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Application of a MOOC in a general physics flipped classroom

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ABSTRACT: General physics is a basic required course at many colleges and universities in the first academic year. With the advancement in scientific technologies, higher education has entered the era of digital learning. Massive open on-line courses (MOOCs) have become more and more popular. In addition to providing opportunities for students' self-learning on the Internet, MOOCs can also be applied in flipped classrooms on the campus. Team-based learning (TBL) is a student-centred teaching strategy with a specific structure. TBL is suitable for use in flipped classrooms. The Ministry of Education in Taiwan launched a four-year MOOCs programme in 2014. *Easy to Learn Mechanics* (ELM) is one of the courses receiving grants in 2014. The aim of this study was to explore the learning outcomes of students in the *Mathematics* topic of ELM in a TBL-based flipped classroom. It was found that applying a MOOC in a TBL-based general physics flipped classroom is helpful to enhance students' learning outcomes and develop students' ability in self-learning and communication skills in a team work context.

INTRODUCTION

General physics is a compulsory course for many freshmen in the departments of sciences, engineering and medical care. General physics covers a wide range of topics, including classical mechanics, mechanical wave, thermodynamics, electromagnetism, optics and modern physics, and so on [1-2]. Every department has planned various academic credits and teaching hours in general physics according to the majors taught in the departments. Instructors usually follow the requirements of the department and do the appropriate planning and arrangements for students to enhance their learning outcomes, which include general knowledge of physics that should be learnt, and critical thinking and problem-solving skills that should be developed. In the learning style, students are expected not only to have passive listening in the classroom, but also to have active self-learning and teamwork.

With the rapid development of science and technology and the flourishing of multimedia, higher education has entered the era of e-learning. MOOCs are the abbreviations of massive open on-line courses. Considering the limited attention span in visual and audial modalities of human beings, the teacher divides the curriculum into many small units, and records videos (about 15 minutes per video). The unit is followed by a formative assessment, so that students can immediately test their learning status. If students do not understand the content of the unit, they can go back and watch the video again and, then, do the test. In such step-by-step learning, the learning outcome is solid. At the end of the course, there is a summative assessment. A certificate can be obtained once the requirements of the course have been completed. Teaching materials including videos and PowerPoint are uploaded onto an open platform. Students can arrange their own time and place for self-learning [3-8].

There are also forums available for communication between lecturers and students from all over the world [9-10]. In addition to providing self-learning on-line, MOOCs can also be applied in flipped classrooms. In the flipped classroom, the teacher will design activities to lead the students' brainstorming, and transform teacher-centred passive learning into student-centred active learning [11-13].

Team-based learning (TBL) is a teaching strategy with specific structure, including pre-class preparation, individual readiness assurance test (iRAT), team readiness assurance test (tRAT), appeals, mini-lecture, team activities, and peer assessment [14-16]. TBL is suitable for use in the flipped classroom [17].

In view of the vigorous development of MOOCs, the Ministry of Education in Taiwan launched a four-year MOOCs programme in 2014. For the first year in 2014, five MOOCs with at least 18 hours of videos and under supervision of the vice-president of each college or university could be submitted for application. As a result, 99 courses were selected to obtain the grant. The rules for 2015-2017 underwent some minor changes. *Easy to Learn Mechanics* (ELM) is one of the courses receiving the grants in 2014. ELM includes nine topics: mathematics, kinematics, Newton's laws of motion, work and energy, momentum and collision, rigid body rotation, balance and elasticity, gravitation and oscillation. Each topic has several units, for a total of 98 units [18].

At present, Taiwanese high school students have varied learning hours and developed abilities in physics due to the selection of the social- or the scientific-oriented curriculum programme. In the multi-entry system in Taiwan, social-oriented students also have the opportunity to enter the departments of sciences or health care. In the freshman class, some students have studied calculus, but some students have not yet done so. Furthermore, some students may come from foreign countries or mainland China, so peers obviously vary in their learning backgrounds.

The first topic of ELM is the mathematics needed in mechanics. In addition to the vectors mentioned in the ordinary physics textbooks, trigonometric functions and calculus are also added. The calculus mainly focuses on polynomial functions. Furthermore, the solution of the quadratic equation is also reviewed.

