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Technological Pedagogical and Content Knowledge among Undergraduate Education Degree Students at Universiti Teknologi Malaysia

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Abstract

This study aims to identify technological pedagogical and content knowledge (TPACK) among undergraduate physics education degree students at Universiti Teknologi Malaysia (UTM). A paper-and-pencil test was used to collect data on their conceptual understanding of Archimedes' principle. They were also requested to write a teaching lesson plan for the topic of Archimedes' principle. The data gathered was analysed qualitatively using content analysis. The finding indicates that, these respondents possessed many alternative conceptions in the buoyancy concept and more interestingly, those who have not undergone the Teaching Practice (TP) demonstrated more alternative conceptions compared to those who have. Moreover, those who have undergone TP tended to use question-and-answer method to deliver this topic.

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Keywords: Archimedes' principle; teaching practice; teaching strategies; technological pedagogical content knowledge

1. Introduction

Technology integration in teaching and learning (T&L) is important to deliver content with suitable teaching strategies. The concept which mixes together the elements of technology, pedagogy and content knowledge is named as technological pedagogical and content knowledge (TPACK). Mishra and Koehler (2006) defined TPACK as the fundamental of effective teaching through technology, the representation of concept through technology, pedagogical techniques which apply technology and technological use to construct new understanding from the existing knowledge among students. Briefly, the components of TPACK are pedagogical

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content knowledge (PCK), technological content knowledge (TCK) and technological pedagogical knowledge (TPK). In the purposes of this study are to:

- (i) To identify the teaching strategies used by undergraduate physics education degree students to deliver the topic of Archimedes' principle.
- (ii) To identify the alternative conception among undergraduate physics education degree students in the topic of Archimedes' principle.
- (iii) To identify the TPACK of undergraduate physics education degree students in the teaching of Archimedes' principle.

In this study, technology is defined as digital technology and ICT in education (Jimoyiannis, 2010) such as video, simulation or computer-based experiment while the pedagogy focuses on teaching strategies or the whole planning of a teacher to deliver contents using a systematic way in teaching and learning (Moore, 2009; Richard, 2009; Tileston, 2004). Teaching strategies are rooted in learning theories such as expository learning theory by Ausubel (1978) and discovery learning by Bruner (1960).

An alternative conception is referred to the pre-concept possessed by students which inexact with the concept defined by scientists (Abimbola, 1988). The existence of alternative conceptions among undergraduate physics education degree students focused on Archimedes' principle related to buoyancy phenomena. It is important to investigate the alternative conceptions among them because according to She (2002), buoyancy concept is a high level concept and students tended to form alternative conceptions among students. A study conducted by Khalijah Mohd Salleh and Abu Bakar Abdullah (2008) also found that Archimedes' principle is the most difficult topic in fluid mechanic area. In summary, Archimedes' principle contents concepts that are difficult for students or teachers to understand.

2. Literature Review

Previous studies in TPACK and alternative conceptions have given many valuable inputs for this study.

2.1. *Alternative conceptions*

A study conducted by Loverude *et al.* (2003) revealed that physics students were facing problems in understanding the topic of Archimedes' principle especially the buoyancy concept. The researchers found that physics students cannot apply the buoyancy concept even in a very easy situation. They cannot relate the role of object's volume to determine the buoyant force. They also cannot differentiate between the volume and mass of an object to get the volume of fluid displaced. Abimbola (1988) said this alternative conception is the challenge for teachers to transform pre-concept possessed by students. The process of transformation from an alternative concept to a real concept should be made through a systematic way of teaching by the teachers. Therefore, an alternative conception can be corrected through effective teaching using suitable teaching strategies and integration of technology in T&L.

2.2. *Technological pedagogical and content knowledge*

Khalijah Mohd Salleh and Abu Bakar Abdullah (2008) studied problems faced by students and teachers in learning Archimedes' principle. They suggested that a computer simulation programme should be developed to visualise the buoyancy concept. Nurul Ain Hamzah and Zaleha Ismail (2008) also carried out a study in TPACK among undergraduate education degree students. They suggested that TPACK-based e-learning system should be

developed to fulfill students' various learning abilities. Meanwhile, Nilsson (2008) carried out a study on the significance of reflection and teaching experience to strengthen teacher's knowledge. Nilsson (2008) found that teaching experience (e.g. teaching practice) could strengthen the knowledge of teaching. Teaching practice (TP) is for undergraduate education degree students to apply their knowledge in teaching in real situation in schools. Kamaruddin Husin (1986) stated that TP is important as a chance for undergraduate education degree students to expand their experience in teaching, build their vision of teaching and to enhance their competency as prospective teachers.

