A Comparison of Students' Understanding of Concepts in Fluid Mechanics through Peer Instruction and the T5 Learning Model

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Abstract

Peer discussions are effective in facilitating active learning in both lectures and online forums and this is supported by research indicating an increase in students' conceptual understanding as a result of the interactions. This research aims to compare student understandings of concepts in fluid mechanics after deploying peer discussion as a teaching method in two different formats (T5 Learning Model and Peer Instruction). The T5 Learning Model is the developed form of Mazur's Peer Instruction in an online environment. This paper mainly focuses on comparing the outcome between Peer Instruction in classroom and the T5 Learning Model. The sample group comprised the first year students majoring in engineering, who registered for the class of introductory physics. A group of students (N=148) was taught through the established Peer Instruction (PI) method developed by Eric Mazur from Harvard University; another group (N=223) was taught through the new T5 Model, which is an on line peer discussion forum developed at the University of Waterloo, Canada. The Fluid Mechanics Conceptual Test (FMCT) was designed to assess students' understanding of basic fluid mechanics concepts. The FMCT is a 12-item, two-tier test. The first tier of an item is a conventional multiple-choice question with four choices. The second tier presents some reasons for the given answer for the first tier. The research results illustrate that both the PI and T5 Model as used in this study enable students to obtain 'learning gains' in accordance to Hake's method, at the level of medium gain (0.54 and0.52 respectively). While this study demonstrates that the T5 Model is another peer discussion teaching method that is as effective as the PI teaching method, more research needs to be undertaken to support this comparison.

Introduction

As a result of the dedication of physics educators to research throughout the past 40 years, we have learnt how to develop students' conceptual understanding in physics. The approaches tend to be catagorised into three groups:1) identification and analysis of student difficulties; 2) development and assessment of instructional strategies; and 3) development and validation of broad assessment instruments. Active learning, which includes instructional strategies that require students to do meaningful learning activities and think about what they are doing, is an output from the second approach. Active learning strategies are varied, and each variation is distinctive from another, depending on the aim of lesson, including 3 groups of active learning. The first group of active learning strategies focus on addressing a question and discussing results and include the Interactive Lecture Demonstration (Sokoloff & Thornton, 2004; Tanahoung, Chitaree, Soankwan, Sharma, & Johnston, 2009; Wattanakasiwich, Khamcharean, Taleab, & Sharma, 2012) and Peer Instruction (Mazur, 1999). The second group of pedagogies focus on developing understanding in physics from hands-on experience, by experimenting with prepared equipment; Workshop Physics (Laws et al., 1997), Workshop Tutorials (Sharma, Millar, & Seth, 1999) and Studio Physics (Cummings, Marx, Thornton, & Kuhl, 1999). The third group focuses on working on difficult questions, so that learners are able to spend time thinking through carefully in order to develop a clearer understanding of physics principles such as Cooperative Problem Solving (Heller, Keith, & Anderson, 1992) and Physics by Inquiry (McDermott, Shaffer, & Rosenquist, 1996). Active learning that was successfully applied in classrooms has the following key components:

- Students spend much of class time actively engaged in doing/thinking/discussing physics-not listening to someone else talk about physics, and the lecture in class time which is given by the instructor, is not confined to the dissemination of knowledge.
- Students interact with their peers.
- Students receive immediate feedback on their work.
- Instructors act as a facilitator for student's development.
- Students take responsibility for their knowledge.

This means that students take part in activities, study the texts, and complete assignments in class.

For educational development in the 21st Century, it cannot be denied that information and communication technology (ICT) is a crucial tool in assisting learning activities to become more efficient. ICT has changed the way teachers teach and students learn, such that education is not limited to only class time; nor is it limited to between instructors and peers only. Students can access experts, both within the university and outside, whether domestic or international. This research was motivated by the idea of incorporating online connectivity and addresses the research question: does active learning, such as Peer Instruction (Mazur & Hilborn, 1997), continue to be effective if transferred to an online learning management system (LMS) and what ensures an efficacy?

Peer instruction

Peer instruction (PI), developed by Mazur & Hilborn (1997) is a superior teaching strategy in promoting student conceptual understanding and problem solving skills compared to the traditional lecture. The heart of the PI teaching method is the students' participation in answering a question set called a *ConcepTest* (CT). CTs are multiple choice conceptual questions that focus on a single topic. In the relatively short time of between 10-15 minutes, students respond to CTs and then discuss their answers with their peers for 2–5 minutes, after which they respond to the same questions a second time. Instructors can use CT response data to inform teaching decisions in real time (Miller, Lasry, Lukoff, Schell, & Mazur, 2014). PI can be used across a broad range of content in physics, from primary education to tertiary education. Aside from physics, PI can also be used to teach chemistry, life science, engineering, astronomy and mathematics (Fagen, Crouch, Yang, & Mazur, 2000). PI helps the students' normalized gain to become higher than that of traditional teaching. The method also helps create motivation for the students to study the content in class (Crouch & Mazur, 2001).