This article explores the learning outcomes of students on the *Mathematics* topic of ELM in a TBL-based flipped classroom.

CONTENTS OF TEACHING MATERIALS

ELM covers 9 topics mentioned above. The top 1 *Mathematics* consists of 13 units, as shown in Table 1.

Table 1: Thirteen units of top 1 Mathematics of ELM.

Unit	Title	Unit	Title
1	Calculator Operation	8	Unit Vectors
2	Physical Quantities and Units	9	Scalar Product
3	Significant Figures	10	Vector Product
4	Quadratic Formula	11	Calculus
5	Trigonometric Functions	12	Second Derivative
6	Inverse Trigonometric Function	13	Integration
7	Vectors		

TEACHING STRATEGY

Fifty-one students participated in the General Physics course. This General Physics course with three credits was a required course in a department of a medical university at Taiwan at the 1st semester of the 2014 academic year. There was only one instructor in the course. Students were randomly divided into 13 groups, and each group had three to four students.

Before entering the classroom, the students first watched videos of Topic 1 *Mathematics* of ELM. After entering the classroom, iRAT with ten multiple-choice questions were performed. After completing the iRAT, tRAT was performed. There were 15 multiple-choice questions in tRAT, including the first ten questions same as the iRAT, plus five more-difficult questions, so that students could have more discussion during the team time.

Scratch cards with the immediate feedback assessment technique (IF-AT) function were used for students to respond to the tRAT. On the scratch card, the correct answer was shown as "*". If the student scraped the correct answer the first time, 10 points could be obtained. Five points and two-and-a-half points could be obtained, if the correct answer was obtained at the second or third time, respectively. No points could be obtained if the correct answer was obtained at the fourth time. During the tRAT time, the group could discuss freely, reach a consensus and, then, scrape the answer.

After the tRAT was completed, the teacher collected the scratch cards and answered students' questions. Then, the teacher could explain the parts for which some groups did not obtain the right answer at the first time. The teacher could also ask the students to respond orally to some questions in which every group obtained the right answers to see, if the students fully understood the concepts or if there were still some blind spots. Afterwards, the teacher could give a mini-lecture to explain the concepts or blind spots.

Results were calculated as iRAT personal scores accounted for 70%, and tRAT group results accounted for 30%. The mathematical TBL, TBL_math, was equal to iRAT × 0.7 + tRAT × (100/150) × 0.3. TBL_ math scores accounted for the 10% of the final grade of the general physics course.

ANALYSIS OF LEARNING OUTCOMES

The minimum iRAT score of 51 students was 10 points, and the maximum iRAT score was 100 points. The minimum tRAT score was 90 points, and the maximum tRAT score was 100 points. The distribution of iRAT and tRAT scores is shown in Figure 1. The first rank of iRAT scores was the 71-80 points with 17 students (33%), followed by 81-90 points, with 16 students (31%). There were three students with iRAT scores below 60 points. tRAT scores were not less than 60 points. The scores of 51 students were averaged and presented as mean standard deviation. The results of iRAT and tRAT were 77.6 ± 15.7 and 94.4 ± 3.2, respectively. The tRAT scores were significantly higher than the iRAT scores ($p < 0.001$ for paired *t*-test statistical analysis). The difference between the mean tRAT and iRAT was 16.8 points.