Finger *et al.* (2010)'s research among undergraduate education degree students indicated that the respondents were capable in using word processing software, presentation software, e-mail and web browsing. However, they were not proficient in the use of web page development, digital video editing and visual thinking software. Niess (2005) conducted a study to examine TPACK among science and mathematics undergraduate education degree students. It was found that some of them were unfavourable in the use of ICT in teaching and had given broader perception about technology application in teaching.

Therefore, TPACK is considered as a vital part in teacher preparation programme in order to produce future teachers who are proficient in the use of ICT in teaching, master in science concept and can apply the best teaching strategies during T&L.

3. Research Methodology

The respondents of this study involved 47 students from UTM in physics education undergraduate programmes. In order to collect data on their content knowledge, a paper-and-pencil test was used to measure their mastery of conceptual understanding of Archimedes' principle. The instrument was adapted from the questions used by Hewitt (2009) on the buoyancy concept. They were also requested to write an individual teaching lesson plan to deliver Archimedes' principle which allowed us to identify the teaching strategies and TPACK. The lesson plans were analysed qualitatively using content analysis (Krippendorff, 2004). Content analysis method was used to capture the important information to achieve the research objectives. The data was analysed through six steps: (1) units making; (2) units sampling; (3) coding; (4) data shrinking; (5) explaining; and (6) narrating.

In the first step, teaching strategies information was identified through text search. After that, the selected texts which were related to teaching strategies were grouped into two categories, expository and discovery teaching methods. The classification was based on literature review as defined by Ausubel (1978) and Bruner (1960). Then, the data was further refined through the classification of combined and single teaching methods. This is important because it would indicate the variety of teaching methods used by the respondents during T&L. Later, the selected data was classified into two groups which were the respondents who have undergone teaching practice and those who have not. The data was presented using percentage of the respondents who use the particular teaching method. The result is as tabulated in Table 1.

This analysis method is also used for the third objective with the same process but in different context which was TPACK. In order to achieve the second objective, an answer scheme was prepared as the standard answer for the buoyancy questions. The respondents' answers were compared with the answer scheme in order to look for different response. Any answers given by the respondents which was not aligned with the answer scheme was classified as alternative conception in Archimedes' principle topic.

4. Results

The results were divided into three parts following the research objectives.

4.1. Teaching strategies

Based on Table 1, there are two types of teaching strategies which are expository teaching and discovery teaching. A number of 60 percent of the respondents who have not undergone teaching practice (TP) used both teaching strategies, 36 percent of them only used the expository teaching and 4 percent of them only used the discovery teaching. However, 64 percent of those who had undergone TP combine both teaching strategies and 36 percent of the respondents only used the expository teaching. None of them used the discovery teaching only.

Table 1. Teaching strategies

Teaching strategies	Percentage of respondents who have undergone TP (%)	Percentage of respondents who have not undergone TP (%)
Combination of expository and discovery teaching	60	64
Expository teaching only	36	36
Discovery teaching only	4	0

Referring to Table 2, for the expository teaching strategy, 75 percent of respondents who have not undergone TP used explanation added with question-and-answer and only 25 percent of them used only explanation while teaching. However, a total of 100 percent of respondents who have undergone TP used explanation added with question-and-answer. Interestingly, 100 percent of both groups used demonstration in expository teaching strategy.

Table 2. Teaching methods under expository teaching strategies

Teaching method	Percentage of respondents who have undergone TP (%)	Percentage of respondents who have not undergone TP (%)
Explanation with question-and-answer	75	100
Explanation only	25	0
Demonstration	100	100

For discovery teaching strategy, 56 percent of the respondents who have not undergone TP used experiment and discussion. A number of 38 percent of respondents who have not undergone TP only used the discussion compared to other group with 50 percent of them used that method. In addition, 6 percent of those who have not undergone TP only used experimental method which is not too far from the other group.