T5 learning model

The T5 learning model is a new cooperative learning approach developed by professors at the University of Waterloo, Canada. The T5 model is an effective tool for online courses, and provides guidance to faculty including incorporation guidance, task designing and giving feedback for supporting their courses. The T5 learning model is has five components: **Tasks** refer to activities that lead the learning process as students interact with content; **Tutoring** means summative feedback from peers and instructors during tasks; **Teamwork** refers to collaboration among peers during tasks; **Topic Resources** refers to content resources to support tasks; and **Tools** refers to tools and technology to support the task, delivery option, and administration (Salter, Richards, & Carey, 2004).

The T5 model was implemented as a teaching tool in Ubon Ratchathani University in 2006 through the online learning management system (LMS) called D4L+P, which stands for Design for Learning plus Portfolio. LMS in this research is not the commercial learning online environment product. The platform has been developed through collaboration between Ubon Ratchathani University and the University of Waterloo (Richards & Sophakan, 2006).

The heart of the T5 learning model is that students need to complete both an individual task and team task before class learning can commence. The task sequence is illustrated in Figure1.

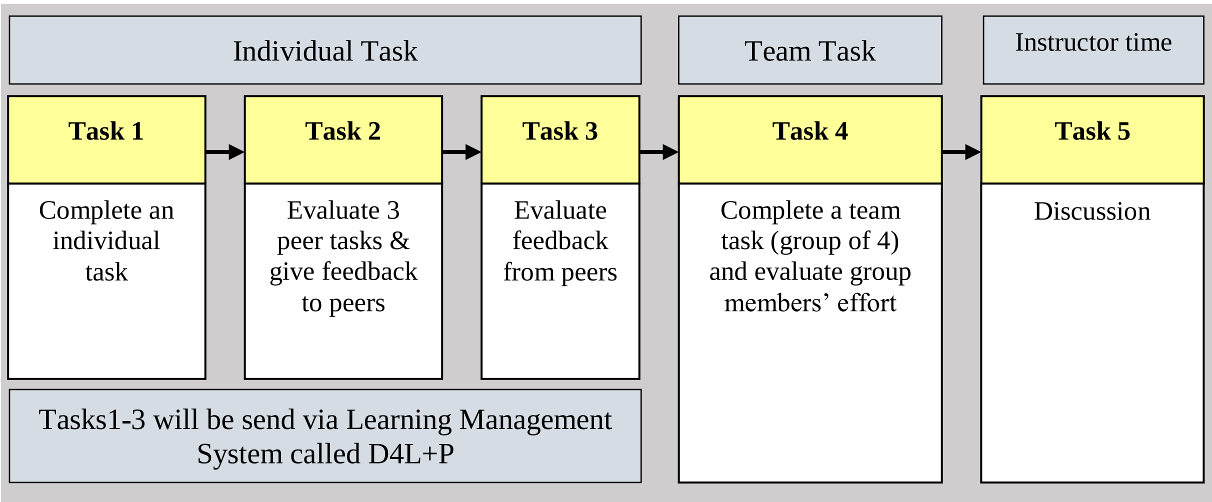


Figure1. The administration of a task (*ConceptTest)* follows the 5-step process.

The sequence of Task 1-5 is as follows:

- **Task 1:** Students answer the given question themselves through self-research which helps them get the overall picture of the lesson from the internet, and the teaching and learning resources provided by the teacher. Those resources can be videos, simulators and etc. However, the instructor needs to consider those materials and how relevant they are to the purpose of the lesson. Once Task 1 is completed, the students then submit through D4L+P system by the due date. If they fail to do so, they will not be able to proceed to Task 2-3.
- **Task 2:** The students will receive peer responses to Task 1 from 3 other classmates through D4L+P system's randomization. Each student provides feedback on Task 1 to all 3 classmates, indicating whether they are inconsistent with scientific knowledge or not. There will also be an evaluation of all classmates' commitment to completing the task through the rubric set by instructors. The instructors need to tell students how to use the rubric for peer marking which focuses on students' effort only. The rubric is not used for the students' knowledge evaluation because students' knowledge is observed by the trend of multiple choices or quizzes score in pre-post peer discussion.
- **Task 3:** The student will receive Task 1 back along with feedback. The student will then be able to consider the feedback received, and decide whether they would like to

adapt their work according to the feedback or not. They can then submit Task 3 through D4L+P system.

- **Task 4:** Students work in groups of four to complete the task questions that correspond to the questions in Task 1. Therefore, the students have to bring their own individual tasks, share their ideas and complete the team task. The work can then be submitted via D4L+P system, and each student can assess the level of contribution to team work through the D4L+P system.
- **Task 5:** The instructor provides feedback and suggestions on the submitted individual and team tasks to fulfill student understanding or to correct their alternative conceptions about the task concepts and then scores the submitted team tasks if necessary.

