes but is not limited to using Physics class to prepare for the national college entrance examination, copying lectures without even understanding the essence and theory, no motivation to learn the subject and so on. Researchers have started moving on into the integration of PBL to their coursework to involve more hands-on and develop the students' critical thinking skills to understand science [5-7].

In this article, we will provide insights on the preliminary results of the student's learning process using project-based approach and team-based approach in their freshmen Physics class as opposed to the traditional paper exam classes that they are accustomed to. The student learning process would incorporate frequent discussions, planning, and development. The objectives of the Physics course would also provide a more innovative approach which includes the design and implementation of physics experiments or projects base from theoretical proofs, learning Physics through real life applications, learning how to work in a team, train students to write project proposals, train students to write project reports and train students to present their work. The rest of the paper will be arranged as follows: Section II will discuss the methodology from the selection process to the class requirements. Section III would discuss preliminary results of this pilot study and Section IV would draw out conclusions for the pilot course.

2. Methodology

Southern Taiwan University of Science and Technology was granted a project by the Ministry of Education entitled "University of the Future" under the program "University Learning Ecosystem for Taiwan." The university has received its first batch of students through selecting students from incoming freshmen students of four different departments namely Department of Electrical Engineering, Department of Electronic Engineering, Department of Computer Science and Information Engineering and Department of Electro-Optical Engineering. The application process included an application form, screening and interview. There were a total of 50 students chosen to participate in this special class. This research still used both chalk and talk for the lectures and PBL to produce the projects for evaluation. We provided them with the background knowledge on the Physics topics and checked the validity of their experiments.

These students were then divided into 10 teams. In accordance to the article "Turning student groups into effective teams," each group would designate a Coordinator (team leader), Recorder, and Monitor. The coordinator would be responsible to supervise that each member is involved in working on the project and remind them about details of the meeting such as the time, place and purpose. The monitor is involved in making sure that each member knows the solution and the strategy to deal with the challenges on hand. Lastly, the checker double-checks the work of all the members before handing in their work [8].

For their Physics course, team leaders were asked to draw lots to determine the topic that their group would pursue at the start of the semester. General topics are as follows:

- Motion in 1 Dimension
- Vectors & 2-D motion
- Laws of Motion (Newton's 3 Laws and Friction)
- Energy
- Momentum and Impulse
- Electric Energy and Capacitance
- Current and Resistance and
- DC Current Circuits

In order to accommodate the ten groups, some of the topics were divided into several sub-topics. Projects included the following:

Group 1: pie face showdown machine, which made use of concepts of spring, force and resistance. They also made another project on comparing the energy usage of 2 different types of bulbs. Group 2 used flux theory, electromagnetic theory to develop an incoming call notification, mini electric generator, "light bulb" from pencil core, tesla coil, and Leiden jar. Group 3 dealt with the Atwood machine, ball bouncing in a pail of water, potential energy to kinetic energy, elastic compression experiment and automatic standing bucket. Group 4 worked on vectors and 2-dimensional motion including a comparative work on the speed of 2 cars of the same model, marbles rolling on 2 different slopes, and pulling force experiments. Group 5 did projects on momentum and collision, from strategically hitting billiard balls, and analysis on the difference of bouncing various types of balls. Group 6 studied electrical energy and capacitance that created projects like portable rechargeable battery, solar cells, electric baton, touch switch, and wind and solar energy generator. Group 7 dealt with DC circuits and made projects such as an adjustable brightness LED lighting, solar fan, AC-DC converter, and wireless communication.

Group 8 worked on Newton's second law and studied the effect on velocity for ramps having different number of slopes, gravitational constant, determining the final velocity, and dropping things from 2 different heights. Next, group 9 is on law of action and reaction that tested a balloon rocket, "running power" power generator from your every step, spinning water dispenser that plans to use rain water to produce electricity and making a cd float to simulate a levitated car. Lastly, group 10 discussed Newton's first law, inertia. It included the distance a bottle would land after going off from a moving scooter, pulling a piece of paper from between 2 bottles without toppling the upper bottle, and the dangers involved in high acceleration, high velocity driving. The groups were then required to discuss and plan the projects that they wish to accomplish in accordance to their respective topics. The students were evaluated through three stages.

First is their project proposal submission. The students are required to choose their project, write down the methodology, design the project and discuss among themselves and the professor on how to implement the project. The theoretical calculation of the expected results was required before the students perform their individual experiments at least ten times. They are required to record their findings, and the problems they encountered. During the midterm exams week each member of the group are required to submit and present their project proposals together with their initial findings and challenges. The project proposal includes motivation of the study, problems to be discussed, literature review, materials and its cost, experimental procedures, problems and solutions, preliminary results and discussions, and references.