Table 3. Teaching methods under discovery teaching strategies

Teaching method	Percentage of respondents who have undergone TP (%)	Percentage of respondents who have not undergone TP (%)
Experiment and discussion	56	43
Discussion only	38	50
Experiment only	6	7

Overall, there are no undergraduate physics education degree students who have undergone TP used only the discovery teacher strategies while teaching. Also, not all of those who have undergone TP used question-and-answer method while explaining the concept to the students. Interestingly, all the respondents from both groups used the demonstration method in expository teaching.

4.2. Alternative conceptions

In overall, the undergraduate physics education degree students who have undergone TP have less alternative conception compared to another group in the topic of Archimedes' principle. The alternative conceptions appeared in the item which measured the relationship between buoyant force and mass or volume of object. The findings indicated that 96 percent of respondents who have not undergone TP have alternative conceptions compared to 64 percent from another group for that item. The question of the given situation is:

“There are two blocks, block A and B. Both have the same volume, but A have a higher mass compared to B. Both blocks are fully immersed in water. Are the A and B blocks having the same magnitude of buoyant force?”

The examples of alternative conceptions were illustrated in Table 4. This example is summarised from the answered given by the respondents.

Table 4. Alternative conceptions

The respondents who have undergone TP	The respondents who have not undergone TP
No, both object A and B have different buoyant force. According to the formula $F = mg = \rho Vg$, the buoyant force is different for different mass of object. Both A and B sink fully in the water but their buoyant force are different. (N=14)	Block A and B does not have the same magnitude of buoyant force as the greater the mass, the higher the buoyant force. Blocks A will have larger buoyant force compared to B. (N=24)

Based on Table 4, both groups believed that mass will impact into the magnitude of buoyant force. However, the real concept which defined by scientist stated that mass would not affect the buoyant force. The factor which influences the magnitude of buoyant force is the volume of object. The same magnitude of volume of object would result in the same magnitude of buoyant force.

4.3. Technological pedagogical and content knowledge

Based on Table 5, 88 percent of undergraduate physics education degree students who have not undergone TP used PowerPoint in teaching, 76 percent of them used video, 20 percent respondents used simulation application and 8 percent of them used graphic image like photo. For the other group, 91 percent of them used PowerPoint, 54 percent of the respondents used graphic image, 45 percent used the video while 18 percent of this group used simulation.

Table 5. Technological use in teaching

Technology	The respondents who have undergone TP (%)	The respondents who have not undergone TP (%)
PowerPoint	91	88
Video	45	76
Simulation	18	20
Graphic Image	54	8

Referring to Table 5, the undergraduate physics education degree students intended to use PowerPoint when teaching the topic of Archimedes' principle. A big different was illustrated in the use of graphic image which showed a higher percentage of respondents for those who have undergone TP.

For the technological pedagogical knowledge, it is related with the integration of computer in teaching strategies. Table 6 shows the finding on computer integration in teaching.

Table 6. Technological integration in teaching

Technology integration	The respondents who have undergone TP (%)	The respondents who have not undergone TP (%)
Computer-aided Explanation	91	92
Computer-aided Demonstration	86	88
Computer-aided Discussion	14	28
Computer-aided Experiment	0	0

Based on Table 6, none of the respondents used the computer-aided experiment in teaching the topic of Archimedes' principle. The high percentage in computer-aided is due to the use of PowerPoint.

5. Discussion

In terms of teaching strategies, both groups used the discussion and experimental method to deliver the topic of Archimedes' principle. It is aligned with the suggestion by Ministry of Education Malaysia (2005) and Khalijah Mohd Salleh & Abu Bakar Abdullah (2008) who suggested the use of discussion and experimental method for this topic. Both teaching methods were based on the discovery learning theory initiated by Bruner

(1960). As for the expository teaching strategies, all respondents who have undergone TP used this strategy through explanation and question-and-answer. However, only 72 percent of those who have not undergone TP used the similar methods. When explanation is coupled with question-and-answer will give a chance to teachers to know their students' understanding for a topic. Lilia *et al.* (2002) stated that teachers should describe the concept to the students and obtain feedbacks from students while teaching. In addition to expository teaching strategy, this research indicated that 100 percent of respondents used the demonstration method in teaching Archimedes' principle. It is allied with the suggestion made by Moore (2009) who reported that demonstration is suitable for the science activities in teaching. Archimedes' principle is one of physics topics in science area. Science activities such as the demonstration of the buoyancy topic by using teaching tools can help students to understand the specific topic. From this situation, the students' conception on buoyancy will increase.

