Peer instruction: An evaluation of its theory, application, and contribution

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Abstract

Many qualitative and quantitative studies performed on peer instruction based on interactive engagement method used in many different disciplines and courses were reviewed in the present study. The researchers examined the effects of peer instruction on students' cognitive skills (conceptual learning, problem solving, reasoning ability, etc.) and affective skills (attitude, confidence, motivation perception, satisfaction, etc.). The qualitative document analysis was used in the present study. Therefore the studies, published in the books, dissertations, journals, proceedings, etc.) performed on peer instruction with the help of several search engines (Web of Science, Google Scholars databases, etc.) based on certain keys (peer discussion, peer instruction, peer interaction, etc.) were evaluated between 1997 and 2017. Besides, the theoretical framework, the advantages and disadvantages and the applications of peer instruction in many different disciplines were presented in detail. In the most of qualitative and quantitative studies; cognitive and affective skills, conceptual learning, problem solving performance, perception, confidence, and beliefs of different student groups instructed with peer instruction was reported to be higher than those of different student groups instructed with traditional teaching methods. Some suggestions were also presented in the light of reviewed studies for future research at the end of the current study.

Keywords: interactive learning, interactive engagement method, peer discussion, peer instruction, peer interaction

Introduction

Smith, Sheppard, Johnson & Johnson (2005, p. 88) stated traditional teaching methods as “the information passes from the notes of the professor to the notes of the students without passing through the mind of either one.” Students are generally instructed with traditional teaching methods in many different disciplines and courses. They have difficulties in problem solving, deriving the relationships, knowledge of representations, and conceptual learning in these methods (Crouch & Mazur, 2001; Savelsbergh, de Jong, & Ferguson-Hessler, 2011; Thompson, Christensen, & Wittmann, 2011). Many studies (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014; Hake, 1998; Preszler, Dawe, Shuster, & Shuster, 2007) revealed that traditional teaching methods are not sufficiently effective on students' problem solving performance, conceptual understanding, self-efficacy, confidence, and motivation. The result of other studies (Gok, 2015; Mazur, 1997; Shaffer & McDermott, 2005) indicated that many students especially had difficulties in learning and understanding fundamental concepts of physics.

These difficulties based on misconceptions were generally encountered in the literature.

Freeman et al. (2014, p.8410) reported "students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning". Harlow, Harrison, & Meyertholen (2014) indicated the importance of students' behavior toward physics learning in and out classroom. The behaviors, attitudes, beliefs and expectations of the students might positively be altered with the help of effective teaching strategies. Therefore the researchers (Beatty, 2004; Bretzmann, 2013; McCreary, Golde, & Koeske, 2006; Caldwell, 2007) have been developing new teaching approaches and models based on active and interactive learning for a long time. Some of these approaches are cooperative problem solving, flipped classroom, inquiry based learning, peer learning model, peer-led teaching and learning model, problem based learning, project based learning, STEM (science, technology, engineering, and mathematics) classroom, studio classroom, etc.

One of these approaches is peer instruction. Some definitions could be given concerning peer instruction: "an interactive teaching technique that promotes classroom interaction to engage students and address difficult aspects of the material" (Mazur & Watkins, 2010, p.39), "an instructional strategy for engaging students during class through structured questioning process that involves every student" (Crouch, Watkins, Fagen, & Mazur, 2007, p.4), "one approach which makes the learner more central to what is happening in the classroom, engaging them individually and in peer groups to foster individual' construction of their understanding" (Spacco, Parris, & Simon, 2013, p.1). The description of peer instruction according to Porter, Lee, Simon, & Zingaro (2011, p.1) is "students individually respond to a question, discuss with peers, and respond to the same question again." Durmont (2013) defined the method of peer instruction based on polling and challenging about students' responses. Crouch & Mazur (2001, p.970) claimed that "peer instruction modifies the traditional lecture format to include questions designed to engage students and uncover difficulties with the material." Recently, Michinov, Morice & Ferriéres (2015, p.1) have determined as "Peer Instruction (PI) is an interactive student-centered instructional strategy for engaging students in class through a structured questioning process that improves the learning of the concepts of fundamental sciences."

The roles and responsibilities of instructors and students should also be determined in peer instruction. The task of instructors is modeling appropriate social skills such as listening and providing constructive feedback more in-depth. Also they should reinforce positive behaviors by discussing the responses that students give (Giuliodori, Lujan, & DiCarlo, 2006). The students could interpret and constitute correlations between new constructing information and existing knowledge (Cortright, Collins, & DiCarlo, 2005).

Shortly, peer instruction is an interactive teaching strategy for instructors and a collaborative learning strategy for students in and out of the classroom activities. Both the instructors and the students have play an important role in this strategy. The students think, analyze, discuss, and challenge on the materials with peers on the other hand the instructors create constructivist learning environments, observe the classroom, listen to students and provide the real-time feedback.

The Theoretical Structure of Peer Instruction

Peer instruction is an interactive teaching strategy based on the constructivist learning theory and social constructivism. Yaoyuneyong & Thornton (2011, p.129) pointed out "constructivist environments are designed to both challenge and support students' thinking process and to facilitate active learning, whereby students are able to discover from themselves rather than simply receive the facts, concepts and principles in the question." They reported that the constructivist environments support the involvement of the students, allow them to take responsibility for their own learning, let them foster the problem solving skills of the students, and collaboratively help them to solve qualitative and quantitative problems in groups. Michinov et al. (2015, p.2) indicated that peer instruction is "based on a social constructivist approach to learning, in which social interaction plays a crucial role in the construction of knowledge, and where discussion and collaboration between peers have a positive impact on learning."

The Development of Peer Instruction

Mazur (1997) instructed physics courses using traditional teaching methods at Harvard University. His courses were interesting and amusing because he constantly tried to use alternative instructional strategies and assessment tools. He revealed that students were able to solve standard problems, but had difficulty in understanding some basic conceptual questions on the Force Concept Inventory. Therefore he investigated an alternative instructional strategy to solve this problem.

He (1997) thought how to improve conceptual learning and problem solving performance of the students and to prevent overcoming misconceptions of the students and then he developed an interactive teaching strategy called peer instruction (PI).

Peer instruction is actually a combined teaching model. Students can do warm-up exercises with Just in Time Teaching strategy (Novak, Gavrin, Christian, & Patterson, 1999), they can increase their engagement with Tutorials in Introductory Physics (McDermott, Shaffer, & the PEG at UW, 2002) in discussion section among peers, they can solve problem with Group Problem-Solving Activities (Heller, Keith, & Anderson, 1992). Peer instruction engages students with the help of classroom activities. These activities are "reading the course material", "thinking on the concept tests or multiple-choice questions", "quantitative or qualitative problem solving", etc.

Nowadays peer instruction is conducted in conjunction with other interactive learning methods (Durmont, 2013; Gok, 2015; Mazur & Watkins, 2010; Michinov et al., 2015; Novak et al., 1999; Nicol & Boyle, 2003; Sayer, Marshman, Singh, 2016a; Simon, Esper, Porter, & Cutts 2013; Smith, Wood, Adams, Wieman, Knight, Guild, & Su, 2009; Suppapittayaporn, Emarat, & Arayathanitkul, 2010; Wang & Murota, 2016) such as flipped classroom, just in time teaching, wikis, think pair share, problem solving strategy steps, structured inquiry, stepladder technique, etc. to be more effective, efficient, and practicable.

These combined teaching models called Hybrid Peer Instruction (HPI) enhanced students' understanding, learning, interest, motivation, and attitude towards courses; encouraged students thinking about challenging fundamental concepts; helped students to improve more advanced critical thinking skills and better metacognitive skills; provided real time formative feedback to students, and helped instructors make better usage of class time.

The purpose of the research investigated the positive and negative effects of the peer instruction on students' cognitive domain (conceptual learning, conceptual reasoning, problem solving, learning gain, etc.) and affective domain (beliefs, motivation, confidence, etc.) between 1997 and 2017.

Method

In the present study 92 studies conducted on peer instruction between 1997 and 2017 years in the literature were reviewed. 71 open access journals, 12 proceedings, 7 books, and 2 dissertations were analyzed according to the cognitive and affective of the students in this context. Some keywords (peer discussion, peer interaction, peer instruction, clickers or classroom response systems, flashcards, interactive engagement method, concept test or standardized test) regarding peer instruction were searched with the help of several search engines (Google, Web of Science, ERIC, Google Scholars databases). The research were reported into to three main sections (theoretical framework, advantages and disadvantages, and applications) as follows.

The application processes (presentation, discussion, explanation, and evaluation) of peer instruction, the importance of concept test questions and response time in peer discussion and finally the using of low and higher technological tools was presented in the first section. The advantages and disadvantages of peer instruction were expressed in the second section. The applications of peer instruction in different disciplines were discussed in the last section.

Results and Analysis

I. The Application Process of Peer Instruction

The application process of peer instruction could be explained in four stages. The first stage is presentation, the second stage is discussion, the third stage is explanation, and the last stage is evaluation. The explanation of these stages was given as follows respectively.

The first stage is presentation

Instructor performs several short presentations on a concept in the course. The instructor poses a concept test to the students. Students are especially expected to read necessary knowledge regarding the subjects before coming to the class in this stage. This stage presents a strong interaction between peer instruction and just in time teaching (Novak et al., 1999) based on reading assignments. Reading assignments are quite important to save energy and time during peer discussion performed among peers.

The second stage is discussion

Initially, students answer and vote the posed concept test individually without being influenced by other student' responses (Nielsen, Hansen, & Stav, 2016). The students can record the response individually if it is needed. The students begin to discuss on finding the correct response between peers after the students answer the response. The common answer on the concept test is voted either using low technological tools (e.g., flashcards, show of hands) or high technological tools (e.g., tablets, smartphone, clickers, laptops, etc.). The heart of peer instruction is the discussion stage. The discussion among peers enhances deeper thinking and complex reasoning skills on concept tests, provides to share and foster alternative thoughts and ideas, and discovers the difference solution ways.