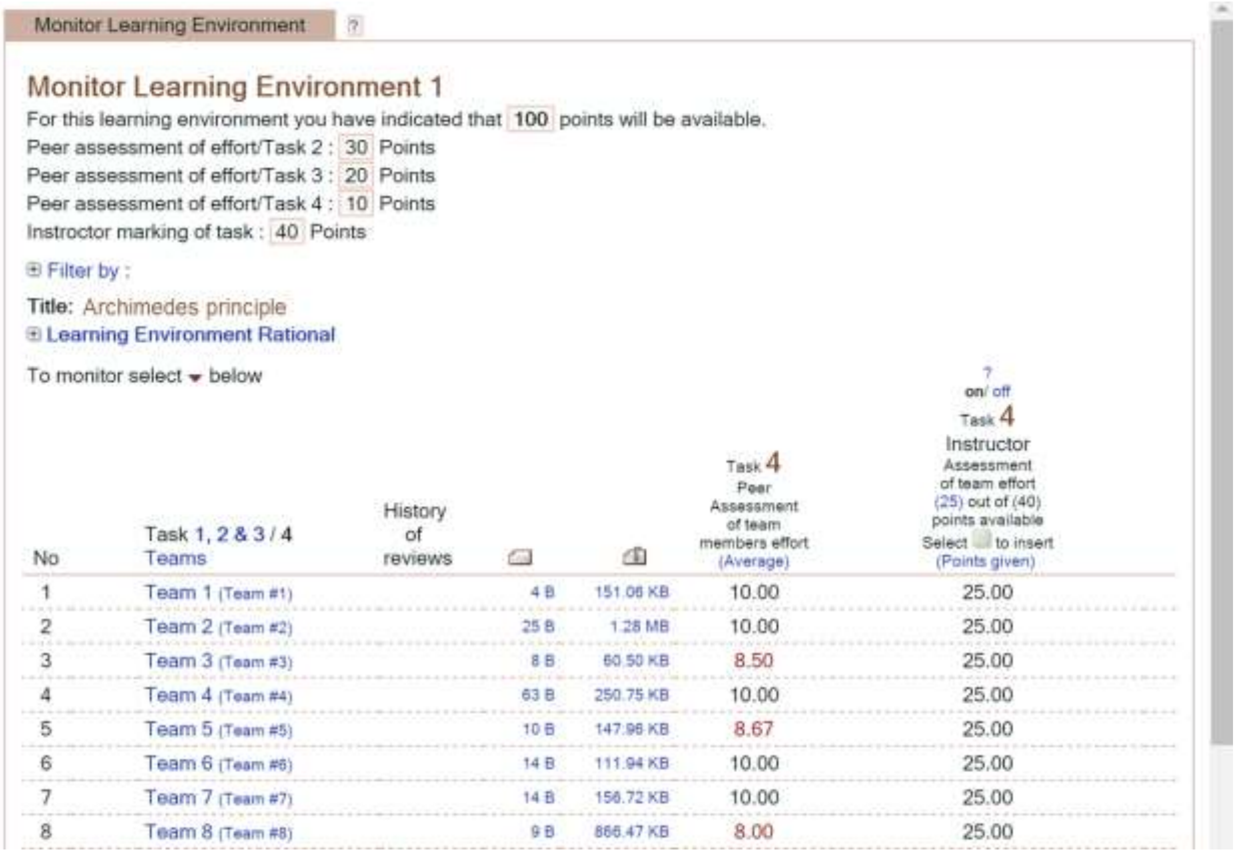


Figure 2: The screen of tasks 1-4 for the students and teachers' assessment

From Figures 1 and 2, it can be demonstrated that the T5 learning model emphasises that students work both individually and in groups through the system of D4L+P. Afterwards, students and instructors are able to discuss collaboratively in class for greater understanding. This strength is what enables the T5 learning model to be used in organising learning activities in various subjects, such as science and social science. It was discovered that the T5 learning model helps students to obtain a significantly increased learning gain, compared to traditional learning methods (Supasorn, 2014; Wuttisela, Wuttiprom, Phonchaiya, & Saengsuwan, 2016). Learning gain which is used to determine the progress of learning by using pre-posttest framework has 3 degrees of gain including lower, medium and high (Hake, 1998). It also enhances project-based learning, enabling students to provide constructive feedback, similar to experts (Wuttisela et al., 2016).

To conclude, the T5 Model is an online peer discussion through the LMS system. It separates the students into groups, with four students per group. The discussion occurs internally within each group. This is different from the PI teaching method, where discussion occurs face-to-face in the class. The entire class is able to observe the entire process and participated from the first to the last steps.

Students' understandings of fluid mechanics concepts

An important goal of science teaching and learning management is the development of students' scientific concepts. Students encounter difficulties changing their preconceived ideas, which differ from accepted scientific theory; this is often called alternative conception or misconception and these ideas disrupt the learning process. Preconceived ideas can hinder the reception of new scientific concepts. The learning environment, including experience, social and cultural aspects, can influence the reception of scientific concepts (National Research Council, 1997). Vice versa, there is a debate about the value of misconception. The way of engaging students to the deeper understanding in concepts can be triggered by misconception (Meyer & Land, 2003). According to Meyer and Land's work, we designed Task 1 in the T5 model for to survey students' misconceptions. If they have misconceptions, we could use these as material to help them understand more about the topic. Furthermore, the misconception can lead students to critical thinking and understanding in the concept (Muller, Bewes, Sharma, & Reimann, 2008).

Results from the physics education research has revealed that students have conceptions about physical phenomena (knowledge they have developed of the physical world) before entering a physics class. The conceptions formed by students to explain physical phenomena may not agree with the models of physical phenomena scientists have developed based on experimentation. However, the students' models may be valid in certain cases. In order for students to alter their conceptions to agree with experimental observations, it is necessary to understand their pre-conceptions and develop materials that will present them with experimental evidence (or thought experiments) that challenges their conceptions, compelling them to alter their conceptions (Sokoloff &Thornton, 1998).