For the part of alternative conception in Archimedes' principle, many of the respondents from both groups believed that mass of an object will impact the magnitude of buoyant force. It is concurrence with a research carried out by Loverude *et al.* (2003) who found that physics students were confused about mass and volume of object. Hewitt (2009) stated that objects with the same volume will have same magnitude of buoyant force if they are fully immersed in fluid. This indicated that undergraduate physics education degree students in UTM have the alternative conception of the role of object's volume to find out the buoyant force magnitude.

For technological pedagogical and content knowledge (TPACK), the respondents in both groups had a tendency to use PowerPoint slide presentation in teaching. It is similar to the research result of Finger *et al.* (2010). In terms of computer integration in teaching strategies for Archimedes' principle topic, none of the respondents from both groups used the computer-based experiment. To conduct this type of experiment, teachers need to be competence in using computer, instrument of the experiment and data representation. They also need to be equipped with the necessary facilities. For this reason, they should be exposed to these methods to handle this type of experiment in order to gain the profits of using it such as shorten the teaching period, increase the productivity of experiment and make data analysis easier (Osborne and Hennessey, 2006). According to Khalijah Mohd Salleh & Abu Bakar Abdullah (2008), computer simulation can help students to visualise the buoyancy concept and also increase the conceptual understanding among them. This is aligned with the findings of this research which showed that more than 86 percent of the respondents preferred to use the computer simulation. As for the computer-based discussion, it is suggested to use web page development such as e-learning to enhance the discussion among students in the classroom. This study found that a small percentage of respondents in both groups used this method. A research carried out by Nurul Ain Hamzah & Zaleha Ismail (2008) reported that TPACK-based e-learning should be developed in order to make learning more interactive. This indicated that the undergraduate physics education degree students should increase their competency to develop the web page like e-learning. In summary, the respondents in this research need to increase their skills in technological knowledge which concern with the skill of using hardware and software.

6. Implication

This study suggests that teacher education program need to focus on reinforcing the conceptual understanding, teaching strategies for specific topic and technological skill among undergraduate physics education degree students. Their conceptual understanding should be strengthened because they will become teachers in future. They should have the accurate conceptual understanding in buoyancy. Therefore, lecturers can use the method of conceptual attainment in their teaching by making intensive investigation of variables in Archimedes' principle for the undergraduate physics education degree students. The most important thing is to relate the buoyant force with the volume of object which result the weight of fluid displaced.

Regarding the teaching strategies, the undergraduate physics education degree students should be exposed with the skills of question-and-answer. The training should be continuous through the course of Physics Teaching Method. In order to reinforce the technological use in teaching, undergraduate physics education degree students should be exposed with the skills of handling the computer-aided experiment and the development of web page such as the e-learning. These can be realised during the course of Educational Technology or the extra courses of computer to increase the computer skill among them.

7. Conclusion

The findings indicate that, these undergraduate physics education degree students have many alternative conceptions in the buoyancy concept and more interestingly, those who have not undergone the Teaching Practice (TP) demonstrated more alternative conceptions compared to those who have. Similarly in the aspect of teaching strategies for the topic, those who have undergone TP tended to use question-and-answer method to teach this topic which encourages two-way interactions with students in the classroom. All respondents preferred the teaching method of demonstration and in terms of TPACK, all of them tended to use PowerPoint slide presentation as the tool to deliver the topic. It is interesting to find out that TP plays an important role in forming the undergraduate physics education degree students' concept mastery and the selection of teaching methods to be used for specific topic. TP should be the stage for the undergraduate physics education degree students to try a mixture of teaching methods and technological use across different topics in Physics. It is also recommended that some emphasis should be given by the university lecturers to the teaching of the basic concepts in Physics as these undergraduate physics education degree students exhibited alternative conceptions in some of the elementary concepts in Physics. The use of ICT and computer-based experiments can also be taken into account of teaching this topic as to strengthen their TPACK.

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