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The Effect of Student Collaboration in Solving Physics Problems Using an Online Interactive Response System

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Abstract: Advanced technology helps educational institutes to improve student learning performance and outcomes. In this study, our aim is to measure and assess student engagement and collaborative learning in engineering classes when using online technology in solving physics problems. The interactive response system used in this study is a collaborative learning tool that allows teachers to monitor their students' response and progress in real time. Our results indicated that students have highly positive attitude toward using the interactive response system as a tool in education in order to improve collaborative learning and student engagement in classes. Consequently, student-learning performance has been improved considerably, and technology was successfully incorporated in engineering classes.

Keywords: *Interactive response system, collaborative learning, online technology, solving physics problems.*

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Introduction

Collaborative learning

In recent years, learning environment in educational institutes has become increasingly competitive. Different techniques have been introduced to make learning more efficient and effective (Wicks, Craft, Mason, Gritter, & Bolding, 2015). One such technique is collaborative learning technique. The basic idea in collaborative learning is that understanding can be built through joint intellectual efforts by students and teachers (Garrison, Anderson, & Archer, 1999; Rippel, Schaefer, Mistee, & Panchal, 2009). Collaborative learning is a method in which group of students works together in small groups each member of the group is responsible for their group mates learning as well as their own. Collaborative learning is a learning technique in which students teach and learn from each other, share knowledge and experiences, and develop interdependence (Panitz, 1996).

Studies show collaborative learning helps learner to developed skills such as critical thinking, gain deeper understanding on the topic, improve their individual reasoning capabilities, and ability to express themselves through interaction with peers (Rojas-Drummond, & Mercer, 2003; Scheuer, Loll, Pinkwart, & McLaren, 2010). It gives the student ability to think critically (Angeli et al., 2003) and encourages students to contribute in giving the answer and expressing their opinion (Lantz, 2010). Engaging students in a collaborative learning environment improves their epistemic activity as permanent learners (Scardamalia & Bereiter, 2006). Research has revealed that collaborative learning positively affects student success (Stump et al., 2011). Some studies reported that female students used collaboration as a learning strategy greater than their male classmates (Stump et al., 2011).

Collaborative learning and technology

Technology, from abacus to computer has always been used promote collaborative learning (Resta & Laferrière, 2007). In an information and communications technology-supported classroom, students learn through collaboration (Lee, Tsai, Chai, & Koh, 2014). Computer-assisted collaborative learning encourages active learning and knowledge construction through the collaboration with peer. It is facilitated and assisted by software tools, which make it handy for engineering courses (Gomez-Sanchez et al., 2009).

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In recent years, special attention has been devoted to collaborating learning tools. There are different types of tools, which have been used by educational institutions. Learning management tools such as Moodle, which widely used in the different education system provide facilities to access knowledge resources, sharing files, and forums for discussions without the limitations of time and distance (Boettcher, 2003). Wiki is another famous collaborative learning tool. The strength of wiki as a collaborative learning tool can be seen in a well-known project Wikipedia. A wiki is a collaborative web site providing integrated function of social communication and facility to effortlessly generate information resources (Anthony, Smith, & Williamson, 2009). Recently, collaborative game-based learning tools made an impact in academia (Zafar, Mueen, Awedh, & Balubaid, 2014). Integrating game in the student learning process allows students to organize information resources and share with other students what they have gained throughout the game-playing process. In addition, it is observed that game-based learning enhances student strategic thinking skill and let a student to be more attentive in the classroom (Gonzalez-Gonzalez, & Blanco-Izquierdo, 2012). Finally, using clicker devices is a handy way to get student responses. Studies shows clicker make learner to be attentive and engage in the class (Blasco-Arcas, Buil, Hernández-Ortega, & Sese, 2013). Teacher projected question on the projector and let student select one of the answer options by clickers.