Even though students in Thailand learn about fluid mechanics from primary schools to university level, misconceptions are still found. This is consistent with other researcher's findings (Wuttiprom & Chatmontri, 2015). The misconception described is about the concept of weight and its implications. For example, in response to the question: if a tea bag is dipped into a teacup, would the other hand holding the teacup feel the weight changes or not? The majority of the students, (63.3%) answered incorrectly, with only 41.8% believing that the weight would remain the same. Students believe that when an object is submerged into the water the force of the fluid acts on it. Newton's third law states that for every action there is an equal and opposite reaction. The downward force of the object on the water equals the upward force of the water on the object; the resultant force on the object is zero (Moreira, Almeida, & Carvalho, 2013). The other example is a misconception revealed from the research by Mohazzabi and James (2012). Students were asked to forecast the value on a scale, once a ruler is dipped into a beaker containing water and placed on the scale. The majority of the students said that the weight read on the scale would not change, justifying that the ruler does not touch the scale directly. A demonstration showed that once the ruler is dipped deeper into the water, the value read on the scale increased. However, the majority of the students were still unable to explain why it is so. Some stated that the scale senses a greater force when the ruler is submerged because the fluid pressure at the bottom of the beaker is higher and exerts a greater downward force on the bottom of the beaker. This is similar to the research by Kincanon (1995), whose example involves dipping a finger into a beaker containing water placed on the scale. The majority of the students in this case also said that the value read would not change. The examples of misconceptions in fluid mechanics above also appears with Thai students in the research by Wuttiprom (2013) and Wuttiprom & Chatmontri (2015).

Research questions

To identify students' conceptual understanding in fluid mechanics before and after the use of peer instruction and the T5 learning model, the following research questions were posed:

1. Is there evidence of improvement in mean scores between pre- and post-instruction for the peer instruction and T5 learning model?
2. How much improvement was there in the fluid mechanics concept for the two approaches (as measured by average normalized gains)?
3. How does the degree of improvement depend on the learning approach of implementing (peer instruction or the T5 Learning Model)?
4. Which conceptual area in fluid mechanics is challenging for students?

Methodology

Context

This research took place in the first year calculus-based physics course in the academic years 2015 and 2016 at Ubon Ratchathani University, which is a university in northeast of Thailand. There are approximately 900 students enrolled in this course who major in science and engineering. These students are generally divided into six classes based on their major. Each class had roughly 150 students and was taught by different lecturers and in different styles. The course is designed to enable students to develop an understanding of tertiary physics concepts of mechanics, wave, fluid mechanics, and thermodynamics. The classes of both groups were conducted by one instructor, and the curriculum was not modified for the T5 model in this case. The only limitation was time, so the steps of the T5 model that had been set up should be finished in three weeks. Two classes which were taught by the same instructor had the same teaching and assessment processes. Fluid mechanics contents were taught three hours per week for three weeks; two-hour and one-hour lecture without laboratory. Before each lecture, students were asked to complete the web-based reading assignment (Novak, 2011).

Sample

The sample was drawn from two groups of engineering students, during the fluid mechanics course. The first group (N=148), called the PI group, was taught by the Peer Instruction (PI) technique (Mazur & Hilborn, 1997). Each key point in a lecture takes a minimum of 15 minutes to cover: 7-10 minutes of lecturing, 5-8 minutes for a *Concept Test*. One hour of lecturing therefore requires about four key points. The PI group was taught for nine hours of class time. The second group (N=223), called the T5 Model group, was taught by conventional lecturing during class time; the instructor explained fluid mechanics principles and then distributed a worksheet on the principle with some problems which students solved in the class. After finishing two two-hour lectures, the students were required to complete a *ConcepTest* through the online learning management system, following the 5-step process (see Figure 1):

1) Review the provided resources and then complete an individual task;

2) Give constructive feedback and score three randomized as well as anonymous peer tasks;

3) Receive and score feedback from peers;

4) Complete a team task (corresponding to Task 1) by a group of four and score group members' participation; and

5) Instructor comments on the submitted team tasks to fulfil student understanding (one hour discussion) and then score the submitted team tasks (Salter, Richards & Carey, 2004).

The T5 Model group was taught 5-hours of class time and 4 hours of time on task on the online site.

Questionnaire assessing students' concept of fluid mechanics

The Fluid Mechanics Conceptual Test (FMCT) was designed to assess students' understanding of basic fluid mechanics concepts and covered four main subtopics in university-level calculus-based introductory physics: pressure and depth in a static fluid, Archimedes principle, equation of continuity, and Bernoulli's equation of continuity. The FMCT is a 12-item, two-tier test. The first tier of an item is a conventional multiple-choice question with four choices. The second tier presents some reasons for the given answer for the first tier. The FMCT was developed iteratively involving trials with a total of 728 students from first year university students. The scores of this group were then analysed using five well known statistical tests described in Ding, Chabay, Sherwood and Beichner (2006). The results, difficulty index (0.36), discrimination index (0.33), point biserial correlation coefficient (0.42), Cronbach's alpha reliability index (0.88), and Ferguson's discrimination index (0.95), indicate that FMCT is a reliable test with adequate discriminatory power. The FMCT behaves in a similar manner to other concept surveys, including international studies with Thai students, see for example Wattanakasiwich, Taleab, Sharma and Johnston, (2013) and Wuttiprom, Sharma, Johnston, Chitaree and Soankwan (2009).