Second is the final project report wherein they need to redo their experiments and discuss their new findings. As for the problems that they encountered, they are to find Physics theories to support their findings and draw up their own solutions and conclusions on the task at hand. The goal is to let them start learning how to find solutions to the challenges met while accomplishing this task. The assessment is done through the grading of the midterm and final project reports which focuses on the completeness of the theoretical background, the calculations, the materials and procedure. Further, the results were checked and their respective conclusions. Lastly, the organization of the paper is also included in the grading.

Third is through the peer evaluation. Peer evaluation evaluates a member's participation in group activities and the accomplishment of their share of workload. Although the Physics projects can be accomplished individually we require them to rely on teams to work on their projects. This not only inspires team building but more importantly they can gain more insights on what they are doing and could receive different opinions along the way. Thus, through this evaluation, the professor can have a second opinion from their peers on how the student is working in his team.

3. Results and discussion

3.1 Student teaming and student discussions

Traditional learning would require students to sit in well-organized rows and columns and are made to listen to professors' lectures that usually last for several hours in a day. This type of passive learning has been going on for decades but recently more and more people are adjusting to project based or team based approach in engineering education [9]. For the special class, not only did we require them to form teams, they are also encouraged to sit in groups and have more active discussions as shown in figure 1. For PBL and TBL, team discussions play an important role because they are required to discuss goals, project details, procure materials, and work on accomplishing their projects through mutual help. Figure 2 shows the versatile meeting time and places that the students utilized to discuss with professors. Students can meet at different places and professors meet them in these places, that includes open meeting areas, empty classrooms, or at one of the university canteens. Subsequently, almost half of the students have no or barely minimum knowledge of Physics when they started the course. Thus, lectures on the topics and their respective experiments helped in providing not only theoretical knowledge but also hands-on results wherein they learned the difference between theoretical calculations and actual figures after conducting their experiments.

3.2 Sample experimental results

In this section, we would like to discuss the results which were written by one of the groups assigned to the topic on free fall of objects. In one project they demonstrated the difference between theoretical figures and actual figures of the gravitational constant g base from experiments conducted in the university.

Figure 1 Typical classroom lectures in Taiwan and in most of the world is shown in (a) and for our class we try to give them more freedom to discuss

Figure 2 Students meet at different places and professors meet them in these places, for example in the photo above, it displays a meeting with students at one of the university canteens.

In this experiment the student made use of a bottle a constant mass and dropped it from different heights to determine the calculated *g* as shown in figure 3. Theoretically, air resistance is neglected but, in this experiment, we would like to determine how much difference would there be between the constant 9.8 m/s^2 and the results from an actual experiment. The bottle was dropped from the 2nd floor and 3rd floor of the Computer Science building with heights of 5 m and 9.7 m respectively. Videos were taken in order to determine the time required for the bottle to reach the ground. Then the following equation

$$s = V_o t + \frac{1}{2} a t^2 \qquad (1)$$

was used to determine the acceleration due to gravity. The variable s represents the height in meters and t is time in seconds. The initial velocity, V_o, was 0.
The equation is simplified into

$$s = \frac{1}{2} g t^2 \ , \qquad (2)$$

and eventually *g* can be calculated using the equation

$$g = \frac{2\,S}{t^2} \qquad (3)$$

The experiment was conducted 10 times and having the theoretical *g* as 9.8 m/s^2, the calculated *g* of the bottle dropped from the 2nd floor showed an average difference of 12.14% while the bottle dropped from the 3rd floor showed an average difference of 15.16%. Details on the results of the experiments are shown in Table 1.
Base from the experiments, the students learned that although the textbooks teach us that the value of g is 9.8 m/s^2 but in actual practice there are more variables to consider in calculating the free fall of an object. Significant difference can be observed as the object goes to higher altitude. Further studies can be made by subsequent students of this class.

3.3 Documentation

Training on documenting experiments also helped them learn the importance of taking down notes, do some further readings, and present their results in a scientific manner. This process also helped them to hone their skills in using word processing software such as Microsoft Word and acquire the skills to write an organized and formatted report.

The projects were also funded by the program and thus the students are required to plan their materials and quote for the costs. Subsequently, they would write a procurement form before they are allowed to buy the materials and the expenses are reimbursed after the receipts and necessary documentations are completed. This trains and prepares the students of real life scenarios in companies when buying materials.