The importance of peer discussion was particularly emphasized in many studies. Brooks & Koretsky (2011) expressed the positive influence of group discussion on responses and confidence of the students instructed with peer instruction. Lasry, Charles, Whittaker, & Lautman (2009) investigated the importance of in-class discussion between peers during the application process of the peer instruction. They reported that many students have correct answers after peer discussion. There was a notable increase in students conceptual understanding and they explained this increase based on other cognitive and metacognitive processes such as self-reflection, time-on-task, etc. Nicol & Boyle (2003, p.465) reported that "peer discussion provided opportunities to think about the problem in more detail, to explore alternative viewpoints and problem-solving approaches, and to ask for and hear different explanations." Crouch & Mazur (2001) indicated that peer discussion was quite crucial to the success of peer instruction. Therefore Tucker, Scherr, Zickler, & Mazur (2016) suggested an exclusive analysis model for evaluation of classroom group interactions. They revealed the differences between audio-visual and visual only coding and their study indicated that audio-visual coders were more confidential than only visual coders.

Sayer, Marshman, & Singh (2016b) claimed that peer instruction was very effective on deep-learning of the students during discussion with peers. Wang & Murota (2016) found the effectiveness of peer discussion on students' creative performance in all levels (higher, medium, and lower levels) and on improvement of their ideas after evaluation with peers. Also the studies on genetics course of Smith et al. (2009) at the University of Colorado, and on general biology course Perez, Strauss, Downey, Galbraith, Jeanne, & Cooper (2010) at the University of Wisconsin showed similar results.

The third stage is explanation

The answers of the students are interpreted and discussed in interactive environment classroom. The classroom participation in this stage is quite important for sharing ideas, views and thought of the students. The students are able to make connections and relationships between the new and existing knowledge. Besides the instructors provide to the students the crucial and critical explanation on subjects or concept test questions.

The last stage is evaluation

The instructors make the formative assessment in this stage. They evaluate the response of the students and then explain the correct responses of the posed concept test questions. The real time feedback on evaluations of the students is very important to provide meaningful learning. The instructors complete the process by explaining correct responses of concept test questions and then the instructors continue other concept test questions or other subjects.

The application processes of peer instruction were shortly summarized step-by-step in terms of instructors and students. The indicated application processes may change according to disciplines, courses, backgrounds and age of the students, etc.

1. Instructors perform several short presentations and then they pose some concept test questions.
2. The students are individually given time to think for finding a response regarding posed concept test questions.
3. The students show and/or record individual responses.
4. The students can see the distribution of responses with the help of graphics if instructors use classroom response systems during application. If the students use flashcards for showing the response, the instructors immediately explain to the students the distributions of responses.
5. The students begin to discuss on the concept test questions and they try to convince each other on the right answer. The evaluation of peer discussion has three steps.
    i. if the percentage of correct answers is lower than 30%, the instructors explain the concept again in detail.

ii. if the percentage of correct answers is between 30% and 70%, the instructors begin peer discussion among peers. After peer discussion, the students revote for the same concept test question or isomorphic concept test question .

iii. if the percentage of correct answers is higher than 70%, the instructors briefly explain/evaluate the answer of concept test and then passes other concept test questions.

The Importance of Concept Test Questions and Response Time in Peer Discussion

Peer instruction is quite important to discuss and answer posed concept test questions. The learning of students instructed with peer instruction during in-class discussion depends on both the quality of concept test questions and the robust background knowledge of the students (Mazur & Watkins, 2010). The concept test questions should be especially designed and chosen based on selecting and defining target behaviors. Concept test questions should be also designed for higher-level thinking and plausible distracters to evaluate students' thinking processes. Butchart, Handfield, & Restall (2009) expressed that the right level of difficulty is the main target for a high quality question. Alternative question types (isomorphic, multiple-choice, open-ended, short, true/false, etc.) besides concept test questions were used in the application of peer instruction (Bruck & Towns, 2009; Porter et al., 2011; Smith et al., 2009; Zingaro & Porter, 2014).

Some studies (Rao & DiCarlo, 2000; Smith et al., 2009; Turpen & Finkelstein, 2009) reported that student learning gains mostly increased with higher-level intellectual questions rather than basic recall questions. Knight, Wise, & Southard (2013) revealed that " the majority of student discussions included exchanges of reasoning that used evidence and that many such exchanges resulted in students achieving the correct answer. Students also had discussions in which ideas were exchanged, but the correct answer not achieved. Importantly, instructor prompts that asked students to use reasoning resulted in significantly more discussions containing reasoning connected to evidence than without such prompts" (p.645). Crouch & Mazur (2001, p. 973) stated "the choice of questions, the amount of time devoted to each question, the amount of lecturing, and the number of questions per class can and should be adapted to best suit a particular context and teaching style."

Smith et al. (2009) and Zingaro & Porter (2014) used the isomorphic (assessment of the same concept by using two different questions) questions on the same concept in order to evaluate the performance of the students. They revealed that isomorphic questions before and after discussion were very effective on conceptual understanding. Lasry, Charles, & Whittaker, (2016) stated that peer instruction enhanced the probability of getting a correct answer for similar questions.

Vickrey, Rosploch, Rahmanian, Pilarz, & Stains (2015) claimed that peer instruction improved students' learning which could be approved by the difference between first and second vote. Perez et al. (2010) examined the effect of displaying a bar graph of the student responses on students' second vote regarding concept test question after peer discussion. They revealed that when students monitored the most common response, the second responses of some students were affected. This could cause pseudo increase in the performance. They reported that the tendency of the students was found 38% for true/false questions, and 28% for multiple-choice questions. The display of voting for first responses were crucial for voting of the second responses after discussion among peers. Because many students could likely be influenced from displaying the bar graph of the first responses, this influence could be prevented students' thought on concept test questions (Brooks & Koretsky, 2011; Nielsen, Hansen- Nygard, & Stav, 2012; Perez et al., 2010). Therefore the responses of the students may be showed without identifying options.

Porter et al. (2011) developed a new metric, "Weighted Learning Gain", which reflects better the learning value of discussion and evaluates student learning gains for isomorphic questions in order to solve the evaluation process during peer discussion. They firstly used the new metric in genetic and computing courses. They found 85-89% of "potential learners" benefit from discussion among peers. Porter et al. (2011) presented a suggestion for future research: using the isomorphic questions for only critical course concepts, where misconceptions are necessary.

Miller, Lasry, Lukoff, Schell, & Mazur (2014) examined response time differences between correct and incorrect answers both before and after peer discussion for concept test questions of varying difficulty with two different student population in introductory electricity and magnetism courses at the Queens University (N=48) and Harvard University (N=93). They also identified the relationship between the response time and the performance of the students on the conceptual survey of electricity and magnetism of incoming physics knowledge, pre-course self-efficacy, and gender. Miller et al. (2014) revealed three conclusions at the end of their research. Firstly, response time of the students for correct answers was significantly faster than response time of the students for incorrect answers on concept test questions both before and after peer discussion. Lasry, Watkins, Mazur, & Ibrahim (2013) supported the findings with the similar results. Secondly, the students constructed logical connections between existing knowledge and new constructing information. They had higher self-efficacy with faster response times both before and after peer discussion. Lastly, there was not gender difference in response rate on concept test questions, although the male students registered considerably more attempts before submitting a final response than did female students. If the students know the response of a concept test question, they can instantly answer the correct response without thinking on the concept test question or if they do not know the response of concept test, they would like to think the correct/incorrect responses based on misconceptions at a given time without knowing the concept. These results demonstrated that the students should not be given too much time to respond in order to prevent distractions of the students in an interactive environment classroom. Turpen & Finkelstein (2009) determined the average voting time (from 100±5s to 153±10s) for answering concept test questions given by students.

Miller, Schell, Ho, Lukoff, & Mazur (2015) examined response switching over one semester of an introductory electricity and magnetism course instructed with peer instruction at Harvard University. They reported the correlations between response switching and academic self-efficacy. The students with low self-efficacy switched more frequently their responses than the students with high efficacy students. The study revealed the correlations between switching and the difficulty of the questions. Besides they indicated that when the difficulty level of the questions was higher, the students generally altered their responses. The results showed that " instructors may need to provide greater support for difficult questions" (p.1). The research result of Zingaro (2014) supported their research results and he also reported that peer instruction increased self-efficacy.

Lasry et al. (2013) investigated response time differences between correct and incorrect answers of conceptual questions both before and after instruction. They explained the relations between response time and confidence. They reported that if the students had lack of confidence, their response time was longer. Peer instruction positively changed the students' approach to concept test questions

The Using of Low and Higher Technological Tools

The response of the students could be evaluated with several different ways such as classroom response system or "clicker", show of hands, and flashcards. There are advantages and disadvantages of these assessment tools as noted below. The simplest of the them is to use "show of hands". Students read the concept test question and think about it. Instructors say firstly "hands up everyone who thinks the answer is A", secondly "hands up everyone who thinks the answer is B", and so on. There are two fundamental problems in the assessment. The first problem is that the students are influenced other students' response during voting and some of the students are embarrassed giving incorrect answer by raising their hands. The participation of the students to the course in relation to this situation could reduce. The instructors should encourage students to think about the answer to the posed concept test question to overcome this drawback. The second problem is that the instructors have difficulty in collecting answer of the students and the instant feedback could take time in terms of the instructors.

The other alternative for voting is to use flashcards. These flashcards have reasonable price and simple to design and prepare for the instructors. Each student is provided with a set of flashcards ("A", "B", "C", "D", "E" or colored flashcards "Red", "Yellow", "Blue", "Green", "Black"). The students vote simultaneously by holding up the flashcards indicating to their response. The instructors could easily count the flashcards and provide the instant feedback to the students. The students cannot easily see other responses because they raise their cards at the same time and the flashcards are single-sided.

The last alternative for voting is to use classroom response systems or clickers. The disadvantage of the classroom response systems is being more expensive than the others. However there are some useful properties of these systems. The usage of the systems is quite easy and practical for not only students but also instructors. The students' responses are submitted anonymously, the results of the students can be displayed in graphical form and the responses of the students could be recorded in the systems, the instructors also might provide instantly feedback to the students.

Pollock, Stephanie, Dubson, & Perkins (2010) conducted peer instruction in the form of clicker questions in many upper-division courses (electricity and magnetism, and quantum mechanics) at the University of Colorado. They examined and discussed the purpose of concept tests, the sustainability of the clicker questions, the difficulty of this activity, and the supply of classroom logistics for many upper-division and junior-level courses. Consequently, they came to an agreement at the end of discussion. Generally the implementation of the clicker questions between 2 and 5 was suitable for upper-division courses (20-60 students) in 50 minutes throughout peer instruction. Beatty, Gerace, Leonard, & Dufrense (2006) indicated designing effective questions for classroom response systems or clickers.