Web-based student response systems

In the last two decade, web-based student response systems have been used for many purposes, including collaborative learning (Oliver & Omari, 2001). There are many useful online free student response systems available for teachers to creatively engage students using smart technology which is readily accessible (http://socrative.com/; http://webclicker.org/; http://www.quizsocket.com/; https://getkahoot.com/; http://versoapp.com/; http://www.infuselearning.com/; etc.). In this study, we promote student collaboration through an interactive response system app (Socrative) to increase their performances in the physics course.

The interactive response system used for this study enables the instructor to pose questions to large groups of students using their personal devices with the results being collated automatically and displayed in real time. Of particular benefit is the capability to download the prepared quizzes as a pdf document and student's results as an Excel report. It is an online student response system, allows teachers to judge student understanding and monitor their progress by providing educational exercises (Awedh, Mueen, Zafar, and Manzoor, 2014). Actually, it is a software that helps teachers to design and constructs many different types of questions. It provides opportunities to make learning fun, increase student engagement in the classroom, encourage deeper discussion, promote collaboration, and deliver feedback at speed (Turner, 2015). It is an essential tool that allows students to collaborate in solving real-time problems. With this interactive response system, students use their Internet-connected devices to engage with questions posted by their professors (Matthew, 2012).

To get started using the interactive response system, the instructor creates a teacher account and assigns a room number, students then are able to log on to that room. The room number becomes the login key for students to access course material through a web browser. Instructors can create multiple choices, true/false, and short-answer questions and ask them as an online assessment or survey. When the instructor runs surveys or assessments, students can use their laptop, smart phone, computer, or tablet to access the interactive response system's website, and respond anonymously on their devices. When the survey or assessment begins, the instructor can display live results as they are submitted. All data collected for each assessment are stored and archived within the interactive response system and can easily be retrieved and exported in an Excel spreadsheet for further analysis.

Coco and Slisko (2013) found that the interactive response system helps students to understand physics concepts, facilitate the argumentation and help to exchange opinions between students. Dervan (2014) indicated that, it increases the level of student engagement while delivering lectures; it offers lecturers the opportunity to, quickly and easily, enhances the delivery of their lectures or tutorials in a way that increases the interaction with students which lead to a better learning.

Awedh, Mueen, Zafar, and Manzoor (2014) investigated the effect of using the interactive response system and Smartphones on the collaborative learning of students. They have shown that student engagement and collaboration in class using the interactive response system and smartphones improved student learning performance. Kaya and Balta (2016) showed that the interactive response system is a right tool that can help to improve students' engagement in English teaching classes and students (male or female) show positive attitudes towards using the interactive response system in the classroom. Dakka, (2015) conducted a student response system based on getting an immediate student feedback to short quizzes for level 5 engineering students using the interactive response system tool. The results indicated that using such method, using the interactive response system, improve learning experience of the students and enhanced their performance. Balta and Guvercin (2016) indicated that along with the interactive response system's usual usage it can also be used to increase students' performances on exams by sharing homework questions through the interactive response system.

Significance of the study

Educational institutes are looking for more competent technology to help to improve student learning performance and outcomes. However, students' attitude toward these technologies has a major impact upon the effectiveness of these technologies (Boser & Daugherty, 1998). Students learn best when they are active participants in the education process (Davis, 2009). They learn more when they discuss and practice course content, and apply concepts, and ideas. Recently, special attention has been devoted to improve collaborative learning in educational institutions (Fischer et al., 2007).

The relationship between technology usage, collaborative learning, and achievement is not well discussed in an engineering education context (Stump et al., 2011). In this study, a student response system has been utilized to afford and enhance student learning in a self-directed and collaborative manner. The aim of the study is to find out the effect of student collaboration (when compared to individual learning) in solving physics problems using the interactive response system technology in class and the students' attitudes towards this technology. The research questions are determined as:

- Does students' collaboration through the interactive response system in solving physics questions is effective when compared to individual problem solving?
- Does students' collaboration through the interactive response system in solving physics questions vary across gender groups?
- Does students' attitude toward the interactive response system vary across the gender groups?