Procedure of data collection

This test was administered before and after the lecture. A *t*-test statistics was carried out to determine the significance of the difference between the mean scores of the PI and T5 model groups. As well as, the average normalized gain was used to investigate the effect of peer instruction and the T5 learning model approach on students' achievement on conceptual understanding about fluid mechanics. The normalized gain, <g>, a measurement of the increase in score between pre- and post-testing (actual gain) expressed as a fraction of the range of possible score increases (maximum possible gain), were calculated as <g> = (<%post - %pre) / (100 - %pre). Normalized gain was used to correct for differential capacity for learning gain at either end of the measurement scale (Hake, 1998). It is possible for a student who attains a higher pre-test score to attain a smaller absolute gain (post-test score minus pre-test score). This floor and ceiling effect can be minimized by using <g> analysis. Normalized gain has been used characterization of conceptual improvement in physics courses with both lecture and online pedagogies (Georgiou & Sharma, 2015; Hill, Sharma, & Johnston, 2015). It can be calculated using either the average scores of the class or individual students' scores and has been classified into high gain (<g> ≥ 0.7), medium gain (0.7 > <g> ≥ 0.3), and low gain (<g> < 0.3). Insight into student learning is also provided by analysis of results from FMCT tests, by categorizing answers with similar patterns from students in both the PI group and T5 Model group.

Results

Pre and post test results

The pre- and post-test score paired sample t-test results for the PI showed a significant: t(294)= 8.4221, p<.05. In the same way, the pre- and post-test score results also showed a significance in the T5 Model group: t(444)= 11.252, p<.05.

Independent t-tests were used pre- and post-test scores in the PI and T5 Model group. There was no significant difference between the evaluation test results of the PI Model and T5 groups prior to the instruction: t(369)=0.7032, p<.05. No significance difference could likewise be seen in the groups after the instruction: t(369)= 1.626, p<.05.

Table 1: Pre-test, post-test and normalized gain following conceptual area

Conceptual area	PI Model Group (N=148)			T5 Model Group (N=223)		
	Pre-test %	Post-test %	gain <g>	Pre-test %	Post-test %	gain <g>
Pressure and depth in a static fluid	35.31	79.17	0.65	40.41	80.33	0.61
Archimedes principle	19.50	59.64	0.50	27.93	66.61	0.53
Equation of continuity	15.13	65.30	0.58	16.19	58.34	0.50
Bernoulli's equation of continuity	21.43	54.93	0.43	19.93	57.16	0.46
Average	**22.84**	**64.76**	**0.54**	**26.12**	**65.61**	**0.52**

Upon considering each conceptual area (Table 1), it appears that students from both the PI Model and T5 Model have the % pre-test, post-test and normalized gain in the same topics which falls within the medium gain (between 0.3 and 0.7). These normalized gains are higher when compared to the research of Tanahoung, et al., (2009), Georgiou and Sharma (2014) and Hill, Sharma and Johnston (2015) which teach with the interactive lecture demonstration approach.

Students' understanding of fluid mechanics concepts

The students answer to individual items in the test give insight into the students' learning. Each of the conceptual areas is comprised of 3 questions. The students must answer both tiers correctly in order to gain the score. Each question is worth 4 points, with %pre-test, %post-test and normalized gain of each question illustrated in Table 2.

Table 2: Pre-test, post-test and normalized gain for each item

Item No.		Pressure and depth in a static fluid			Archimedes principle			Equation of continuity			Bernoulli's equation of continuity			avg.
		1	2	3	4	5	6	7	8	9	10	11	12	
PI	Pre	55.40	45.00	5.54	14.06	17.80	26.63	2.07	22.65	20.67	18.43	20.64	25.23	22.84
	Post	82.00	77.00	78.50	50.45	67.98	60.50	68.00	62.86	65.05	40.34	65.32	59.14	64.76
	Gain	0.60	0.58	0.77	0.42	0.61	0.46	0.67	0.52	0.56	0.27	0.56	0.45	0.54
T5	Pre	61.20	47.60	12.43	35.74	23.40	24.65	5.82	18.34	24.42	22.76	12.55	24.47	26.12
	Post	80.50	72.50	88.00	58.08	76.00	65.76	60.33	52.50	62.19	45.88	62.28	63.31	65.61
	Gain	0.50	0.48	0.86	0.35	0.69	0.55	0.58	0.42	0.50	0.30	0.57	0.51	0.52

The results presented demonstrate the students' understanding in fluid mechanics concepts, both before and after the class, in questions with similar patterns in both the PI group and the T5 Model group.

The important part of PI and the T5 Model

This case fits with Question 3 (Pressure and depth in a static fluid), which is a question with the highest normalized gain in the PI group and the T5 Model being 0.77 and 0.86 respectively, which is a high gain. We asked students to answer the question given the situation that if we bore many holes in a bottle and fill it up with water, the water from which hole can go farthest as shown in Figure 3.