Several studies (Brady, Seli, & Rosenthal, 2013; Lindstrom & Schell, 2013; Edwards, Aris, Shukor, & Mohammed, 2015; Sayer et al., 2016b; Schmidt, 2011) mentioned that the moving from low technology tools (e.g., flashcards or show of hands) to higher technological tools (e.g., classroom response systems, smart phone, laptops, etc.) was efficient to save time and energy, it was helpful to present the display of statistical data graphically, and it encouraged the anonymous students to participate in the classes. Gok (2011) indicated that clickers were necessary in large-class environment for saving time and energy, and providing real time feedback and flashcards were also useful in small-class environment.

Mazur & Watkins (2010) suggested that higher technological tools made formative feedback easier for instructors to evaluate and interpret the response of students in a large classroom. But Lasry (2008) showed that peer instruction was an effective teaching approach solely and it did not depend on the use of higher technological tools such as classroom response systems. He indicated that low technology tools such as flashcards required taking class time to present response of the students or to analyze the distribution of answers, therefore higher technological tools allowed instructors to save time and energy, provided instructors to get precise real-time student feedback, and easily permitted instructors to store the answer of the students concerning concept test questions. The success of peer instruction originated from giving feedback to students by the instructors, readiness of the students, designing of the concept test questions, supplying financial or technological resources, etc.

II. The Advantages and Disadvantages of Peer Instruction

The Advantages of Peer Instruction

Many studies (Antwi, Raheem, & Aboagye, 2016; Crouch & Mazur, 2001; Gok, 2015; Lasry, Mazur, & Watkins, 2008, Lasry et al., 2016; Puente & Swagten, 2012; Suppapittayaporn et al., 2010) indicated that peer instruction was effective on decision-making skills, meaningful learning, conceptual learning, quantitative/qualitative problem solving, and critical thinking. Lasry et al. (2008) reported that peer instruction declined the number of students who dropped the physics course. Schell, Lukoff, & Mazur (2013) reported that peer instruction enhanced the conceptual learning of the students on concept test questions and open-ended questions. Edwards et al. (2015) reveled that peer instruction improved performance, motivation, and interest of 42 postgraduate students from different disciplines (science, engineering, and social) quantitatively and qualitatively.

There are some fundamental advantages of peer instruction in terms of instructors and students as follows. Peer instruction increases the conceptual understanding, problem solving performance, critical thinking, decision-making procedure and reasoning scientific ability of the students from the point of cognitive domain. PI improves the interactions between students and instructors, develops the concentration of the students, and enhances retention of the students. PI also increases the satisfaction and attendance of the students towards courses from the point of affective domain. The instructors also evaluate and record the performance of students with the help of instant feedback in and out of classroom activities. They prefer to use peer instruction because it is economic and easy to apply the different levels of education.

The Disadvantages of Peer Instruction

There are some disadvantages of peer instruction in terms of the instructors and students and these disadvantages could be listed as indicated below: Some students, especially weaker students, need more time to think over concept test questions therefore instructors could not solve more concept test questions during a course. Some students do not like to discuss about concept test questions or taught subjects with peers. Besides they may be embarrassed by their classmates when they answer an incorrect response posed a concept test question therefore peer instruction might not reach the desirable levels.

The instructors have difficulty in the engagement of the students which might fully be difficult during peer discussion in the classroom (Brooks & Koretsky, 2011; Lucas, 2009; Michinov et al., 2015). Fagen, Crouch, & Mazur (2002, p.208) expressed "challenge is the difficulty in fully engaging students in class discussions." Therefore the instructors should motivate the students on concept test questions, walk around the class during peer discussion, and encourage students to share their thoughts with peers. The instructors have also difficulty in evaluating the performance of the students if the number of the students is more than 50 in the classroom and/or if they do not use higher-technological devices such as classroom response systems. Besides the instructors have problem if they do not prepare and design concept test questions related to desired academic goals and objectives.

Beichner & Saul (2003) and Smith, Wood, Krauter, & Knight (2011) revealed that high-achieving (stronger) students more benefited from interactive approaches according to low-achieving (weaker) students. Thus, instructors should consider high and low achieving students uniformly while composing structured peer groups before and after peer discussion. James & Willoughby (2011) found that 38% of student conversations between peers were standard conversations. The remaining proportion (62%) was nonstandard conversations. At this point, the instructors should better structure and organize peer discussion performed between peers. Michinov et al. (2015) reported that the learning gain of the students usually remains at a medium level and this learning gain is quite difficult to reach from this level to high level in interactive learning methods. Mentioned problem may be arisen from students. Because some students do not like to participate actively in and out classroom activities. In this case, the instructors may combine peer instruction with another techniques (e.g., stepladder, just in time teaching, think pair share, etc) if it is needed.

Michinov et al. (2015) compared the effectiveness of individual instruction, classic peer instruction, and stepladder peer instruction on easy and difficult questions of students' performance. Normalized gains of individual instruction and stepladder peer instruction were calculated to be 0.49 for both and normalized gain of classic peer instruction was found to be 0.43 in easy questions. The gains of individual instruction, classic peer instruction, and stepladder peer instruction were calculated to be 0.23, 0.53, and 0.80 respectively in difficult questions. From these data, it could be concluded that classic peer instruction and individual instruction according to stepladder peer instruction were not effective in difficult questions. As a result of this, the instructors may consider the difficulty level of concept test questions or problems.

III. The Applications of Peer Instruction in Different Disciplines

The Applications of Peer Instruction in Science and Engineering Research

Peer instruction has been performed on many different disciplines. For example, Astronomy (James, 2006), Upper-division Biology (Knight et al., 2013), Calculus (Lucas, 2009), Chemical Thermodynamics (Brooks & Koretsky, 2011), Chemistry (Bruck & Towns, 2009), Computing (Porter et al., 2011), Entomology (Jones, Antonenkot, & Greenwood, 2012), Genetic (Smith et al., 2009), Geosciences (McConnell et al., 2006), Information and Communication Technology (Wang & Murota, 2016), Mechanical Engineering (Schmidt, 2011) etc. The results of accessible studies in the literature are summarized as follows.

Crouch & Mazur (2001) reported the results of a 10-year study. The result of study showed that peer instruction enhanced the conceptual reasoning skills and quantitative problem-solving performance of the students in different time and contexts.

Peer instruction, in similar study, was applied during two semesters in calculus course. Pilzer (2001) revealed that there was a significant improvement in the reasoning skill and retention of the students and the students gave approximately 90% correct response the conceptual problems. Besides, the attitude and confidence of the students positively improved toward calculus course. There was only problem reading of the chapters in terms of the students before coming to the class.

A study report was also conducted to 384 PI users on the Project Galileo website. According to survey results, 303 PI users certainly planned to apply peer instruction again, 29 PI users probably would like to conduct again, and finally 7 PI users did not explain their thoughts regarding re-using peer instruction. Cumming & Roberts (2008) also obtained the similar results concerning students' FCI gain factors with teaching of five different instructors in high school classrooms. It could be said that many instructors would like to use the peer instruction again in their courses in the light of the above findings (Fagen et al., 2002).

Peer instruction improved engineering students' physics conceptual understanding, enhanced problem solving skills of the students by solving traditional numerical problems, increased the final examination scores of the students, encouraged class participation of the students, and fostered the confidence of the students at Ghent University (Lenaerts, Wieme, & Zele, 2003).

McCreary et al. (2006) examined and compared the effects of peer-led teaching and learning model and traditional instruction on students' learning and understanding in general chemistry laboratory course at the University of Pittsburgh. They revealed that new instructional approach improved four separate higher-level thinking skills (the consideration of organization structure of a new experiment, the assessment of the experiment process, the explanation of the results, and finally the application of gained skills to a new problem or situation) of the students. It could be said that peer-led teaching and learning like peer instruction may influence the performance of the students on the laboratory studies based on learning by doing.

Lorenzo, Crouch, & Mazur (2006) investigated the effectiveness of interactive engagement methods on gender gap in conceptual learning of the students in an introductory university physics course. Interactive engagement methods not only significantly decreased the gender gap in conceptual learning of the students but also effectively increased the conceptual understanding of the female and male students, besides interactive engagement methods promoted in-class interaction, enhanced collaborations between peers and instructors, and reduced competition between peers. The research of Gok (2014) supported the findings of Lorenzo et al. (2006). He revealed that the gender difference in physics conceptual learning of female and male students instructed with peer instruction was not statistically significant.

The effectiveness of peer instruction for two different levels which are a two-year college (John Abbott College) and a top-tier four-year research institution (Harvard University) were compared (Lasry et al., 2008). The research results indicated that the performance differences between college students and university students by using a standardized test “Force Concept Inventory” were not statistically significant in terms of Hake (1998)’ gain factors (high gain, medium gain, and low gain). Peer instruction showed the same effect on college and university students’ conceptual learning and quantitative problems solving abilities regardless of their academic background knowledge.

Suppapittayaporn et al. (2010) examined the effectiveness of peer instruction with structured inquiry (PISI) on learning activities of the students by using a standardized test "Force and Motion Conceptual Evaluation". The research was conducted to two groups. The first group including 156 secondary school students was instructed with PISI while the other group including 119 secondary school students was instructed with traditional instruction (TI). They calculated Hake's normalized gains as 0.45 (medium gain) for PISI and as 0.14 (low gain) for TI. It could be said that physics learning gain of the students instructed with PISI was higher than physics learning gain of the students instructed with TI.

Mora (2010) compared the effectiveness of two active learning methods on students' cognitive knowledge and learning gain in introductory physical geology course. He indicated a similar level of effectiveness for both peer instruction and lecture tutorials. Kalman, Bolotin, & Antimirova (2010) compared two different teaching approaches. One of the approaches was collaborative group. The other approach was the modified peer instruction. Two instructors taught the introductory physics course with the help of these approaches in university level. The learning gain of the students was compared by using a standardized test "Force Concept Inventory". They revealed that collaborative group approach was more effective than peer instruction approach and besides they reported that the effectiveness of both teaching approaches did not depend on the instructors' experience as long as they follow the same procedures.

