The Impact of Peer Instruction on Students’ Achievement in Mathematics Analysis

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In this research, we investigated the effect of peer instruction method on the first course mathematics education students’ academic achievement and the attitudes of students by using peer instruction method. The implementation was carried out seven weeks with 60 participants in an introduction to mathematics analysis lesson in Suleyman Demirel University in Kazakhstan. Two first course groups were randomly assigned to treatment and control groups. The final results were obtained to measure students’ academic achievement and questionnaires used to indicate attitudes towards peer instruction. Data were analyzed, using analysis of t-test ($p = 0.029$) with an alpha significance level of 0.05. The results of final questions indicated, peer instruction has a significant positive effect on students’ achievement in the introduction to mathematics analysis course and the results of questionnaires demonstrated peer instruction (PI) has a positive impact on peers’ understanding by making learning interesting and interactive, and it also creates conducive atmosphere in the class.

Keywords: peer instruction, mathematics achievement, mathematics analysis, attitudes towards peer instruction method

Introduction

Instructors use the traditional teaching method to transfer their knowledge to students in many different disciplines and courses. They have difficulties in problem-solving, deriving relationships, knowledge of representations, and conceptual learning in these teaching methods (Crouch & Mazur, 2001; Svelsbergh, de Jong, & Ferguson-Hessler, 2011; Thompson, Christensen, & Wittmann, 2011). According to Freeman et al. (2014), “students in classes with the traditional methods have 1.5 times higher chances of failing than students in active teaching method” (p. 1). Therefore, researchers have been developing new teaching approaches and models based on active and interactive learning for a long time. One of these approaches is peer instruction. Mazur and Watkins (2010) defined peer instruction as “An active teaching method that promotes classroom interaction to engage participants and address difficult aspects of the material” (p. 39). In general, peer
instruction is a student-centered active learning method in which students share their knowledge by interacting with each other instead of transferring information from the teacher (Wong, Kwan, Wang, & Luk, 2015). This method changes the pattern of the lecture format from the traditional one to one in which the instructor poses multiple-choice questions during the course, thereby engaging students actively in discussions with their classmates and focus their attention on central concepts (Crouch, Watkins, Fagen, & Mazur, 2007; Crouch & Mazur, 2001; Mazur, 1997). Porter, Bailey Lee, Simon, and Zingaro (2011) described the peer instruction as “students one by one response a question, discuss with groupmates, and response to the same question again” (p. 1). Instructors have noticed that peer instruction enhances deeper understanding of the students by making the class lively and interactive (Crouch et al., 2007; Crouch & Mazur, 2001; Mazur, 1997). Crouch and Mazur (2001) indicated that the peer instruction develops the students’ understanding. According to Akay (2011), in the model of peer instruction, students learn and teach themselves while their friends in a similar social group help them to learn. For this reason, it is thought that the information learned can leave more permanent marks on the students and give students the power to comment. Peer instruction can be defined as a method in which students are actively involved in the education process by discussing within a peer group and helping each other within the group (Crouch & Mazur, 2001; Mazur, 1997; Nicol & Boyle, 2003). Peer instruction is fast, fun, and supportive. Therefore, it has a positive effect on the success of students. Students reach information by doing and living. Since knowledge and skills are students’ own work, they also affect permanence in a positive way. In summary, in peer teaching method, students think, analyze, discuss, and challenge on the materials with classmates while, on the other hand, the instructors create a conducive learning atmosphere, observe the classroom, listen to students, and ensure the real-time feedback. Peer instruction was first applied in teaching fundamental physics concepts using multiple-choice tests in a crowded physics course (Mazur, 1997). Until now, several studies on peer instruction method have been published in different courses and disciplines. Studies focused on academic achievement, motivation, self-confidence, problem-solving, attitude towards mathematics, retention and conceptual understanding. The results of previous studies on achievement in physics (Crouch & Mazur 2001; Gok, 2012; Hughes et al., 2013; Lasry, Finkelstein, & Mazur, 2009; Lorenzo, Crouch, & Mazur 2006; Miller-Young, 2013), in chemistry (Golde, McCreary, & Koeske, 2006; Trent, 2013), in computer science (Simon, Spacco, & Parris, 2013; Zingaro & Porter, 2014), in the medical physiology course (Rao & DiCarlo, 2000), and in the English course (Yaoyuneyong & Thornton, 2011).