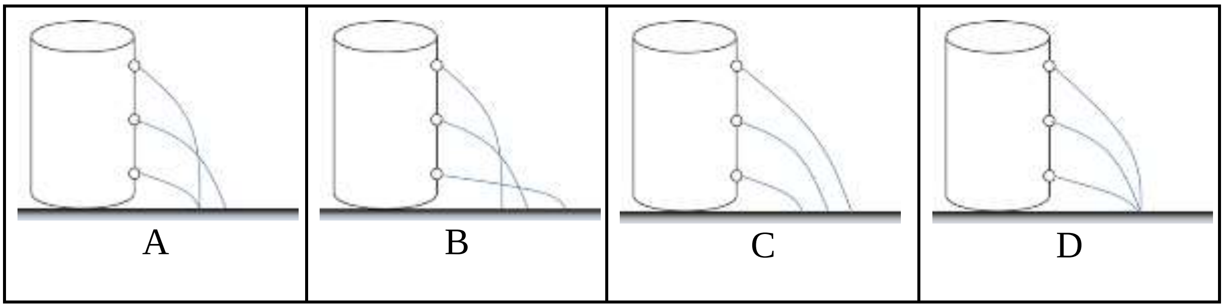
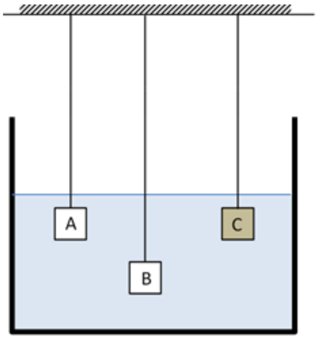


Figure 3: The possible answers for water passing different levels of the holes

Before class, students from both the PI group and the T5 Model group answered correctly (choice A), only 23% and 18% respectively. The option most selected was B. From the interviewing and the investigation of second tier pre-test answers, there are two possible reasons for this: one reason was that they believed the Physics Text Volume 2 written by the Institute for the promotion of Teaching Science and Technology of Thailand (2008); and the other was they considered one dimension or one topic. The results after class were that over 70% of both groups of students were able to answer correctly. The quiz had been posted for peer discussion. After discussion, the number of correct answers from students increased. After revealing the correct answer, we treated them by demonstrating the experiment to confirm their understanding. We have also proven the results both experimentally and theoretically.

How could discussion help students in Archimedes principle?

This case fits question 5 (Archimedes principle), which was modified from the research by Loverude, Kautz, and Heron (2003). It is the question where both groups selected the deceptive answers, both in the first and second tier. The question was: three cubical blocks of equal volume are suspended from strings. Block A and B have the same mass and block C has less mass. Each block is lowered into a fish tank to the depth shown in the Figure 4. Students are asked to rank the buoyant forces acting on each block?



Question 5: Which one is correct ranking the buoyant force acting on each block?

A) A = C < B　　B) A = B < C
C) A = B = C　　D) No correct answers are available

What other reason supports the answer in first tier
A) Blocks of different mass submerged at the same depth
B) Blocks of the same mass submerged to different depths
C) Identical blocks fully and partially submerged

Figure 4: Three blocks of equal volume are suspended underwater by strings. There are two blocks of the same mass at different depths (A and B) and two blocks of different mass at the same depth (A and C).

Prior to the class, students in both the PI group and T5 Model group chose the deceptive answer: B) A = B < C; the highest was at 65% and 72% respectively in the first-tier. For the second-tier, the students also chose a deceptive answer: B) Blocks of the same mass submerged to different depths, the highest is 87% and 95% respectively. They considered that the water's buoyancy affected the objects proportionally with the object's mass. After the class, the number of students who were able to answer accurately increased to 82% and 76% respectively. The correct answer in the first-tier is choice C. The 3 boxes' buoyancy was equal, which is consistent with the rationale in choice C of second-tier. This is because all three blocks displace the same amount of water. ($F_B = \rho V g$ same volume same buoyant force). From interviews of randomly selected students it was revealed that they gave more consideration into the buoyancy equation during the discussion part which helped them answer correctly.

The lowest pre-test score

This case fits with question 7: Equation of continuity. Equation of continuity is one of two important equations for the flow of an ideal fluid. The equation of continuity says that the volume of an incompressible fluid entering one part of a flow tube must be matched by an equal volume leaving downstream. This question asked the students to organize volume flow rate in position 1-4, from maximum to minimum, as illustrated in Figure 5. Prior to the lecture, students in both the PI group and the T5 Model group answers correctly by 2.07% and 5.82% respectively. The deceptive answer that was the most popular was volume flow rate, whose position 1 is more than position 2, 3 and 4 respectively. The given rationale was that the cross section area is small, and thus the water flow will be significant. Volume flow rate will be high. Students generally link volume flow rate with the water flow; this is a common misconception among students.

After a lecture, the students were able to better understand volume flow rates, and were able to answer correctly at 68% and 60.33% in the PI and the T5 Model respectively. This may have occured for two reasons: (1) Students analyzed SI units of equation of continuity, which was m^3/s. The meaning of this equation was that the flow rate is constant at all points in a flow tube, or that flow is faster in narrower parts of a flow tube, slower in wider parts; (2) Students get to conduct the experiment with teachers in class.