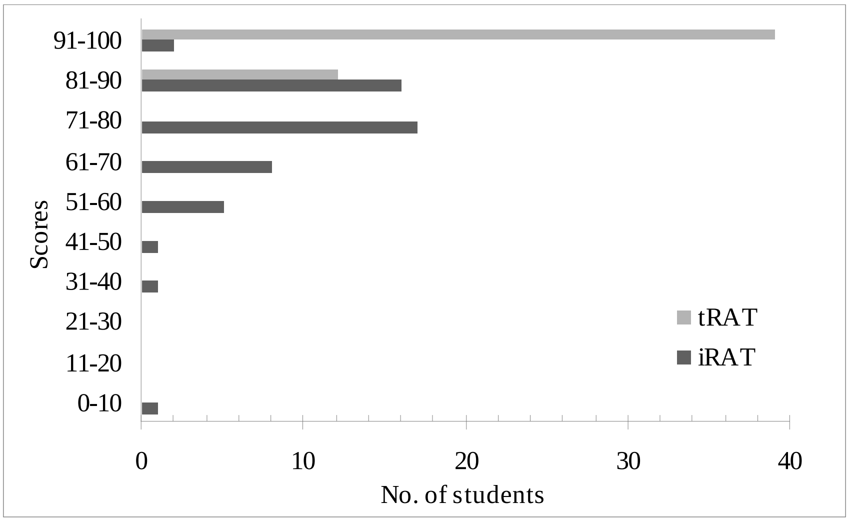

Figure 1: Distribution of all 51 students' iRAT and tRAT scores.

There were 32 females and 19 males among these 51 students. There were the minimum 10 points, and the maximum 100 points for female students' iRAT score; there were the minimum 90 points, and the maximum value of 100 points for the female students' tRAT scores. There were two students with iRAT scores below 60 points. tRAT scores were not less than 60 points. The average scores of the 32 female students were 76.4 ± 16.9 and 94.8 ± 3.4 for iRAT and tRAT, respectively. The tRAT scores were significantly higher than the iRAT scores ($p < 0.001$ for paired *t*-test statistical analysis).

The difference between mean tRAT and iRAT was 18.4 points. The minimum and the maximum score of male students' iRAT were 40 points and 90 points respectively; the minimum and the maximum male students' tRAT score were 90 points and 100 points, respectively. The mean scores of iRAT and tRAT were 80.5 ± 13.1 and 94.1 ± 3.0, respectively, after averaging 19 male students. The tRAT score was significantly higher than the iRAT ($p < 0.001$ for paired *t*-test statistical analysis). The difference between the mean male tRAT and iRAT was 13.6 points.

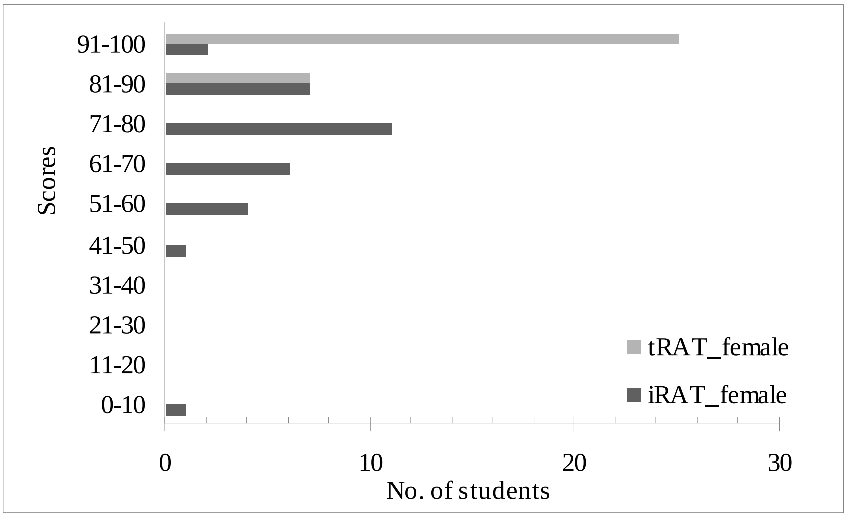

Figure 2: Distribution of 32 female students' iRAT and tRAT scores.

The distribution of female students' iRAT and tRAT scores is shown in Figure 2. The first rank of iRAT score was 71-80 points with 11 students (34%), followed by 81-90 points with 7 students (22%). The distribution of male students' iRAT and tRAT is shown in Figure 3. The first rank of iRAT score was 81-90 points with nine students (47%), followed by 71-80 points, six students (32%). Comparing the iRAT scores between male and female students, although the iRAT scores of male students were 4.1 points higher than that of female students, there was no significant difference between them ($p = 0.2864$) according to independent *t*-test statistical analysis. The tRAT scores of female students were only 0.7 points higher than that of male students. According to independent *t*-test analysis, there was no significant difference in the tRAT scores between female and male students ($p > 0.053$).