Methodology

Participants

This study was conducted with 112 undergraduate students from two different classes, 65 from class-A and 47 from class-B, in the architectural and engineering faculty at a university in Turkey. Students, aged 19-25, were randomly assigned to the classes at the beginning of the academic year by the faculty members. Some demographic variables of the students are given in Table 1.

Table 1. Participants' demographics

		Class-A	Class-B
Variable	Level of the variable	N (%)	N (%)
Gender	Female	10 (15.4)	7 (14.9)
	Male	55 (84.6)	40 (85.1)
Attendance	First time	46 (70.8)	45 (95.7)
	Repeating	19 (29.2)	2 (4.3)
Enrollment	LYS	52 (80.0)	39 (83.0)
	Vertical transfer	3 (4.6)	6 (12.8)
	Lateral transfer	10 (15.4)	2 (4.3)

Since this is an engineering faculty relatively less female (Akgunduz, 2016) students (15.4% and 14.9% in Class-A and B respectively) were enrolled. There were two groups of students in both classes in terms of taking the course first time and repeating the course. The percentage of repeating students were 29.2 % in Class-A while it was only 4.3% in Class-B. Moreover, there are also groups of students who enrolled after finishing the high school (LYS), who enrolled from a college or open education faculty by vertical transfer (Latchem, Ozkul, Aydin, & Mutlu, 2006), and who enrolled from another university by lateral transfer (Peng & Bailey, 1977).

Twelfth grade is the last grade in high school in Turkey. All students take two consecutive high stake national exams (YGS and LYS respectively) toward the end of the grade 12 (Balta, Mason, & Singh, 2016). Depending on their success in these two exams students either enroll at a university, a collage (two-year program year program that corresponds to community college in the United States) or open education faculty. Among the collage and open education faculty students who want to continue their education at a university (four-year program year program) take the vertical transfer exam (DGS) provided that they meet the required conditions. Parenthetically, either they have postgraduate programs or not; all four-year institutions in Turkey are called university. In our sample 4.6% and 12.8% students from both classes were enrolled through vertical transfer. Students also have rights for lateral transfer within the institution and from other institutions. 15.4 percent and 4.3 % of students from Class-A and Class-B were the students who enrolled in the civil engineering department of architectural and engineering faculty through later transfer.

Instruments

Physics question sets, and an attitude survey was used in this study. The 5 quizzes used in this study were composed from Serway (1996) and Giancoli (2000). Depending on the topic of the week the proper items were selected from these books and converted into multiple-choice question sets (4-6 questions). The first book was already translated into Turkish and questions from the second book were translated by the course instructor.

A survey with 21 Likert-type items assessing students' attitudes toward the interactive response system was used to collect data. The survey items are structured in the form of statements that one could agree or disagree with on a scale of 5 (strongly agree) to 1 (strongly disagree) with 3 signifying a neutral response. The survey was developed by the authors. The first eight items were adapted from (Awedh, Mueen, Zafar, & Manzoor, 2014) and the rest were written by the researchers of the current study. Two experts from School of Foreign Languages at a university in Turkey checked the survey items in terms of language and content, and suggested minor revisions. These were the instructors who were actively using the interactive response system in their courses. The survey was initially developed in English then translated to Turkish. The first author translated the survey and one native English speaker (who also speak Turkish), and an English language instructor checked the translated version afterwards suggesting minor changes. The survey was applied to students at the end of the semester, and its reliability coefficient was calculated as .928.