The Implementation of PI

The application of PI method includes seven steps. Initially, the instructor gives a short lecture on a concept in the course; it takes 15-20 minutes. Then, the instructor gives concept test questions; concept test questions are designed to evaluate the student understanding of the basic concepts behind the lecture material. Students solve the question individually and give first responses in two to three minutes. After that the instructor analyzes responses if the correct answers are less than 30%, the instructor explains the lecture again, if the correct answers are between 30% and 70%, the class passes the discussion part and if the answers are higher than 70%, the instructor presents the next question. In the fourth step, students discuss their answers with classmates in one to two minutes. The previous studies (Brooks & Koretsky 2011; Crouch & Mazur 2001; Lasry et al., 2009) indicated that the discussion section is an important part of peer instruction and it affects the students’ responses positively. After the discussion part, students give second responses. In the last step, the teacher collects answers and explains the question. The students vote sometimes, using colored cards or a show
of hands instead of the clickers—the general process is an adaptation of the think-pair-share technique (Knight & Brame 2018).

The concept test proceeds as follows:
1. To give questions;
2. Participants are given time to think;
3. Each participant gives an answer;
4. Participants discuss their responses with classmates;
5. Participants give second responses;
6. Instructor collects answers;
7. Instructor explains correct answers (Crouch et al., 2007).

Peer Instruction in Math Classes

Although the first application of PI in classrooms was done in a physics course, peer education has been spread and used in other disciplines. In addition, several works which are applied in maths also indicated the successful results. In our literature review, we investigated 23 studies in mathematics. Several studies were researched in academic achievement (Abdelkarim & Abuiyada, 2016; Abdelkarim, Abuiyada, & Siddiui, 2016; Akay, 2011; Allison, 2012; Cronhjort, Filipsson, & Maria, 2013; Demirel, 2013; Olool, Mutsotsa, & Masibo, 2016; Ouko & Aurah, 2015; Vasay, 2010), their results demonstrated that peer instruction affected the students’ academic achievement positively. The results of studies about attitudes towards mathematics (Abdelkarim et al., 2016; Akay, 2011; Campit & Garin, 2017; Demirel, 2013; Yardim, 2009) showed peer instruction has a positive impact in attitudes towards mathematics. Allison’s (2012) study indicated that peer instruction affected motivation positively. The other studies (Awinouko, 2018) results showed positive effect in problem-solving ability, Pilzer (2001) in academic math skills, in the attendance Olpak, Baltaci, and Arican (2018), in proficiency level in mathematics Lacaba, Magalona, and Lacaba (2018) and, in retention Demirel (2013).

Purpose of the Study

The purpose of the study is to investigate the impact of peer instruction in first-course mathematics education in the introduction of mathematical analysis class.

Research Question

1. Does peer instruction have any effect in the introduction of a mathematical analysis class?
2. What is the effect of attitudes towards peer instruction teaching procedure during lectures on peer group?

Methodology

The participants in this study were 60 students (34 girls and 26 boys) aged 18-21 in the education mathematics course. None of them had used colored cards in their studies, and they had never studied with peer instruction teaching procedure before.

Materials

Final questions: The final question includes the topics for seven weeks in the syllabus. It contained 10 questions which were prepared by the researcher.
Questionnaire: The survey, which was done before the other study (Al-Hebaishi, 2017), contained 18 items based on a five-point Likert scale (5 = “Strongly agree”, 4 = “Agree”, 3 = “Neutral”, 2 = “Disagree”, and 1 = “Strongly disagree”).

Procedure

Initially, the instructor provided the students instructions on how to use PI during the class. The application of PI was carried out as defined by Mazur (1997). In the first course, curriculum introduction to mathematical analysis has three hours. Each class included two parts: the first part of 15-20 minutes of the class was for the lecture while PI was carried out in the other part of the class. For the PI, initially, the lecturer presents the question and two minutes were given to the students, to think and solve the concept test question individually. Then, students gave first responses by using colored cards and the result was shown on the screen as a histogram. After analyzing the histogram, students discuss their responses with their peers in two minutes. In the discussion part, students provide their reasons and try to convince their peers that their responses are correct. Several studies indicated that the discussion part of peer instruction increases correct answers.

Figure 1 illustrates the alteration of students’ responses that during the discussion change from an incorrect answer to the correct answer (Crouch & Mazur, 2001).

Figure 1. Change of answers.

After discussion with their peers, the students were given the opportunity to change their first answers if they desired in one minute. The instructor presents the histogram of second responses and students observed it. Lastly, the instructor explains the correct answer of the question in two minutes.