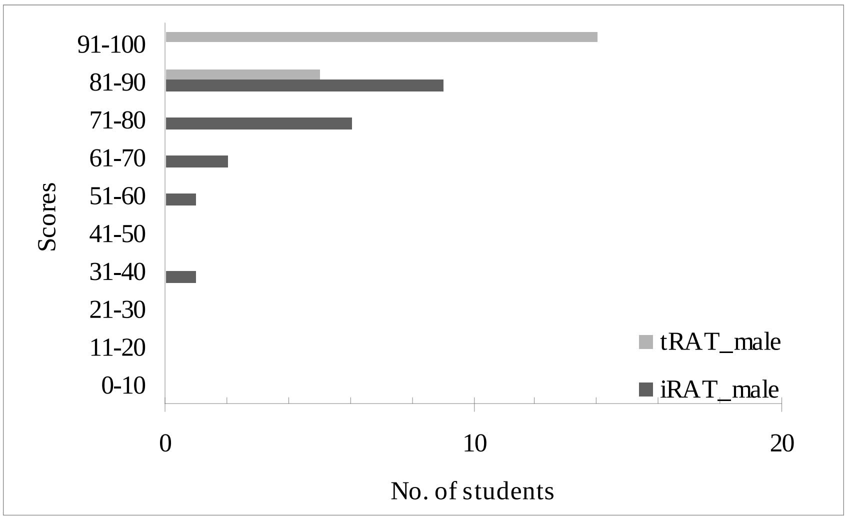

Figure 3: Distribution of 19 male students' iRAT and tRAT scores.

From the analysis of tRAT scratch cards, it was shown that only one group (1/13 = 7.7%) answered 15 questions correctly, eight groups (61.6%) answered 14 questions correctly, two groups (15.4%) answered 13 questions correctly, and two groups (15.4%) answered 12 questions correctly. Table 2 lists the number of groups that gave the wrong answers. There were 10 groups (77%) giving the wrong answers to Question 5, three groups (23.1%) to Question 13, two groups (15.4%) to Question 3 and Question 14, respectively, and one group (7.7%) to Question 4 and Question 10, respectively.

Table 2: Results of tRAT.

Item	No. of groups (correct answer)	Item	No. of groups (correct answer)
1	13	9	13
2	13	10	12
3	11	11	13
4	12	12	13
5	3	13	10
6	13	14	11
7	13	15	13
8	13		

Question 5 was about the cross product of vectors; Question 13 was about the determination of effective figures after two figures multiplication; Question 3 was about the determination of effective figures after two figures addition; Question 14 was about second derivative of a polynomial function with power less than 1 or less than 0; Question 4 was about the slope of a straight line through two points; and Question 10 was about the indefinite integral of a polynomial function. According to the results in Table 2, the teacher could be able to interact with students, understand the difficulties and blind spots of students, and explain and clarify the contents. The students would be more engaged in the group discussion and teacher's explanation.

During the iRAT, the whole classroom was very quiet. However, during the tRAT, the passion of students on discussion could be felt. It was really inspiring; especially, some high-pitched cries could be heard when the students scraped right answers. Even some sighs of chagrin be heard when wrong answers were scraped; the students were really engaged in the activities. Scratching cards can really enhance the students' interest in active learning and team interaction.

TEACHING REFLECTION

MOOCs have been a new trend in higher education. Since 2008, several famous universities in the world, including Stanford University and Berkeley University in the United States, have developed many MOOCs uploaded at Coursera, Edx, Udacity and other well-known network platforms. Once the videos and assessment are uploaded onto the network platform, irrespective of gender, age, location and time, as long as there is a network, people with learning enthusiasm can follow their own paced self-learning. The New York Times called 2012 a year of MOOCs. More and more colleges/universities have joined the production of MOOCs. MOOCs can enable the people in countryside locations or with poor economic status to have the opportunity to undertake prestigious university courses. MOOCs bring a wave of universalisation and internationalisation. Since 2014, the Ministry of Education in Taiwan has started a four-year call for MOOCs programme. In the first year, 99 MOOCs obtained the grant. These 99 MOOCs were mainly Chinese-based, so that all Chinese speakers in the world could self-learn these courses.