The interactive response system app

The first author was teaching electricity and magnetism to two classes of civil engineering students during the spring semester of 2015-2016 academic year. The successful use of the interactive response system in English learning classes at the same institution (Kaya & Balta, 2016) inspired us to use it in physics classes. The spring semester is 14 weeks, and we used the interactive response system for five weeks until the midterm exams. In each week, there are three class hours in the physics course. In the first two hours, the instructor presented the physics topics along with solving questions, showing simulations, conducting science demonstrations, etc. In the third hour he aimed to use student collaboration in solving physics questions. He shared question sets, each of 4-6 items, on the interactive response system and initially students solved the questions individually (about 15 min.) while seeing the questions on their mobile phones. Then, they solved the questions in groups of two-four students (15 min.). Students were free in composing the groups. Members of the groups worked together to solve all items from the beginning. Students were encouraged to discuss the questions among them even they initially had correct answers. Since they had a mixture of correct and incorrect responses after the individual work, the collaboration had students turn to their peers, compare answers, justify their response, and attempt to come to agreement. This collaboration and use of the mobile phones did not only helped students to learn from their peers but also kept students engaged during the course. All group members generally submitted the same answer after the consensus. It was also possible for the collaboration to yield a wrong answer.

Finally, the instructor solved all questions along with discussions (15 min.). In both classes, students were given five bonus points for participating in the interactive response system applications. The general procedure of the interactive response system application was as follows:

1. The instructor previously (usually a day before the course) prepared the questions sets. He generally selected the questions from Serway (1996) and Giancoli (2000). He then logged the interactive response system as a teacher (http://socrative.com/) and uploaded these multiple-choice questions to the interactive response system.
2. Each week, at the third course hour, the teacher started the quiz and students logged in, by using their mobile phones, as a student.
3. Students solved the questions for 15 minutes individually. After 15 minutes, the instructor ended the quiz and downloaded students' results as an Excel sheet. Students could see their responses on the screen. Then he re-started the same quiz, and students solved the questions while collaborating for more 15 minutes. Finally, at the end of this period, the instructor ended the quiz and again reflected their results on the screen. Thus, students could see their progress. The instructor then solved all questions, and saw the students' difficulties in solving physics problems along with their misconceptions. The instructor naturally spent more time on the concepts that were mostly misunderstood by the students. Actually, it was an instant feedback.
4. These activities lasted about five weeks and at the end of the spring semester, the attitude survey was applied to reveal students' views about the interactive response system. The interactive response system which also allows for Likert-type questions to be filled out rapidly and anonymously was used to collect survey data.

Thus, the student response system was used (i) to ease collaboration, (ii) to get instant responses, (iii) to encourage student engagement, and (iv) to collect data.

Data analysis

Both data collected each week and from attitude survey were separately analyzed. Students' individual quiz results are compared to their group results with t-test for five data sets collected for five weeks. Students' overall individual quiz performances are also compared to their overall group performances. Finally, both overall results (individual versus group) are assessed in terms of demographic variables with t-test and one-way ANOVA.

Findings

The aim of the study was to search the effect of student collaboration in solving physics problems through the interactive response system platform. Students from two classes responded to a total of five question sets. The question sets were first solved individually (pre-test) then in groups (post-test). Students' individual results are compared to group results by t-tests represent in Table 2.

Table 2. Descriptive statistics of the quizzes

Class	Quiz	Test	N	Mean	Std. Dev.	ES*
A	1	Pre-test	49	21.84	19.07	.60
		Post-test	49	38.37	33.62	
	2	Pre-test	39	43.69	21.25	.95
		Post-test	39	66.15	26.02	
	3	Pre-test	36	33.58	18.84	.45
		Post-test	36	41.67	16.90	
	4	Pre-test	37	43.89	19.33	0.83
		Post-test	37	60.54	20.81	
	5	Pre-test	24	28.71	21.93	2.03
		Post-test	24	70.83	19.54	
B	1	Pre-test	37	51.11	26.01	1.62
		Post-test	37	87.57	18.47	
	2	Pre-test	14	40.00	22.19	-.18
		Post-test	14	35.71	25.03	
	3	Pre-test	39	37.90	18.23	.22
		Post-test	39	42.05	18.80	
	4	Pre-test	31	33.87	16.95	.54
		Post-test	31	43.87	20.28	
	5	Pre-test	20	16.85	17.49	1.22
		Post-test	20	38.00	17.05	