Gok (2012a) examined conceptual learning, problem solving skills, and beliefs about physics and physics learning of the students. The performance of the students was evaluated by using a standardized test "Conceptual Survey of Electricity and Magnetism" and beliefs about physics and physics learning of the students were appraised by asking a survey "Colorado Learning Attitudes about Science Survey" which comprises of eight categories. The research was organized according to Solomon four- group design. Peer instruction was conducted to the experimental groups while traditional instruction was performed to the control groups. Besides the problem solving skills of the students by using five common problems in final examination were evaluated and analyzed according to problem solving strategy steps which consist of three steps (identifying the fundamental principles, problem solving and checking). He revealed that the problem solving skills and conceptual learning (g=0.62 "high gain") of the students in the experimental group were higher than the problem solving skills and conceptual learning (g=0.36 "medium gain") of the students in the control group. Besides the results of CLASS for five subscales (conceptual understanding, applied conceptual understanding, problem solving general, problem solving confidence, and problem solving sophistication) supported the findings of the CSEM in favor of the experimental group.

Gok (2012b) practiced peer instruction strategy on classical mechanics by using a different standardized test "Force Concept Inventory". He reported that the conceptual learningof the students instructed with peer instruction was quite higher than the conceptual learning of the students instructed with traditional instruction. But the difference of motivation between experimental group and control group was not found statistically significant. Fagen et al. (2002) calculated the fractional gain as medium for the interactive engagement courses by using FCI.

Morgan & Wakefield (2012) revealed the effectiveness of peer conversation on students' physics examination performance. They did not observe any relationship between peer conversation and students' examination performance. But they reported that peer conversation enhanced the interactivity between peers in the course. They finally stated "interaction may be more important than arriving at the correct answer" (p.51).

Miller-Young (2013) investigated the evaluation process of peer instruction on students' deep learning strategies and attitudes towards learning with pre-class reading quizzes in engineering dynamics course. Peer instruction had positive effect on learning of the students. The performances of higher achieving students, medium achieving students, and low achieving students were enhanced with pre-class reading quizzes and the perception of the students also improved towards learning.

The differences in learning gain of students between peer instruction and traditional instruction were also searched by using two different standardized tests which are Force Concept Inventory and Force Motion Concept Evaluation (Harvey, 2013). The results of the research indicated that the differences between peer instruction and traditional instruction was not statistically significant in the comparison of test scores. Besides, the attitude, confidence, belief and expectation of the students instructed with peer instruction were more positively enhanced relative the students instructed with traditional instruction.

Trent (2013) examined the effects of think pair share technique based on peer instruction on the performance of the students. The research was conducted to two groups with 57 students enrolled in chemistry course. The 20 students in control group were instructed with traditional teaching methods while the 37 students in experimental group were instructed with think pair share. The performance of the students in the groups was evaluated with chemistry achievement test. However, the differences between students' performance and learning gain in the groups were not statistically significant.

Spacco et al. (2013) examined the impacts of peer instruction on students' performance in Computer Science Principles course by using the same teaching materials at the University of California. The study was conducted to two groups. The first group was instructed with peer instruction including student-centered learning while the other group was instructed with traditional teaching methods including teacher-centered teaching. The final examination achievement of the students instructed with peer instruction was averagely 5.7% higher than the final examination achievement of the students instructed with traditional teaching methods. Besides they revealed that the interaction between applied teaching strategies and background of the students was very strong.

Nishimura & Nitta (2014) evaluated the preparation and reflection effects of peer instruction on students' conceptual learning by using a standardized test "Force Concept Inventory" during two years. The reflection was especially helpful in the monitoring of high school students' understanding and it was efficient to change/modify the lesson plans based on students' understanding in terms of the instructors.

Atasoy, Ergin & Sen (2014) examined the effects of peer instruction on the attitude of the students. The research conducted to 46 high school students. The attitude of the students instructed with peer instruction was evaluated with Physics Attitude Scale. The scale consisted of four factors which are “physics course perception”, “appreciating the value of physics course”, “expectations about physics course” and finally “hesitations about physics course”. According to the research results, the differences between “appreciating the value of physics course”, and “expectations about physics course” were statistically significant.

Morice, Michinov, Delaval, Sideridou, & Ferriéres (2015) compared the learning gains and subjective benefits between peer instruction and individual learning during chromatography course. Peer instruction enhanced subjective benefits (engaging, learning transfer, motivation, regulation of cognition, satisfying, etc.), but it failed to illustrate a greater learning gain.

Zingaro & Porter (2014) examined the value of a PI question in an introductory computer science course from beginning to end: sole vote, group discussion, group vote, and instructor-led classwide discussion. They revealed that "the value of the instructor-led classwide discussion was evident in increased students performance over peer-discussion alone". Besides the instructor-led classwide discussion was quite considerably for weak, average, and strong of students and was of particular value for weak students.

The effects of peer instruction on conceptual understanding and problem solving skills of the students were examined with the help of standardized tests (Mechanics Baseline Test "MBT" and Force Concept Inventory "FCI") (Antwi et al., 2016). The research conducted to two groups in the senior high school. One of the groups was the experimental group instructed with peer instruction. The other group was the control group instructed with traditional teaching methods. The results of the research indicated that the FCI and MBT scores of the experimental group students were higher than the FCI and MBT scores of the control group students. The conceptual learning and problem solving skills of the students in the experimental group were found higher than the conceptual learning and problem solving skills of the students in the control group.

Lasry et al. (2016) designed three variations (discussed, reflected, and distracted) of peer instruction by three instructors on three groups (totally 108 students). The data of the research were collected by using conventional final examination, a standardized test (Force Concept Inventory), and a survey (Maryland Physics Expectations). The Hake' normalized gains of the groups instructed with peer instruction were averagely calculated to be 0.46 for FCI while this value for the control group was found to be 0.33, the final examination score of experimental groups was calculated to be 75 in average while this value for the control group was found to be 63 and finally the decrease in the MPEX scores for three experimental groups was observed but this decline was statistically significant for conventional peer instruction. When the results of the research were specifically evaluated for the experimental groups, the success rate of correct answers more observed in the reflection group according to the others. They indicated that the effects of peer instruction on conceptual understanding, attitude, expectation, and problem solving skills of the students were not dependent on instructors. But, Turpen & Finkelstein (2010) and Turpen & Finkelstein (2009) explained that the construction of different classroom norms and the different implementation of peer instruction with different instructors could change the sense-making of students in introductory physics courses.

Gok & Gok (2016) investigated the effectiveness of peer instruction on learning strategies, conceptual learning, and problem solving performance of the university students in chemistry course. They reported that the learning gains, learning strategies (cognitive/metacognitive strategies and resource management strategies), and problem solving performance of the students instructed with peer instruction were higher than those of the students instructed with traditional instruction.

Sayer et al. (2016a) examined the effectiveness of just-in-time teaching based on peer instruction in quantum mechanics course. They analyzed the performance of the students "on pre lecture reading quizzes, in class clicker questions answered individually, and clicker questions answered group discussion" (p.1), and compared the performance of the students by using "open-ended retention quizzes administered after all instructional activities on the same concepts" (p.1). Asking questions after the lecture enhanced student performance compared to reading quizzes. After group discussion following individual responses, the performance of the students on the clicker questions also increased.

The belief and attitude of students enrolled in introductory physics course according to gender were investigated with four groups including 441 students according to gender (Zhang, Ding, & Mazur, 2017). The first group was instructed with traditional teaching methods and the others were instructed with peer instruction. The students in the first two groups (variable groups) of peer instruction were consistently changed during the semester and the students in the other group were fixed throughout the semester. The belief and attitude of the students on physics and physics learning enhanced in peer instruction groups of the research. The results of the fixed group were more positive relative to the results of the variable groups. Besides, female students in the peer instruction groups were higher the belief and attitude about physics learning than male students.

The Applications of Peer Instruction in Social Science

Peer instruction has also been performed on many social science disciplines (e.g., English (Al-Hebaishi, 2017), Philosophy (Butchart et al., 2009), Physiology (Cortright et al., 2005, etc.).

Rao & DiCarlo (2000) revealed that peer instruction enhanced the performance of the students on quizzes in medical physiology course. Cortright et al. (2005) also investigated the impact of peer instruction on meaningful learning. The research was conducted to 38 students enrolled in Exercise Physiology course at East Carolina University. They revealed the positive effects of peer instruction on meaningful learning and problem solving skills of the students. Giuliodori et al. (2006) examined the effectiveness of peer instruction on qualitative problem-solving questions of the student performance based on a scenario in Veterinary Physiology course. They reported that peer instruction significantly enhanced attention of the students. They especially stated that there was a 35% progress in the qualitative problem solving performance of the students after peer discussion between peers.

The achievement of the two group students enrolled in Textiles courses was compared (Yaoyuneyong & Thornton, 2011). Students including the control group only used classroom response systems in combination with traditional instruction while the other students including the experimental group used classroom response systems in combination with peer instruction. They revealed that the examination achievements and final scores of the students in the experimental group were higher than those of the students in the control group, but the performance of the students in the control group on class project was better than that of students in the experimental group. There was not any statistically significant difference between the quiz performances of the two groups. Durmont (2013) investigated the conceptual reasoning, learning experience, and satisfaction of the students in English course at the Yverdon University of Applied Sciences. The researcher found the positive effects of peer instruction on teaching foreign language.

Conclusion

Many qualitative and quantitative studies performed on peer instruction in many different disciplines (physics, science, engineering, social, etc) were reviewed and analyzed in the present study. The brief results of reviewed studies was given in Appendix. Some of the studies focused on the effectiveness of peer instruction on high school, college, and university students' performance, conceptual learning, problem solving, critical thinking, perception, attitude, motivation, confidence, and belief, etc. in comparison with traditional teaching methods. Some of others examined the effectiveness of peer instruction on gender factor. Some studies investigated the effects the interactive engagement methods (just in time teaching, think pair share, hybrid approaches, etc.) with peer instruction on students' learning gain. Several studies reported the influence of low and higher technological tools on peer instruction. The other studies analyzed the impact of instructors' teaching experience and students' academic background on peer instruction. When the results of the indicated studies were generally evaluated, it could be said that the cognitive and affective skills of the students instructed with peer instruction regardless of teaching experience of the instructors, considering academic background and gender of the students, using low and higher technological tools were higher than those of the students instructed with traditional teaching methods.