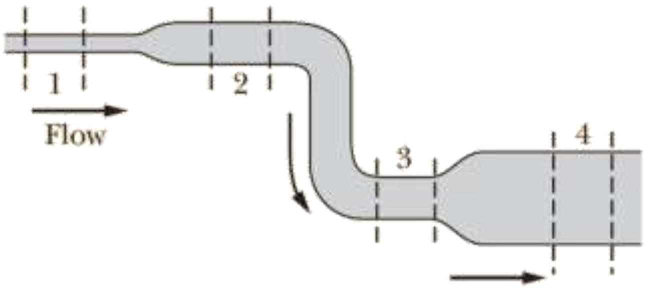


Figure 5: Volume flow rate diagram

Answers were chosen in equal proportion of 25%

This case fits with question 12 on Bernoulli's equation of continuity. The students in the PI group and the T5 model group answered with different choices at an equal proportion of 25%. This shows that most of students had misconceptions in this topic. Once the lecture was completed, the students from the T5 model were able to answer more correctly than students from the PI group by almost 20%. This may be because students from the PI group were only able to observe the demonstration in class (the demonstration is similar to the question in Figure 6). Students in the T5 model group had researched other phenomenon; e.g. the flow rate of air under an aircraft wings, Bernoulli's principle on two pieces of paper, Bernoulli's principle on a basketball ball, Bernoulli's principle on a car's spoiler, Bernoulli's principle sprayer- at least 3-5 phenomenon each-all related to Bernoulli's equation in daily life and explored in class discussion. From the pattern of the T5 model, we can discern 2 possible reasons; 1) the T5 model forces students to study and interact more outside the class which yielded the better result or, 2) the material provided online helped students understand more about the topic.

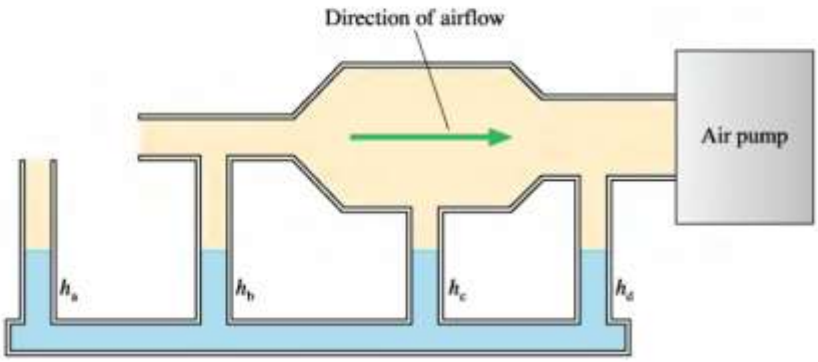


Figure 6: The correct answer is $h_b > h_d > h_c > h_a$. The liquid level is higher where the pressure is lower. The pressure is lower where the flow speed is higher. The flow speed is highest in the narrowest tube, zero in the open air.

Discussion

In this study, we have demonstrated the learning gains conferred to students through Peer Instruction and the T5 model. A peer discussion is a part of Peer Instruction which lets students discuss among neighbors in the class as a face to face method following the model developed by Eric Mazur (1997). Likewise, the T5 model that our Ubon Ratchathani University has developed, enabled us to create the learning management system which supports peer discussion in an online format. It is called Designing for Learning plus Portfolio (D4L+P). By calculating the learning gains from the two methods, we found the learning gains for both methods were medium.

Peer Instruction is a form of interactive learning applicable for classrooms with large numbers of students at the university level. This learning management format is popular as it helps learners comprehend physics better. The crux of peer instruction learning management is the management system of interactions between instructors and students, as well as students and students. This is done through a question set where answers must be selected, which is called: '*ConcepTest'*. The PI survey results indicate that most of the assessed PI courses produce learning gains commensurate with interactive engagement pedagogies from which most of learning gains are considered medium, and more than 300 instructors (greater than 80%) consider their implementation of Peer Instruction to be successful (Crouch & Mazur, 2001). From mean scores between pre- and post-instruction for the Peer Instruction group, which rose in a statistically significant manner, and with the value of normalized gain at medium gain, it indicates that Peer Instruction is another learning format that helps improve conceptual understanding of learners.

Peer Instruction, apart from being one of the most effective strategies to improve students' understanding, also leads to positive changes in students' attitudes and beliefs (Zhang, Ding, & Mazur, 2017). Therefore, the researchers decided to adopt the effective teaching format of Peer Instruction to use with an online tool, Designing for Learning plus Portfolio (D4L+P), developed solely to support the T5 (tasks, tools, tutorials, topic resources, and teamwork) method of teaching and learning. To say that the T5 is PI instruction in an online format would not be wrong. The researchers are confident enough to state that the mean scores between pre- and post-instruction for the T5 Model group increases significantly, with the value of normalized gain at medium gain. Observed learning gains using the T5 model were no different from the PI group, which shows that the T5 Model effectively is a parallel teaching method with a similar level of efficacy to Peer Instruction.

These findings, and the design of the study itself, raise to several areas of discussion including the capacity of the instructor as a moderator for peer discussions, the usefulness of *ConcepTest* question, the level of difficulties in creating tasks, and duration of discussion (Miller et al., 2014).