*Effect size

Student who did not participate in any of the individual or group work was excluded from the analysis. For instance, in Class-B 40 students responded individually and 37 supplied answers after collaboration for the first quiz. However, four students who responded individually did not supply responses after group work. Similarly, one student who did not supply an answer when working individually gave an answer after group work. The mean of the individual results was replaced for the individual responses of those who only supplied answers after group work (Tabachnick & Fidell, 2007). Thus, only responses of 37 students were used for comparisons. Similar analyses were made for the other collected data.

Results of physics question sets

Students participated in the interactive response system applications in different amounts varying between 24 and 49 for Class-A, and 14 and 37 for Class-B. Since the difficulty level of each set of the questions were different, the mean of pre- and post- test results vary between 21.84 and 70.83 for Class-A, and 16.85 and 87.57 for Class-B. Except for the second quiz of Class-B; all post-test means are higher than pre-test means (see Table 2).

Effect size is the magnitude of the difference between groups. In other words, how much more effective was the student collaboration? To answer this question, we used Cohen's d (Cohen, 1988) to standardize the difference. The standard interpretation of effect size results offered by Cohen is: .8 = large, .5 = moderate, and .2 = small. As seen from Table 2, the effect size values are ranging from -.18 to 2.03 showing varying effect of student collaboration on their quiz results. The inferential statistics (t-test) regarding mean differences between students' pre- and post-test results are presented in Table 3.

Table 3. t-test statistics of the quizzes

Class	Quiz	t	df	p
A	1	-2.993	75.98	.004
	2	-4.175	76	.000
	3	-1.916	70	.059
	4	-3.565	72	.001
	5	-7.026	46	.000
B	1	-6.952	64.95	.000
	2	.479	26	.636
	3	-.990	76	.325
	4	-2.107	60	.039
	5	-3.873	38	.000

Note: Levene's Test for equality of variances were significant for quiz results of B1 and A2. For these two quizzes the t-test results for "equal variances not assumed" were used.

Except for the quizzes A3, B2, and B3 the pre-and post-test means are significant for all remaining quizzes. In other words, in total, students' collaboration in solving physics questions is effective when compared to individual problem solving.

For further analysis, we separately blended the pre-test and post-test results of all five quizzes. Table 4 presents a series of t-tests regarding the differences between pre- and post-test means of overall quizzes for gender and class variables. The results showed that neither the overall pre-test, nor the post-test scores of male and female students are statistically significant. Similarly, neither the overall pre-test nor the post-test scores of Class-A and Class-B differed significantly. On the other hand, the pre-test and post-test scores of all students are significantly different from each other. In other saying, collaboration of students has significantly affected their scores when compared to their individual engagement in physics questions.

Table 4. t-test statistics for overall results

Variable	Variable	t	df	p
Pre-test	Gender	1.156	110	.123
Post-test		-.806	110	.422
Pre-test	Class	.620	110	.537
Post-test		.710	110	.479
Overall	Pre- versus post-test	-8.406	222	.000

In terms of enrolment, there were three different groups (LYS, lateral transfer and vertical transfer) of students. The differences between the pre- and post-test score of these groups was searched with one-way ANOVA.

Table 5. ANOVA results regarding student enrolment

		Sum of Squares	df	Mean Square	F	p
Pre-test	Between Groups	129.573	2	64.787	.226	.798
	Within Groups	31192.090	109	286.166		
	Total	31321.663	111			
Posttest	Between Groups	484.494	2	242.247	.701	.498
	Within Groups	37669.137	109	345.588		
	Total	38153.631	111			

As seen in Table 5, neither there are differences between pre-test scores ($F(2, 109)= .226$, $p= .798$) nor between post-test scores ($F(2, 109)= .701$, $p= .498$) of the groups. In other words, there are no differences between different groups (LYS, lateral transfer and vertical transfer) of students in solving physics problems individually or with collaboration.