Table 1 Record of the calculated experimental values of *g*

	2F-1	2F -2	2F -3	2F -4	2F -5	2F-6	2F-7	2F-8	2F-9	2F-10
s (m)	5	5	5	5	5	5	5	5	5	5
t (sec)	0.98	1.02	0.98	1	0.92	0.98	0.92	0.99	0.86	0.94
Calculated *g* (m/s^2)	10.41	9.61	10.41	10	11.81	10.41	11.81	10.2	13.52	11.32
Theoretical *g* (m/s^2)	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
% difference	6.24%	1.92%	6.24%	2.00%	20.55%	6.24%	20.55%	4.11%	38.00%	15.50%
Average difference	12.14%									
	3F-1	3F -2	3F -3	3F -4	3F -5	3F -6	3F -7	3F -8	3F -9	3F -10
s (m)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
t (sec)	1.56	1.49	1.47	1.54	1.52	1.61	1.56	1.49	1.52	1.53
Calculated *g* (m/s^2)	7.97	8.74	8.98	8.18	8.4	7.48	7.97	8.7	8.4	8.29
Theoretical *g* (m/s^2)	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
% difference	18.66%	10.83%	8.39%	16.53%	14.32%	23.63%	18.66%	10.83%	14.32%	15.43%
Average difference	15.16%									

3.4 Project and team evaluation

Students were evaluated mainly through the project reports submitted during their midterms and finals exams week. Questionnaires were also given out to each member to perform peer evaluation and provide insights on the attitude and progress of each member. For almost all the students being formed into closely knit groups and working in teams is a totally new concept. They have been used to the “hero method” or “I do everything on my own” approach due to years of competitive examinations. Conflicts arose from ranging from differing opinions or hitchhikers. The role of the instructor is then to coordinate, discuss and guide them on how to work effectively as a team and to accomplish their projects. In the end, all ten groups were able to accomplish their work satisfactorily and we had a semester end exhibition that included their creative design project not discussed in this article as shown in figure 4. The students themselves setup the whole exhibition area and we had STUST faculty members and students who visited our booths and had great discussions with the students. They have received praises for their outstanding work.

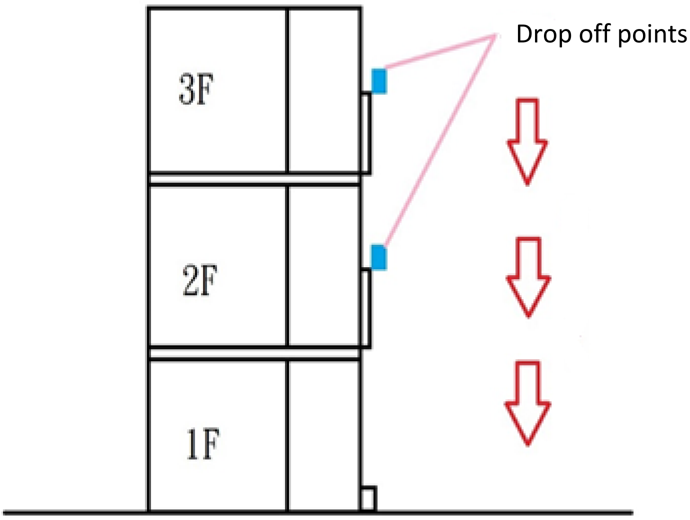

Figure 3 The original set-up and diagram made by the students to study the difference between the gravitational constant *g* at two separate floors of the computer science building.

4. Conclusions

The pilot program was able to successfully implement a team based and project-based learning for the freshmen Physics class. The hands-on approach gave students firsthand experience of Physics in real life and made them learn the differences between solely theoretical Physics and Physics in action. It was also found that students were more curious and appreciative of the physical phenomena after experiencing electricity, free falling objects, gravitational pull, being electrified by static electricity and so on. The program also provided them the experience and opportunity to hone their skills in interpersonal communication and proper documentation. The advantages of the proposed program provided a more flexible learning environment wherein the students can choose their topic of interest and focus on working to make the project work. They were able to work in teams and produce proposals and reports that they have not done before. It also provided them a clear understanding on the difference of theoretical and actual physical phenomena. However, the current learning method had limitations in letting the students learn Physics as a whole since many would have very specific topics. The lack of exams also became a disadvantage since it became challenging to assess the knowledge of the students. In the future, the evaluation methods can be further modified and include regular homework and several exams to ensure that students still get into the class lessons and learn fundamental engineering theories. Improvements on the current practice will be done such as providing additional homework and regular short quizzes. Eventually this kind of practice will be implemented university wide.

Figure 4 Group photo after our Creative Design Project and Physics exhibition.

5. Acknowledgement

We would like to thank the Ministry of Education and the University Learning Ecosystem for Taiwan for financially supporting this project.

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