In the implementation, if after the first response, the correct answers are less than 30%, the instructor gives the lesson again, if the correct answers are between 30% and 70%, then the peer instruction method is implemented and if correct answers are more than 70%, pass on to the next question (Lasry et al., 2009).

Histogram of the first and second answers of the question asked in Figure 2 is given.

Which of the following expression are true? (Since there may be more than one correct answer, determine all correct answers.)

A. If \( \lim_{x \to a} \frac{f(x)-f(a)}{x-a} \) exists, then \( f \) is differentiable at \( a \).

B. If \( f \) is continuous at \( a \), then \( f \) is differentiable at \( a \).

C. If \( \lim_{x \to a} f(x) \) exists, then \( f \) is differentiable at \( a \).

D. If \( f \) is differentiable at \( a \), then \( \lim_{x \to a} f(x) = f(a) \)

Only A
A and C
C and D
A and D
B and C

Figure 2. A typical graph for students’ first and second responses: The correct answer is D.

As seen in Figure 2, the frequency of the correct reply increased from 8 to 22 while the frequency of the wrong reply decreased significantly.

**Results**

**Findings Regarding the Final Questions**

Table 1

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>30</td>
<td>68.67</td>
<td>25.90</td>
</tr>
<tr>
<td>Peer</td>
<td>30</td>
<td>81.00</td>
<td>15.28</td>
</tr>
</tbody>
</table>

The mean of the group who received traditional instruction was 68.67 while the mean of the peer instruction group was 81.00 (see Table 1). This result shows a significant difference on behalf of the peer instruction group. The statistically significance was checked by independent sample \( t \)-test (see Table 2).

Table 2

<table>
<thead>
<tr>
<th>( t )</th>
<th>df</th>
<th>( p )</th>
<th>Mean difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2.25</td>
<td>58</td>
<td>.029</td>
<td>-12.33</td>
</tr>
</tbody>
</table>

The \( t \)-test results indicate that peer instruction has an effect on students’ achievement (\( t (58) = -2.25, p = 0.029 \)).

**Findings Regarding the Questionnaire**

Table 3 indicated the statistical illustrative examination of the attitudinal survey implemented to the treatment group at the end of implementation, which was planned to gain comprehension into their feelings regarding peer instruction teaching procedure.
Table 3

<table>
<thead>
<tr>
<th>Item</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>4.467</td>
<td>0.718</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>4.067</td>
<td>0.964</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>4.267</td>
<td>0.680</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>3.967</td>
<td>0.983</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>4.367</td>
<td>0.699</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>3.867</td>
<td>0.991</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>3.733</td>
<td>0.093</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>4.300</td>
<td>0.640</td>
</tr>
<tr>
<td>9</td>
<td>30</td>
<td>4.367</td>
<td>0.657</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
<td>4.033</td>
<td>0.772</td>
</tr>
<tr>
<td>11</td>
<td>30</td>
<td>4.500</td>
<td>0.563</td>
</tr>
<tr>
<td>12</td>
<td>30</td>
<td>4.067</td>
<td>0.907</td>
</tr>
<tr>
<td>13</td>
<td>30</td>
<td>4.000</td>
<td>0.775</td>
</tr>
<tr>
<td>14</td>
<td>30</td>
<td>4.633</td>
<td>0.806</td>
</tr>
<tr>
<td>15</td>
<td>30</td>
<td>1.800</td>
<td>0.833</td>
</tr>
<tr>
<td>16</td>
<td>30</td>
<td>3.967</td>
<td>0.875</td>
</tr>
<tr>
<td>17</td>
<td>30</td>
<td>4.233</td>
<td>0.629</td>
</tr>
<tr>
<td>18</td>
<td>30</td>
<td>4.300</td>
<td>0.690</td>
</tr>
</tbody>
</table>

The outcomes of the analysis of the survey showed mean scores between 4.633 and 1.800. The top mean score was achieved from Item 14 ($M = 4.633$), showing that 99% of the participators trust that the students should offer help to develop their group mates’ learning. The second maximum mean score was achieved from Item 11 ($M = 4.500$), which demonstrates that approximately 97% of the peer instruction group thinks that the peer instruction method established a sincere interrelation among students. Item 1 achieved the third highest mean score ($M = 4.500$), signifying that 89% of the participators trust that PI creates a supportive ambiance in the classroom. Items 5 and 9 achieved an equal mean score ($M = 4.367$), and jointly reached a fourth place ranking, thus, revealing that 90-95% of the peer instruction group either agreed or strongly agreed that using the peer instruction method makes courses interesting and increases the interaction among students. Lastly, Item 15 obtained the lowest score mean ($M = 1.800$), showing that 70% of participants do not agree that discussion with group mates does not help students to learn. In general, the treatment group had a positive attitude towards the peer instruction teaching method and realized it is helpful in making possible for them to understand key course concepts (see Table 2).