Attitude survey results

The attitude survey was shared on the interactive response system, and 63 students supplied responses. Since 7 students completed only several items on the survey, they were excluded from the analysis. Since the percentage of excluded students are less then %5, their elimination could not significantly affect the results. Figure 1 shows the average scores for all students separated by gender for each item. The maximum possible average score is 5 and students' averages on each item fluctuate around 4.

The average of all students in the survey was 4.14, which correspond to a slightly higher than the agree choice. It means that students have highly positive attitudes toward the interactive response system and its usage in the physics course. Student's responses were the highest on items 16 and 2 (4.57 and 4.48 respectively) while on items 20 and 3, they were the least (3.39 and 3.84 respectively). Correspondingly, "the interactive response system was easy to use and "the interactive response system allowed me to exchange information with classmates" were the most favorable items, and "the interactive response system increased the competition with classmates" and "the interactive response system gave me the opportunity to discuss with the teacher" were the most unfavorable items.

Only for three items (2, 4, and 5) the average scores of female students were higher than that of male students. In other words, when compared to male students, by the interactive response system females exchange more information with classmates and teacher, and by the interactive response system they actively collaborated in their learning experience. On the other hand, male students' attitudes towards the interactive response system were more positive for the rest of the items when compared to female students. For instance, male students think that the interactive response system contributed to positive relationships with classmates, and teacher (items 7 and 8), course was more enjoyable with the interactive response system (item 10), and the interactive response system provided to learn more from classmates (item 11).

Gender differences were clearer on items 18, and 19 where male and female students' averages were 4.65 and 3.78 for item 18 and 4.63 and 3.67 for item 19. In other saying, male students enjoyed using the interactive response system more and they more eagerly recommend using the interactive response system in other courses. The item 9 (the interactive response system contributed to learning physics) was the only item on which both gender groups had equal scores (4.18).