Recommendation

Some suggestions regarding reviewed studies' results could be presented as follows: more researches are needed a) to confirm the impact of high-stake and low-stake grading on peer discussion, b) to examine the effectiveness of some characteristics (demographics, gender, race, background knowledge, etc.) of students, and some properties (teaching experience, etc.) of instructors on peer instruction with more statistical analysis, c) to confirm the effectiveness of interactive engagement methods based on peer instruction on the conceptual understanding and problem solving of the high school, college and university students in many different disciplines, d) to examine the effects of initial and second voting on students' performance, e) to investigate the impact of peer instruction on the psychomotor skills besides cognitive and affective skills of the students.

References

Al- Hebaishi, S. M. (2017). The effect of peer instruction method on pre-service teachers' conceptual comprehension of methodology course. *Journal of Education and Learning*, *6*(3), 70-82.

Antwi, V., Raheem, K., & Aboagye, K. (2016). The impact of peer instruction on students' conceptual understanding in mechanics in central region of Ghana. *European Journal of Research and Reflection in Educational Sciences*, *4*(9), 54-69.

Atasoy, S., Ergin, S., & Sen, A. I (2014). The effects of peer instruction method on attitudes of 9th grade students towards physics course. *Eurasian Journal of Physics and Chemistry Education*. *6*(1), 88-98.

Beatty, I. (2004). Transforming student learning with classroom communication systems. EDUCAUSE Center for Applied Research (ECAR) *Research Bulletin*, *3*, 1-13.

Beatty, I. D., Gereca, W. J., Leonard, W. L., & Dufrense, R. J. (2006). Designing effective questions for classroom response systems teaching. *American Journal of Physics*, *74*(1), 31-39.

Beichner, R. J., & Saul, J. M. (2003). *Introduction to the SCALE-UP (Student-Centered Activities for Large Enrollment Undergraduate Programs) Project*. Proceedings of the International School of Physics "Enrico Fermi", Varenna, Italy.

Brady, M., Seli, H., & Rosenthal, J. (2013). Clickers and metacognition: A quasi-experimental comparative study about metacognitive self-regulation and use of electronic feedback devices. *Computers & Education*, *65*, 56-63.

Bretzmann, J. (2013). *Flipping 2.0 practical strategies for flipping your class.* New Berlin, WI: The Bretzmann Group.

Brooks, B. B. J., & Koretsky, M. D. M. (2011). The influence of group discussion on students responses and confidence during peer instruction. *Journal of Chemical Education, 88*(11), 1477-1484.

Bruck, A. D., & Towns, M. H. (2009). Analysis of classroom response system questions via four lenses in a general chemistry course. *Chemistry Education Research and Practice,10*(4), 291-295.

Butchart, S., Handfield, T., & Restall, G. (2009). Using peer instruction to teach philosophy, logic, and critical thinking. *Teaching Philosophy, 32,* 1–40.

Caldwell, J. E. (2007). Clickers in the large classroom: Current research and best-practice tips.*CBE-Life Sciences Education, 6,* 9-20.

Cortright, R. N., Collins, H. L., & DiCarlo, S. E. (2005). Peer instruction enhanced meaningful learning: Ability to solve novel problems. *Advance in Physiology Education, 29,* 107- 111.

Crouch, C. H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics, 69,* 970-977.

Crouch, C. H., Watkins, J., Fagen, A.P., & Mazur, E. (2007). Peer instruction: Engaging students one-on-one, all at once, in Research-Based Reform of University Physics, edited by E. F. Redish and P. J. Cooney American Association of Physics Teachers, College Park, MD, 2007, *Reviews in PER, 1*(1),
http://www.compadre.org/portal/items/detail.cfm?ID=4990&Attached=1.

Cummings, K., & Roberts, S. G. (2008). *A study of peer instruction methods with high school physics students.* American Institute of Physics Conference Proceedings 1064, 103-106.

Durmont, A. (2013). *Peer instruction to learn English.* Conference Processing of ICT for Language Learning, 6th Conference Edition, Florence, Italy.

Edwards, B. I., Aris, B., Shukor, N. A., & Mohammed, H. (2015). Using response system through voting in peer instruction for learning sustainability. *Jurnal Teknologi, 77*(13), 147-157.

Fagen, A. P., Crouch, C. H., & Mazur, E. (2002). Peer instruction: Results from a range of classroom. *The Physics Teacher, 40,* 206-209.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *PNAS, 111*(23), 8410-8415.

Giuliodori, M, J., Lujan, H., & DiCarlo, S. E. (2006). Peer instruction enhanced student performance on qualitative problem-solving questions. *Advance in Physiology Education, 30,* 168-173.

Gok, T. (2011). Using the classroom response system to enhance students' learning and classroom interactivity. *Eurasian Journal of Educational Research, 45,* 49-68.

Gok, T. (2012a). The impact of peer instruction on college students' beliefs about physics and conceptual understanding of electricity and magnetism. *International Journal of Science and Mathematics Education, 10,* 417-436.

Gok, T. (2012b). The effects of peer instruction on students' conceptual learning and motivation. *Asia-Pacific Forum on Science Learning and Teaching, 13*(1), 1-17.

Gok, T. (2014). Peer instruction in the physics classroom: Effects on gender difference performance, conceptual learning, and problem solving. *Journal of Baltic Science Education, 13*(6), 776-788.

Gok, T. (2015). An investigation of students' performance after peer instruction with stepwise problem-solving strategies. *International Journal of Science and Mathematics Education, 13*, 561-582.

Gok, T., & Gok, O. (2016). Peer instruction in chemistry education: Assessment of students' learning strategies, conceptual learning, and problem solving. *Asia-Pacific Forum on Science Learning and Teaching, 17*(1), 1-21.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*, 64-74.

Harlow, J. J. B., Harrison, D. M., & Meyertholen, A. (2014). Correlating student interest and high school preparation with learning and performance in an introductory university physics course. *Physical Review Special Topics-Physics Education Research, 10*(010112), 1-9.

Harvey, N. C. (2013). *The effects of peer instruction on ninth grade students' conceptual understanding of forces and motion.* Unpublished master's thesis, Louisiana State University, Baton Rouge, Louisiana.

Heller, P., Keith, R., & Anderson, S. (1992). Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. *American Journal of Physics, 60*(7), 627-636.

James, M. C. (2006). The effect of grading incentive on student discourse in peer instruction. *American Journal of Physics, 74*(8), 689-691.

James, M. C., & Willoughby, S. (2011). Listening to student conversations during clicker questions: What you have not heard might surprise you!. *American Journal of Physics, 79*(11), 123-132.

Jones, M. E., Antonenkot, P. D., & Greenwood, C. M. (2012). The impact of collaborative and individualized student response system strategies on learner motivation, metacognition, and knowledge transfer. *Journal of Computer Assisted Learning, 28,* 477–487.

Kalman, C. S., Milner-Bolotin, M., & Antimirova, T. (2010). Comparison of the effectiveness of collaborative groups and peer instruction in a large introductory physics course for science majors. *Canadian Journal of Physics, 88*, 325–332.

Knight, J. K., Wise, S. B., & Southard, K. M. (2013). Understanding clicker discussions: Student reasoning and the impact of instructional cues. *CBE Life Sciences Education, 12*(4), 645- 654.

Lasry, N. (2008). Clickers or flashcards: Is there really a difference? *The Physics Teacher, 46,* 242-244.

Lasry, N., Mazur, E., & Watkins, J. (2008). Peer instruction: From Harvard to the two-year college. *American Journal of Physics, 76*(11), 1066-1069.

Lasry, N., Charles, E. Whittaker, C., & Lautman, M. (2009). When talking is better than staying quiet. *Physics Education Research Conference, 1179*, 181-184.

Lasry, N., Watkins, J., Mazur, E., & Ibrahim, A. (2013). Response times to conceptual questions. *American Journal of Physics, 81*(9), 703-706.

Lasry, N., Charles, E., & Whittaker, C. (2016). Effective variations of peer instruction: The effects of peer discussions, committing to an answer, and reaching a consensus. *American Journal of Physics, 84*(8), 639-645.

Lenaerts, J., Wieme, W., & Zele, E. V. (2003). Peer instruction: A case study for an introductory magnetism course. *European Journal of Physics, 24*, 7-14.

Lindstrom, C., & Schell, J. (2013). *Leveraging technology to enhance evidence-based pedagogy: A case study of peer instruction in Norway*. Actas del VI Simposio: Las Sociedades ante el reto digital. Kapittel 1. 7-18.

Lorenzo, M., Crouch, C. H., & Mazur, E. (2006). Reducing the gender in the physics classroom. *American Journal of Physics*, *74*(2), 118-122.

Lucas, A. (2009). Using peer instruction and i-clickers to enhance student participation in calculus. *Problems, Resources, and Issues in Mathematics Undergraduate Studies*, *19*(3), 219-231.

Mazur, E. (1997). *Peer instruction: A user's manual*. Upper Saddle River, NJ: Prentice Hall.

Mazur, E., & Watkins, J. (2010). Just-in-time teaching and peer instruction. In S. P. Simkins & M. H. Maier (Eds.), *Just-in-time teaching: Across the disciplines, across the academy* (pp. 39-62). Sterling, VA: Stylus Publishing.

McCreary, C. L., Golde, M. F., & Koeske, R. (2006). Peer instruction in the general chemistry laboratory: Assessment of student learning. *Journal of Chemical Education*, *83*(5), 804- 810.

McConnell, D. A., Steer, D. N., Owens, K. D., Knott, J. R., Horn, S. V., Borowski, W., Dick, J., Foos, A., Malone, M., McGrew, H., Greer, L., & Heaney, P. J (2006). Using conceptests to assess and improve student conceptual understanding in introductory geoscience course. *Journal of Geoscience Education*, *54*(1), 61–68.

McDermott, L. C., Shaffer, P. S., & the PEG at UW (2002). *Tutorials in introductory physics*. Upper Saddle River, NJ: Pearson/Prentice-Hall.

Michinov, N., Morice, J., & Ferriéres, V. (2015). A step further in peer instruction: Using the stepladder technique to improve learning. *Computers & Education*, *91*, 1-13.

Miller, K., Lasry, N., Lukoff, B., Schell, J., & Mazur, E. (2014). Conceptual question response times in peer instruction classroom. *Physical Review Special Topics-Physics Education Research*, *10*(020113), 1-6.

Miller-Young, J. (2013). *Using peer instruction pedagogy for teaching dynamics: Lessons learned from pre-class reading quizzes*. Proceedings of the Canadian Engineering Education Association (CEEA13), QC: Montreal, Canada.