Capacity of instructor as a moderator for a peer discussion

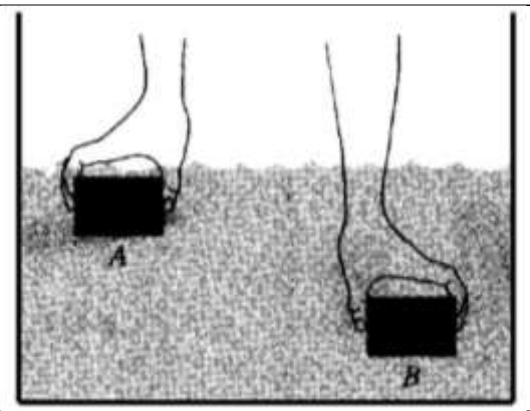
The teaching method of PI relies on the capacity of the instructor. Learners need to bring students into discussions, which can increase the average learning gains of learners from 14% to 22% with just one discussion alone. However, the method of PI has a step of integrated discussion embedded within it. It appears that the PI model helps learners advance their learning more than a lecturer with a discussion alone (Zingaro & Porter, 2014). Comparison was made by having learners discuss collaboratively with learners, and for learners to discuss with fellow learners. The interesting point is that the learners discussed among themselves more than with the instructor. This maybe because the learners and the instructor have less interaction, compared with what already exists within the student group (Durrington & Yu, 2004). The PI teaching method allows learners to discuss collaboratively, while the instructor is more of a moderator rather than a lecturer. A 10 year research study (1990-2000) reveals that the PI teaching grants greater advancement of learners' understanding, from medium to high (Crouch & Mazur, 2001). This is inconsistent with our research. The students taught through the PI have advanced at medium gain level, where the researcher has to be a great moderator, facilitating maximum discussion among learners within the agreed duration.

As for the T5 Model, the role of the instructor as a moderator for peer discussion does not exist, as it is processed by the LMS. The learner can, however, prepare useful resources that will be helpful for discussions in the system.

Discussion would happen according to the set system, from providing feedback to fellow learners in Task 2 and 3. Provision of feedback with peers through the system helps learners to consider and develop an understanding of the content and adapt tasks to become more thorough (Wuttisela, 2016). The group of students preferred online discussion, and there was more critical thinking from students in the online forum by using content analyzing methods. However, the results were mixed and the best way is to blend the two methods in an activity (Guiller, Durndell, & Ross 2008). In the T5 model, we have both online discussion and face to face discussion which is the way to blend two methods into one activity. The researcher believes that even though online peer discussion works through the LMS, feedback provision is also useful in enabling learners to move forward, akin to the PI teaching method. This is similar to this research where learners in the T5 model show learning advancement at medium gain.

The usefulness of *ConcepTest* questions

ConcepTest questions demonstrate how the PI teaching method can be successful. The question does not measure wit or memorization in physics, but measures understanding of actual content (Crouch & Mazur, 2001). In this paper, *ConcepTest* questions were used as a part of peer discussion which engaged students to think critically. Such questions reveal the learners' understanding of the content; an understanding which may be difficult to change (Miller, Lasry, Lukoff, Schell, & Mazur, 2014). For example, the *ConcepTest* on Buoyancy from *Peer instruction: A user's manual* (Mazur, 1997) shows that prior to the discussions, over 80% of both student groups understand that the force exerted on Brick B is more than Brick A (see diagram below). Questions that focus on measuring understanding will reflect learners' point of confusion.



Imagine holding two identical bricks under water. Brick A is just beneath the surface of the water, while brick B is at a greater depth. The force needed to hold brick B in place is

1. larger than
2. the same as
3. smaller than

the force required to hold brick A in place.

Therefore, for this research, the *ConcepTest* questions used with students in the PI groups are also used with those in the T5 Model.

The elements of peer discussion

For the PI teaching method, the duration of discussion of the question for learners ranges between 2-5 minutes. If learners spent too much time discussing, there was a tendency for the answers to be wrong, as opposed to discussion in a short time. Without setting a specific time for discussion, the learner may not decide on an answer even though it has been 5 minutes (Miller, Lasry, Lukoff, Schell, & Mazur, 2014). By allowing learners to show reasons, to think before they start discussing with others, they are more likely to propose an answer with a rationale (Nielsen, Hansen, & Stav, 2016).

For the T5 Model, the duration of discussion for Task 2 (evaluate 3 peer tasks and give feedback to peer) and Task 3 (evaluate feedback from peers) was set at 48 hours. However, for our research, we did not record how much time each student spent on Task 2 and 3. This is a very interesting point that we can develop in our future research.

Conclusion

The PI model and the T5 Model are teaching methods that focus on peer discussion in a different manner. PI is a peer discussion in a face to face manner. The entire class is able to observe the process and take parts from the beginning to the end, with the instructor being a moderator. The T5 Model is an online peer discussion in an LMS system, which was developed to act as a moderator instead of the instructor. In the discussion in online conditions, there were only four members. Both of the PI and the T5 Model helped students achieve the learning gain considered to be medium (0.54 and 0.52 respectively). Generally, for each *ConcepTest* question, the duration for the discussion of the PI teaching method is set at 2-5 minutes. In the T5-Model teaching method, students see the entire *ConcepTest*. The period of discussion is set at 48 hours (the discussion occurs in Tasks 2 and 3). Even though the two types of learning differ, as mentioned above, the research shows that it does not differ much in terms of learning advancement. It can thus be concluded that the T5 Model is another effective teaching method, similar to the PI teaching method which has been accepted for over two decades.

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