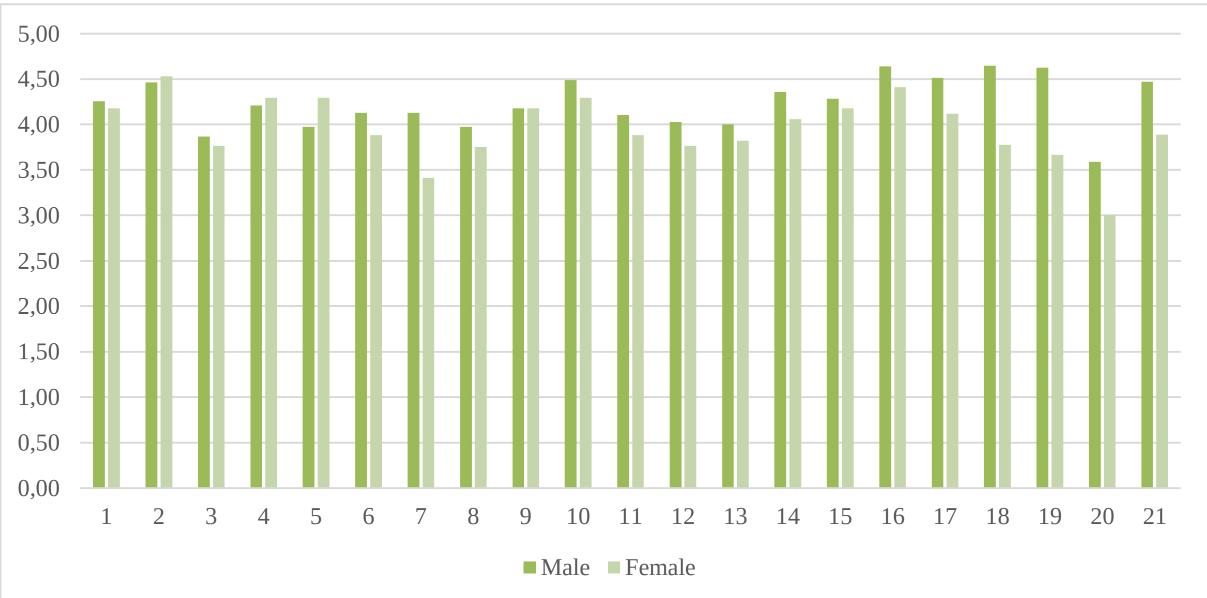

Figure 1. Students average scores on each item across gender groups

Discussion

The results suggested that collaboration through the online response system is an important predictor of students' academic performance in physics. Moreover, the results also showed high positive student attitudes toward the use of the online response system.

In terms of collaborative learning and achievement, we found that the response system had significantly affected on learning process of students which is similar to Awedh, Mueen, Zafar, and Manzoor's (2014) findings. Our conclusions are parallel to that of Stump et al. (2011) where we showed that, women enrolled in engineering courses are not statistically different from their male counterparts in solving physics problems. However, as Seymour and Hewitt (1997) stated, we found that females were more interested in collaborating with other students to solve physics problems. Briefly, our results contribute the consensus among researchers about the positive effects of cooperative learning on student achievement (Slavin, 1995).

In terms of engagement, our findings are in concurrence with that of Coco and Slisko (2013) who also indicate that the student response system had facilitated active physics learning, and had helped students to be more involved in the classes. Likewise, Dervan's (2014) conclusion that the interactive response system improves student interaction is a comparable result to that of ours.

In terms of attitudes, our results are analogous to that of Balta and Guvercin (2016) who disclosed that students have positive attitudes toward the interactive response system when it is used as a homework assignment platform. Similarly, findings regarding the attitude towards the response system was not different from that of Kaya and Balta (2016) who also found that there was not significant difference between male and female students.

Conclusion and Limitations

In this study, our aim was to study the effect of student collaboration in solving physics problems using the interactive response system app as well as students' attitudes towards the use of such an app.

Our results indicated that collaborative learning (despite the differences in students' gender or university enrollments) has significantly affected on learning process of students. It has, considerably, improved solving problems compared to individual attempts. However, the effect of the interactive response system usage on gender, class and enrolment groups was not significant. In other saying, the interactive response system had equally affected the males and females, students from both classes involved in this study, and students from different enrollment groups, in solving physics problems.

The results of the attitude survey showed that, students have highly positive attitudes toward using the interactive response system. However, there existed gender differences in attitudes toward the interactive response system. On item basis, female students exchange more information with classmates and teacher and actively collaborate in their learning experience when using the interactive response system. Male students enjoy and learn more, and improve relationships with classmates and teacher when using the interactive response system; they highly recommend using the interactive response system in other courses. However, both genders agree on using the interactive response system has improved their learning performance.

Based on our experience in using the interactive response system, we can say that it is easy to use the interactive response system from both a lecturer and student perspective. It was observed that students had no difficulty in accessing the application from their devices. It was very easy to set up quizzes on the interactive response system.

It was observed that, after the student collaboration, what was generally left for the instructor was the misconceptions in physics. In other saying, except the misconceptions, with individual and collaborative works students generally can overcome the physics problems. Thus, it can be said that students' collaboration is not enough to remove their misconceptions. Future research may concentrate on the use of the technology in resolving the student misconceptions.

One of the limitations to the study is that the sample did not contain equal student population with respect to gender. This would limit generalization of our findings to engineering student groups with similar gender composition. Another limitation is that we did not have a structured student collaboration. Just grouping students does not initiate collaboration (Brush, 1998). Thus, the information regarding the nature of their collaborative activities are not clear. Despite these limitations, we still suggest that in physics courses, increasing opportunities for collaborative learning through technology integration may be beneficial.

In general, the results from our study reveal that students have positive attitude toward using the interactive response system technologies as a tool in education. It improves collaborative learning and engagement of students in the class which in turn improves student learning performance.

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