Miller, K., Schell, J., Ho, A., Lukoff, B., & Mazur, E. (2015). Response switching and self-efficacy in peer instruction classrooms. *Physical Review Special Topics-Physics Education Research*, *11*(010104), 1-8.

Mora, G. (2010). Peer instruction and lecture tutorials equally improve student learning in introductory geology classes. *Journal of Geoscience Education*, *58*(5), 286-296.

Morgan, J. T., & Wakefield, C. (2012). Who benefits from peer conversation? Examining correlations of clicker question correctness and course performance. *Journal of College Science Teaching*, *41*(5), 51-56.

Morice, J., Michinov, N., Delaval, M., Sideridou, A., & Ferriéres, V. (2015). Comparing the effectiveness of peer instruction to individual learning during a chromatography course. *Journal of Computer Assisted Learning*, *31*, 722-733.

Nicol, D, J., & Boyle, J. T. (2003). Peer instruction versus class-wide discussion in large classes: A comparison of two interaction methods in the wired classroom. *Studies in Higher Education*, *28*(4), 458-473.

Nielsen, K. L., Hansen-Nygard, G., & Stav, J. B. (2012). *Investigating peer instruction: How the initial voting session affects students' experiences of group discussion*. International Scholarly Research Network, 2012(290157), 1-8.

Nielsen, K. L., Hansen, G., & Stav, J. B. (2016). How the initial thinking period affects student argumentation during peer instruction: Students' experiences versus observations. *Studies in Higher Education*, *41*(1), 124-138.

Nishimura, R., & Nitta, H. (2014). A peer-instruction-based physics lecture at high school in Japon. *Proceedings of the 12th Asia Pacific Physics Conference, 1*(017030), 1-4.

Novak, G., Gavrin, A., Patterson, E., & Christian, W. (1999). *Just-in Time Teaching: Blending active learning with web technology*. New Jersey: Prentice Hall.

Perez, K. E., Strauss, E. A., Downey, N., Galbraith, A., Jeanne, R., & Cooper, S. (2010). Does displaying the class results affect student discussion during peer instruction? *CBE-Life Sciences Education, 9*,133-140.

Pilzer. S. (2001). Peer instruction in physics and mathematics. *Primus, XI*(2),185-192.

Pollock, S. J., Stephanie, V. C., Dubson, M., Perkins, K. K. (2010). The use of concept tests and peer instruction in upper-division physics. *Physics Education Research Conference 2010, 1289*, 261-264, Portland, Oregon.

Porter, L., Lee, C. B., Simon, B., & Zingaro, D. (2011). *Peer instruction: Do students really learn from peer discussion in computing?* ICER'11, Providence, Rhode Island, USA.

Preszler, R. W., Dawe, A., Shuster, C. B., & Shuster, M. (2007). Assessment of the effects of student response systems on student learning and attitudes over a broad range of biology courses. *CBE-Life Science Education, 6*, 29-41.

Puente, S. M. G., & Swagten, H. J. M. (2012). Designing learning environments to teach interactive quantum physics. *European Journal of Engineering Education, 37*(5), 448-457.

Rao, S. P., & DiCarlo, S. E. (2000). Peer instruction improves performance on quizzes. *Advance in Physiology Education, 24*, 51-55.

Savelsbergh, E. R., de Jong, T., & Ferguson-Hessler, M. G. M. (2011). Choosing the right approach: The crucial role of situational knowledge in electricity and magnetism. *Physical Review Special Topics - Physics Education Research, 7*(010103),1-12.

Sayer, R., Marshman, E., & Singh, C. (2016a). Case study evaluating just-in-time-teaching and peer instruction using clickers in a quantum mechanics course. *Physical Review Physics Education Research, 12*(020133), 1-23.

Sayer, R., Marshman, E., & Singh, C. (2016b). *The impact of peer interaction on the responses to clicker questions in an upper-level quantum mechanics course.* Proceedings of the 2016 Physics Education Research Conference, 304-307 CA: Sacramento, US.

Schell, J., Lukoff, B., & Mazur, E. (2013). Catalyzing learner engagement using cutting-edge response systems in higher education. In Wankel, C., & Blessinger, P. (Eds.) *In Increasing Student Engagement and Retention Using Classroom Technologies Classroom Response Systems and Mediated Discourse Technologies Vol. 6*, pp. 233-261, Bingley, UK: Emerald Publishing Group.

Schmidt, B. (2011). Teaching engineering dynamics by use of peer instruction supported by an audience response system. *European Journal of Engineering Education*, *36*(5), 413–423.

Shaffer, P. S., & McDermott, L. C. (2005). A research-based approach to improving student understanding of the vector nature of kinematical concepts. *American Journal of Physics, 73*(10), 921-931.

Simon, B., Esper, S., Porter, L., & Cutts, Q. (2013). Student experience in a student-centered peer instruction classroom. *ICER'13, 129-136*. San Diego, California, USA.

Smith, K. A., Sheppard, S. D., Johnson, D. W., Johnson, R. T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education*, *94*(1), 87-101.

Smith. M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science*, *323*, 122-124.

Smith, M. K., Wood, W. B., Krauter, K., & Knight, J. K. (2011).Combining peer discussion with instructor explanation increases student learning from in-class concept questions. *CBE- Life Sciences Education, 10*, 55-63.

Spacco, J., Parris, J., & Simon, B. (2013). How we teach impacts student learning: Peer instruction vs. lecture in CS0. *SIGCSE 2013*, CO: Denver, USA.

Suppapittayaporn, D., Emarat, N., & Arayathanitkul, K. (2010). The effectiveness of peer instruction and structures inquiry on conceptual understanding of force and motion: A case study from Thailand. *Research in Science & Technological Education, 28* (1), 63-79.

Thompson, J. R., Christensen, W. M., & Wittmann, M. C. (2011). Preparing future teachers to anticipate student difficulties in physics in a graduate level course in physics, pedagogy, and education research. *Physical Review Special Topics - Physics Education Research*, *7*(010108),1-11

Trent, K. S. (2013). *The effects of peer instruction technique think-pair-share on students' performance in chemistry*. Unpublished master's thesis, Nicholls State University, Thibodaux, LA.

Tucker, L., Scherr, R. E., Zickler, T., & Mazur, E. (2016). Exclusively visual analysis of classroom group interactions. *Physical Review Physics Education Research*, *12*(020142), 1-9.

Turpen, C., & Finkelstein N. D. (2009). Not all interactive engagement is the same: Variations in physics professors' implementation of peer instruction. *Physical Review Special Topics - Physics Education Research, 5*(020101), 1-18.

Turpen, C., & Finkelstein, N. D. (2010). The construction of different classroom norms during Peer Instruction: Students perceive differences. *Physical Review Special Topics-Physics Education Research*, *6*(020123), 1-22.

Vickrey, T., Rosploch, K., Rahmanian, R., Pilarz, M., & Stains, M. (2015). Research-based implementation of peer instruction: A literature review. *CBE-Life Sciences Education, 14*, 1-11.

Wang, S., & Murota, M. (2016). Possibilities and limitations of integrating peer instruction into technical creativity education. *Instructional Science*, *44*, 501-525.

Yaoyuneyong, G., & Thornton, A. (2011). Combining peer instruction and audience response systems to enhance academic performance, facilitate active learning and promote peer- assisted learning communalities. *International Journal of Fashion Design, Technology and Education*, *4*(2), 127-139.

Zhang, P., Ding, L., & Mazur, E. (2017). Peer instruction in introductory physics: A method to bring about positive changes in students' attitudes and beliefs. *Physical Review Physics Education Research*, *113*(010104), 1-9.

Zingaro, D., & Porter, L. (2014). Peer instruction in computing: The value of instructor intervention. *Computer & Education*, *71*, 87–96.

Zingaro, D. (2014). Peer instruction contributed to self-efficacy in CS1. *SIGCSE'14*, 373-378, Atlanta, GA, USA.

Appendix

Author, Year, Publisher	**Subject**	**Cognitive Domain**	**Affective Domain**	**Results**
Rao, S. P., & DiCarlo, S. E. (2000). Peer instruction improves performance on quizzes. *Advance in Physiology Education, 24,* 51-55.	Medical Physiology	x	-	They reported that "pausing three to four times during a 50-min class to allow discussion of concepts enhanced the students level of understanding and ability to synthesize and integrate material" (p.51).
Crouch, C. H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics, 69,* 970-977.	Calculus-and Algebra-base d Introductory Physics	x	x	PI improved both conceptual reasoning skills and quantitative problem solving performance of the students and PI enhanced the motivation of the students.
Pilzer. S. (2001). Peer instruction in physics and mathematics. *Primus, XI*(2),185-192.	Calculus	x	-	The students showed a significant improvement in reasoning skills.
Fagen, A. P., Crouch, C. H., & Mazur, E. (2002). Peer instruction: Results from a range of classroom. *The Physics Teacher, 40,* 206-209.	Physics	x		PI improved learning gains of the students. More than 300 instructors considered their implementation of PI to be successful.
Lenaerts, J., Wieme, W., & Zele, E. V. (2003). Peer instruction: A case study for an introductory magnetism course. *European Journal of Physics, 24,* 7-14.	Introductory Physics	x	x	PI enhanced problem solving skills, conceptual learning of engineering students; fostered the confidence of the students; encouraged class participants of the students.
Nicol, D, J., & Boyle, J. T. (2003). Peer instruction versus class-wide discussion in large classes: A comparison of two interaction methods in the wired classroom. *Studies in Higher Education, 28*(4), 458-473.	Engineering Mechanic	x	x	PI used in the wired classroom helped students to improve their understanding of difficult concepts and increased their motivation.
Cortright, R. N., Collins, H. L., & DiCarlo, S. E. (2005). Peer instruction enhanced meaningful learning: Ability to solve novel problems. *Advance in Physiology Education, 29,* 107-111.	Exercise Physiology	x	x	PI enhanced meaningful learning and ability towards problem solving of the students and PI changed attitude of the students positively.
James, M. C. (2006). The effect of grading incentive on student discourse in peer instruction. *American Journal of Physics, 74*(8), 689-691.	Astronomy	x	-	They reported that "conversation partners with greater knowledge tended to dominate peer discussion and partner with less knowledge were more passive" (p.689). Also "students engaged in a more even examination of ideas from both partner" (p.689).
Lorenzo, M., Crouch, C. H., & Mazur, E. (2006). Reducing the gender in the physics classroom. *American Journal of Physics, 74*(2), 118-122.	Introductory Calculus-bas ed Physics	x	-	Interactive engagement methods reduced the gender gap in physics performance. Female students' performance was higher than male students' performance.
Author, Year, Publisher	**Subject**	**Cognitive**	**Affective**	**Results**