ELM was one of the 99 courses obtaining the grant in 2014. It could not be completed without support from the Faculty Development and Teaching Resource Center of the School. Even though it took a lot of effort to develop a MOOC, it was still worthwhile in providing useful information for those who needed it. However, although there are many convenient on-line self-access learning courses, on-line education cannot completely replace campus education. Face-to-face communication between teachers and students or between students and students is still a very important part of education. MOOCs can not only be used as self-learning courses on the Internet, but can also be applied in flipped classrooms on campus.

It is better to teach children how to fish, not just give them fish. At present, civilisation is in an era of information flooding. It is impossible to absorb all knowledge by students in the classroom within a limited time. The skills needed for students are not to rote-memorise much knowledge, but to think critically, if the knowledge is correct or not and how to apply it - this is evaluation and synthesis; higher cognitive thinking.

It is also a multi-disciplinary age. Many tasks need to be done by teamwork. Students should have the skills to know how to work in a team and how to communicate with team members. It is important for students to realise what they do understand and what they do not know, so that they can know what they can contribute to the team and what they can learn from teammates. How to get consensus in different views is also a very important ability needing to be developed.

Flipped classrooms transfer the traditional teacher-centred passive learning into student-centred active learning. It has been reported that flipped classrooms do enhance students' learning motivation, learning interest, class engagement and teamwork. How to design effective activities in the flipped classrooms is still a challenge for teachers to face. TBL is a teaching strategy, which can be used in flipped classroom.

TBL has its fixed architecture. It is not very difficult to perform TBL in the class. TBL was originally developed to solve the problems of low participation in large classes. However, TBL can also be applied to small classes. TBL is often applied in the field of medical education, because many clinical cases allow students to have the opportunity to discuss through the team. A consensus is reached through statements of teammates. If the selected answer is different from the one given by the teacher, it may require further appeal and discussion with the teacher. However, some practical experiences have shown that TBL can also be applied in the natural sciences, such as general physics and circuits [19-21].

In the general physics flipped classroom, there was a positive result. tRAT scores were significantly higher than iRAT ($p < 0.001$). During tRAT, students can also feel the inspiring atmosphere of discussion. Teachers can also learn from the tRAT, realise what problems the majority of students have in difficulties in learning. The number of female students was higher than that of male students. It is not uncommon for those with sexist bias to think that female students' ability in natural science is slightly inferior to that of male students; however, in this general physics flipped classroom, there was no difference in iRAT and tRAT scores between male and female students. Female students are perceived by some as being slightly inferior to male students in the ability of sciences, but this was not validated.

The key to have success in a flipped classroom is that students can complete pre-study. It is important to select suitable materials for students to preview according to students' time and loading. To have students possess self-learning, habitual activities need to be performed systematically. How many TBL-based flipped classrooms are performed also depends on the students' situation. In designing the iRAT and tRAT questions, teachers can also think of more worthwhile intellectual questions for students to discuss.

If the tables and chairs in classrooms can be moved around, students can arrange tables and chairs suitable for their group discussion. With regard to the number of members in a TBL group, some scholars in the field of medical education recommend five to seven persons, and that the team members come from different backgrounds. The higher the heterogeneity is, the better is the intention to provide more perspectives in the discussion. In this general physics class, each group had three to four persons. Because physics discussions need to be written and calculated, having three to four persons in the seating arrangement makes it easier to focus and students also have more opportunities for participation and interaction. iRAT and tRAT in the proportion of the final grades was inconclusive. The current proportion of iRAT accounted for 70% and tRAT accounted for 30%; this encourages students to complete the preview.

Teachers need to spend more time preparing for TBL-based flipped classrooms using a MOOC as preview material rather than traditional teaching methods. However, it is worthwhile to do so while seeing the students have enthusiasm in learning and have progress in learning outcomes. Of course, other conductive teaching strategies in general physics, such as experiments demonstration, program simulation, and outdoor teaching to make the curriculum more diverse, vivid and interesting are also worth encouraging.

CONCLUSIONS

Applying a MOOC in a TBL-based general physics flipped classroom is helpful to enhance students' learning outcomes, and develop students' ability to self-learning and interpersonal interaction. The *Mathematics* topic of ELM is suggested as an example. No doubt, this teaching strategy can be extended and applied to other topics or subjects.

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