**Discussions**

The present study examined the effect of the peer instruction procedure on the first-course education math students in an introduction to mathematics analysis course at Suleyman Demirel University with 60 students. A final quiz consisting of 10 questions was prepared by the author to measure the success of the students. The peer instruction procedure was applied in teaching course concepts to the treatment group while the comparison group was exposed to the traditional instruction method approach. According to statistical analyses, there were statistically significant differences between both groups’ average mean final scores. This study is distinctive from other similar studies on this topic in that, it is the first study guided in Suleyman Demirel University.

The results of this study support other research, which approves that PI improves student performance and
learning. For instance, Crouch and Mazur (2001) found significant rises in conceptual problem-solving skills across a 10-year duration of peer teaching experience in physics classes. Likewise, Rao and DiCarlo (2000) noticed that PI developed medical student achievement on quizzes. Similarly, Lucas (2009) reported that PI increases student participation and understanding. As a final example, Cortright, Collins, and DiCarlo (2005) found that a student’s ability to solve novel problems was significantly improved after the PI.

According to Zingaro and Porter (2014), the peer instruction procedure is a collaborative pedagogical application within course lectures. This procedure has delivered important development in the final examination performance of the students by actively engaging the students in deepening their understanding from the instructor’s explanation to establishing their own learning patterns. Therefore the rates of failures were observed decreasing and students were being retained (Simon et al., 2013). This procedure is being implemented in a wide field of science courses, mathematics, and other branches at the secondary education, colleges, and university (Mazur, 2013).

Peer instruction teaching procedure makes a supportive learning atmosphere wherein participants support each other during the learning procedure, and cooperate in order to establish information and reach a comprehension regarding crucial concepts (Al-Hebaishi, 2017). According to the study conducted, most of the participants strongly agree that students should assist each other to improve their peers’ learning. Moreover, the majority of the participants strongly agree that PI creates a friendly relationship among students inside and outside the classroom environment thus leading to a supportive atmosphere in class. In addition to that, most of the participants from the study conducted strongly agree that PI makes the course interesting and also increase interaction among the students. The majority of the participants also strongly disagreed that oral discussion with group mates does not help students to learn.

Conclusions

In summary, according to the study conducted, PI teaching procedure improves significantly the learning of the students as well as of peers compared to traditional teaching method. We found a significant increase in students’ performance, similar to the study overseen by Crouch and Mazur (2001) they observed that learning gains doubled when using PI than when using traditional lecture procedure. The results of the survey demonstrated, PI builds a conductive learning environment by making learning interesting and interactive. The participants think that PI is an effective teaching method for their career. PI opens up classroom discussion among students and their peers making the class active and lively, this leads to effective learning among the students as comprehensions and understanding is enhanced (Simon, Kohanfars, Lee, Tamayo, & Cutts, 2010).

Recommendations

Despite PI being one of the most studied teaching concepts, more studies should be done to test on the implementation of the peer discussion technique within classrooms. The consequence of public display of results is still uncertain and the impact on students’ understanding should be studied further. Researchers should be able to test on the different implementation techniques because teachers use different ways and this causes confusion among instructors on which implementation system is more effective. Instructors need to create conducive environment within the classrooms before implementation of PI. They should ensure students know the value of argumentation, logic and reasoning in their discussions to ensure they do not have shared misconceptions and perceptions and that they understand the concepts better by looking at the problem in
different angles coming up with several logical solutions that they can explain to others and the teacher.

**Limitations**

One of the biggest limitations of peer discussion is that it can create shared false misconceptions among students because it is unclear as to whether students have independent thought or take the ideas of their peers. When students share their ideas in a discussion, it is unclear whether it teaches students “what to think” or “how to think” and may end up making students use the ideas of others instead of their own leading to shared perceptions. Some students may also end up having discussions that may not be consistent with the topics in class causing a distraction to the other students. The real impact of peer instruction cannot be realized without putting into account several variables, such as variations between students and instructors in education. The differences between the instructors’ implementation technique is important because it can determine the magnitude of the impact of PI within classrooms. Studies have also shown different implementation ways which lead to different impacts hence a standardized system is needed in order to determine the real impact of PI on education.

**References**