		Domain	**Domain**	
McCreary, C. L., Golde, M. F., & Koeske, R. (2006). Peer instruction in the general chemistry laboratory: Assessment of student learning. *Journal of Chemical Education, 83*(5), 804- 810.	Chemistry	x	-	PI enhanced learning of the students in the Workshop labs.
McConnell, D. A., Steer, D. N., Owens, K. D., Knott, J. R., Horn, S. V., Borowski, W., Dick, J., Foos, A., Malone, M., McGrew, H., Greer, L., & Heaney, P. J (2006). Using conceptests to assess and improve student conceptual understanding in introductory geoscience course. *Journal of Geoscience Education, 54*(1), 61–68.	Geology	x	x	PI increased achievement attendance, and satisfaction of the students.
Giuliodori, M, J., Lujan, H., & DiCarlo, S. E. (2006). Peer instruction enhanced student performance on qualitative problem-solving questions. *Advance in Physiology Education, 30*, 168-173.	Physiology	x	x	PI increased the performance of students on qualitative problem solving and fostered the perceptions/attitudes of the students.
Crouch, C. H., Watkins, J., Fagen, A.P., & Mazur, E. (2007). Peer instruction: Engaging students one-on-one, all at once, *in Research-Based Reform of University Physics*, edited by E. F. Redish and P. J. Cooney American Association of Physics Teachers, College Park, MD, 2007, Reviews in PER, 1(1), http://www.compadre.org/portal/items/detail.cfm?ID=4990&Attached=1	Introductory Physics	x	x	PI improved learning of the students, increased satisfaction of students and instructors
Lasry, N., Mazur, E., & Watkins, J. (2008). Peer instruction: From Harvard to the two-year college. *American Journal of Physics, 76*(11), 1066-1069.	Physics	x	-	PI increased conceptual learning and problem solving skills of the college and university students. Both higher and lower background-knowledge students benefited from PI.
Lasry, N. (2008). Clickers or flashcards: Is there really a difference? *The Physics Teacher, 46*, 242-244.	Algebra-based Mechanic	x	-	"From a teaching perspective, clickers have a number of very practical advantages", "From a learning perspective, using PI with clickers does not provide any significant learning advantage" (p.46).
Cummings, K., & Roberts, S. G. (2008). A study of peer instruction methods with high school physics students. *American Institute of Physics Conference Proceedings 1064*, 103-106.	Algebra-based Introductory Physics	x	-	The results showed a strong correlation between use of PI and improved student conceptual understanding.
Lasry, N., Charles, E. Whittaker, C., & Lautman, M. (2009). When talking is better than staying quiet. *Physics Education Research Conference, 1179*, 181-184.	Algebra-based Introductory Physics	x	-	PI increased peer discussion between peers.
Butchart, S., Handfield, T., & Restall, G. (2009). Using peer instruction to teach philosophy, logic, and critical thinking. *Teaching Philosophy, 32*, 1–40.	Philosophy	x	x	PI increased interaction, attention and critical thinking skills of the students.
Author, Year, Publisher	**Subject**	**Cognitive Domain**	**Affective Domain**	**Results**

Smith. M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science, 323*, 122-124.	Genetic	x	-	Peer discussion increased students' conceptual understanding.
Lucas, A. (2009). Using peer instruction and i-clickers to enhance student participation in calculus. *Problems, Resources, and Issues in Mathematics Undergraduate Studies, 19*(3), 219-231.	Calculus	x	x	PI together with clicker were very effective in enhancing student engagement and learning. The students felt safe to make mistakes and motivated to get clicker scores by participating.
Bruck, A. D., & Towns, M. H. (2009). Analysis of classroom response system questions via four lenses in a general chemistry course. *Chemistry Education Research and Practice,10*(4), 291-295.	Chemistry	x	-	Lower order cognitive skill questions decreased during peer discussion while higher order cognitive skill questions increased by instructors.
Turpen, C., & Finkelstein N. D. (2009). Not all interactive engagement is the same: Variations in physics professors' implementation of peer instruction. *Physical Review Special Topics - Physics Education Research, 5*(020101),1-18.	Introductory Physics	-	-	"Case studies of six professors demonstrate how these variations in classroom practices, in aggregate, create difference classroom norms, such as the relative emphasis on student sense-making vs answering making during Peer Instruction" (p. 1).
Perez, K. E., Strauss, E. A., Downey, N., Galbraith, A., Jeanne, R., & Cooper, S. (2010). Does displaying the class results affect student discussion during peer instruction? *CBE-Life Sciences Education, 9*,133-140.	Introductory Biology	x	-	The study indicated that observing the most common response can bias a student's second vote on a question and may be misinterpreted as an increase in performance due to student discussion alone.
Mazur, E., & Watkins, J. (2010). Just-in-time teaching and peer instruction. In S. P. Simkins &M. H. Maier (Eds.), *Just-in-time teaching: Across the disciplines, across the academy* (pp. 39-62). Sterling, VA: Stylus Publishing.	Introductory Physics	x	-	JITT and PI worked well together to advance and deepen student understanding and helped the instructor make better use of class time.
Mora, G. (2010). Peer instruction and lecture tutorials equally improve student learning in introductory geology classes. *Journal of Geoscience Education, 58*(5), 286-296.	Introductory Physical Geology	x	-	PI and lecture tutorials provided statistically significant cognitive knowledge and understanding gains.
Suppapittayaporn, D., Emarat, N., & Arayathanitkul, K. (2010). The effectiveness of peer instruction and structures inquiry on conceptual understanding of force and motion: A case study from Thailand. *Research in Science & Technological Education, 28* (1), 63-79.	Physics	x	-	Peer instruction method with structured inquiry was more effective than traditional instruction in promoting students' conceptual change.
Author, Year, Publisher	**Subject**	**Cognitive Domain**	**Affective Domain**	**Results**
Pollock, S. J., Stephanie, V. C., Dubson, M., Perkins, K. K. (2010). The use of concept tests and peer instruction in upper-division physics. *Physics Education Research Conference 2010, 1289*, 261-264, Portland, Oregon.	Physics	x	-	The using of concept tests and PI increased performance of the students on targeted conceptual post-tests.

Kalman, C. S., Milner-Bolotin, M., & Antimirova, T. (2010). Comparison of the effectiveness of collaborative groups and peer instruction in a large introductory physics course for science majors. *Canadian Journal of Physics, 88*, 325–332.	Physics	x	-	Collaborative group approach was more effective on conceptual understanding of the students than modified peer instruction. The effectiveness of both approaches did not depend on instructors' experience as long as they follow the same procedures.
Turpen, C., & Finkelstein, N. D. (2010). The construction of different classroom norms during Peer Instruction: Students perceive differences. *Physical Review Special Topics-Physics Education Research, 6*(020123), 1-22.	Introductory Physics	-	x	They found "significant correspondence between the researchers' interpretations and students' perceptions of Peer Instruction in these environments" (p.1). Besides they revealed that "variation in faculty practices can set up what students perceive as discernibly different norms" (p.1).
Gok, T. (2011). Using the classroom response system to enhance students' learning and classroom interactivity. *Eurasian Journal of Educational Research, 45*, 49-68.	Physics	x	x	PI in combination with clicker increased conceptual learning of the students. PI enhanced the interaction between students and instructor.
Porter, L., Lee, C. B., Simon, B., & Zingaro, D. (2011). Peer instruction: Do students really learn from peer discussion in computing? *ICER'11*, Providence, Rhode Island, USA.	Computing	x	-	Peer discussion improved the performance of the students.
Brooks, B. B. J., & Koretsky, M. D. M. (2011). The influence of group discussion on students responses and confidence during peer instruction. *Journal of Chemical Education, 88*(11), 1477-1484.	Chemical Thermodynamics	x	x	PI positively affected thinking and confidence of the students.
Smith, M. K., Wood, W. B., Krauter, K., & Knight, J. K. (2011). Combining peer discussion with instructor explanation increases student learning from in-class concept questions. *CBE-Life Sciences Education, 10*, 55-63.	Genetic	x	-	The combination of peer discussion with instructor explanation increased average performance of the students considerably when compared with either alone.
Schmidt, B. (2011). Teaching engineering dynamics by use of peer instruction supported by an audience response system. *European Journal of Engineering Education, 36*(5), 413–423.	Introductory Engineering Dynamic	x	x	The using of PI supported by an classroom response system increased learning outcome, especially conceptual learning. The students were very satisfied with these combination.
Author, Year, Publisher	**Subject**	**Cognitive Domain**	**Affective Domain**	**Results**
Yaoyuneyong, G., & Thornton, A. (2011). Combining peer instruction and audience response systems to enhance academic performance, facilitate active learning and promote peer-assisted learning communalities. *International Journal of Fashion Design, Technology and Education, 4*(2), 127-139.	Textile	x	x	They revealed that the examination achievements and final scores of the students in the experimental group were higher than those of the students in the control group, but the performance of the students in the control group on class project was better than that of students in the experimental group. There was not any statistically significant difference between the quiz performances of the two groups. PI improved the

				perception of the students.
Nielsen, K. L., Hansen-Nygard, G., & Stav, J. B. (2012). Investigating peer instruction: How the initial voting session affects students' experiences of group discussion. *International Scholarly Research Network, 2012*(290157), 1-8.	Introductory Physics	-	x	"The students emphasize the individual thinking period as crucial for constructing explanations, argumentation, and participation during discussions, and hence for facilitating learning. However, displaying the results from the initial vote can be devastating for the quality of the discussions, especially when there is a clear majority for a specific alternative" (p.1).
Morgan, J. T., & Wakefield, C. (2012). Who benefits from peer conversation? Examining correlations of clicker question correctness and course performance. *Journal of College Science Teaching, 41*(5), 51-56.	Physics	x	-	The study was reported there was not any relationship between peer conversation and students' performance. But peer conversation enhanced the interactivity between peers.
Gok, T. (2012a). The impact of peer instruction on college students' beliefs about physics and conceptual understanding of electricity and magnetism. *International Journal of Science and Mathematics Education, 10,* 417-436.	Physics	x	x	PI improved conceptual understanding, problem solving performance of the students. PI changed beliefs about physics and physics learning of the students positively.
Gok, T. (2012b). The effects of peer instruction on students' conceptual learning and motivation. *Asia-Pacific Forum on Science Learning and Teaching, 13*(1), 1-17.	Physics	x	x	PI increased conceptual learning of the students. But, PI did not influence motivation of the students instructed with PI and TI.
Jones, M. E., Antonenkot, P. D., & Greenwood, C. M. (2012). The impact of collaborative and individualized student response system strategies on learner motivation, metacognition, and knowledge transfer. *Journal of Computer Assisted Learning, 28*, 477–487.	Entomology	x	x	The motivation and confidence of the students including peer instruction group and individualized response group revealed a decrease . The regulation of cognition of female students in PI group and male students in IR group improved. " The PI group scored significantly higher on the test of near transfer than the IR group" (p.477).
Author, Year, Publisher	**Subject**	**Cognitive Domain**	**Affective Domain**	**Results**
Lindstrom, C., & Schell, J. (2013). Leveraging technology to enhance evidence-based pedagogy: A case study of peer instruction in Norway. *Actas del VI Simposio: Las Sociedades ante el reto digital.* Kapittel 1. 7-18.	Science	x	x	PI in combination with clickers increased the performance of the students. Students and were satisfied with PI and clickers.
Miller-Young, J. (2013). Using peer instruction pedagogy for teaching dynamics: Lessons learned from pre-class reading quizzes. *Proceedings of the Canadian Engineering Education Association (CEEA13)*, QC: Montreal, Canada.	Dynamics	x	x	PI developed the learning and performance of the higher, medium, and low achieving students. PI positively changed the perception of the students.
Simon, B., Esper, S., Porter, L., & Cutts, Q. (2013). Student experience in a student-centered peer instruction	Computer Science	x	x	The students were very active on arguing, discussing, explaining with their peers in PI instead of listening

classroom. *ICER'13, 129-136*. San Diego, California, USA.				and taking notes in their standard courses. PI improved meta-cognitive skills, learning behaviors, perceptions, attendance and better attentiveness of the students towards courses in student-centered learning environments.
Durmont, A. (2013). Peer instruction to learn English. *Conference Processing of ICT for Language Learning*, 6th Conference Edition, Florence, Italy.	English	x	x	PI fostered critical thinking and writing skills. PI improved self-esteem, motivation, and satisfaction of the students.
Knight, J. K., Wise, S. B., & Southard, K. M. (2013). Understanding clicker discussions: Student reasoning and the impact of instructional cues. *CBE Life Sciences Education, 12*(4), 645-654.	Biology	x	-	They reported that "the majority of student discussions included exchanges of reasoning that used evidence and that many such exchanges resulted in students achieving the correct answer. Students also had discussions in which ideas were exchanged, but the correct answer not achieved. Importantly, instructor prompts that asked students to use reasoning resulted in significantly more discussions containing reasoning connected to evidence than without such prompts" (p.645).
Harvey, N. C. (2013). *The effects of peer instruction on ninth grade students' conceptual understanding of forces and motion*. Unpublished master's thesis, Louisiana State University, Baton Rouge, Louisiana.	Physics	x	x	The study reported that there was not a clear positive advantage in learning outcomes of PI according to TI in all of the classes. The students liked to see PI in more classes.
Trent, K. S. (2013). *The effects of peer instruction technique think-pair-share on students' performance in chemistry*. Unpublished master's thesis, Nicholls State University, Thibodaux, LA.	Chemistry	x	-	The difference in performance and learning gain of the students between interactive engagement and traditional instruction was not found statistically significant.
Author, Year, Publisher	**Subject**	**Cognitive Domain**	**Affective Domain**	**Results**
Spacco, J., Parris, J., & Simon, B. (2013). How we teach impacts student learning: Peer instruction vs. lecture in CS0. *SIGCSE 2013*, CO: Denver, USA.	Computer Science	x	-	Examination performance of the students instructed with PI was averagely 5.7% higher than examination performance of the students instructed with TI. They reported that there was not significant interactions among gender and grade or class status and grade.
Schell, J., Lukoff, B., & Mazur, E. (2013). Catalyzing learner engagement using cutting-edge response systems in higher education. In Wankel, C., & Blessinger, P. (Eds.) *In Increasing Student Engagement and Retention Using Classroom Technologies Classroom Response Systems and Mediated Discourse Technologies* Vol. 6, pp. 233-261, Bingley, UK: Emerald Publishing Group.	Physics	x	x	The usage of Learning Catalytics increased performance and engagement of the students.
Atasoy, S., Ergin, S., & Sen, A. I (2014).	Physics	-	x	PI was effective on "appreciating the

The effects of peer instruction method on attitudes of 9th grade students towards physics course. *Eurasian Journal of Physics and Chemistry Education. 6*(1), 88-98.				value of physics course" and "expectations about physics course".
Nishimura, R., & Nitta, H. (2014). A peer-instruction-based physics lecture at high school in Japan. *Proceedings of the 12th Asia Pacific Physics Conference, 1*(017030), 1-4.	Physics	x	-	The reflection effects of PI was helpful in monitoring of students' understanding and it was efficient to change/modify the lesson plans for the instructors.
Gok, T. (2014). Peer instruction in the physics classroom: Effects on gender difference performance, conceptual learning, and problem solving. *Journal of Baltic Science Education, 13*(6), 776-788.	Physics	x	x	The difference in conceptual learning between female and male students was not found statistically significant. But male students' problem solving performance was higher than female students' problem solving performance. PI changed affective ideas of the students positively.
Zingaro, D., & Porter, L. (2014). Peer instruction in computing: The value of instructor intervention. *Computer & Education, 71*, 87–96.	Computer Science	x	-	The results reported that "the value of the instructor-led classwide discussion was evident in increased students performance over peer-discussion alone" (p.87).
Miller, K., Lasry, N., Lukoff, B., Schell, J., & Mazur, E. (2014). Conceptual question response times in peer instruction classroom. *Physical Review Special Topics-Physics Education Research, 10*(020113), 1-6.	Introductory Physics	x	x	Response time of the students for correct answers was significantly faster than response time of the students for incorrect answers on concept test questions both before and after peer discussion. The students constructed logical connections between existing knowledge and new constructing information. They had higher self-efficacy with faster response times. there was not gender difference in response rate on concept test questions.
Author, Year, Publisher	**Subject**	**Cognitive Domain**	**Affective Domain**	**Results**
Zingaro, D. (2014). Peer instruction contributed to self-efficacy in CS1. *SIGCSE'14*, 373-378, Atlanta, GA, USA.	Computer Science	x	x	PI increased exam scores and self efficacy of the students.
Gok, T. (2015). An investigation of students' performance after peer instruction with stepwise problem-solving strategies. *International Journal of Science and Mathematics Education, 13*, 561-582.	Physics	x	x	PI developed the using of problem solving strategy steps of the students on concept test questions, mid-term and final examinations, and homework assignments. PI changed the perspective of the students toward problem solving affirmatively.
Michinov, N., Morice, J., & Ferriéres, V. (2015). A step further in peer instruction: Using the stepladder technique to improve learning. *Computers & Education, 91*, 1-13.	Chemistry	x	x	"Results that learning gains were greatest in the Stepladder PI group, and that this effect was mainly observed for difficult questions" (p.90). The satisfaction of students instructed with Stepladder PI was higher than classic PI and individual instruction.

Morice, J., Michinov, N., Delaval, M., Sideridou, A., & Ferriéres, V. (2015). Comparing the effectiveness of peer instruction to individual learning during a chromatography course. *Journal of Computer Assisted Learning, 31*, 722-733.	Chromatography	x	x	Peer instruction enhanced subjective benefits (engaging, learning transfer, motivation, regulation of cognition, satisfying, etc.), but it failed to illustrate a greater learning gain. Besides, "students perceived the peer instruction method as being more satisfying, engaging and useful than the individual learning method"(p.722).
Miller, K., Schell, J., Ho, A., Lukoff, B., & Mazur, E. (2015). Response switching and self-efficacy in peer instruction classrooms. *Physical Review Special Topics-Physics Education Research, 11*(010104), 1-8.	Introductory Physics	x	x	They reported the correlations between response switching and academic self-efficacy, and the correlations between switching and the difficulty of the questions.
Edwards, B. I., Aris, B., Shukor, N. A., & Mohammed, H. (2015). Using response system through voting in peer instruction for learning sustainability. *Jurnal Teknologi, 77*(13), 147-157.	Pedagogy	x	x	The performance, interest, motivation and engagement of the students by using PI in combination with clickers increased.
Wang, S., & Murota, M. (2016). Possibilities and limitations of integrating peer instruction into technical creativity education. *Instructional Science, 44*, 501-525.	ICT	x	-	Peer discussion was effective in improving all levels of students' creative performances.
Gok, T., & Gok, O. (2016). Peer instruction in chemistry education: Assessment of students' learning strategies, conceptual learning, and problem solving. *Asia-Pacific Forum on Science Learning and Teaching, 17*(1), 1-21.	Chemistry	x	x	PI fostered learning strategies, conceptual learning, and problem solving performance. PI positively changed the attitude and perception of the students toward course.
Author, Year, Publisher	**Subject**	**Cognitive Domain**	**Affective Domain**	**Results**
Antwi, V., Raheem, K., & Aboagye, K. (2016). The impact of peer instruction on students' conceptual understanding in mechanics in central region of Ghana. *European Journal of Research and Reflection in Educational Sciences, 4*(9), 54-69.	Physics	x	x	PI improved the conceptual understanding and problem solving skills of the students. PI positively effected on attitude of the students.
Lasry, N., Charles, E., & Whittaker, C. (2016). Effective variations of peer instruction: The effects of peer discussions, committing to an answer, and reaching a consensus. *American Journal of Physics, 84*(8), 639-645.	Physics	x	x	All PI groups' conceptual learning (CU) and traditional problem solving performance (TPSP) was found higher than lecture-based instruction. They revealed that the effects of PI on CU TPSP, attitude, and expectations of the students were not dependent on the instructors.
Nielsen, K. L., Hansen, G., & Stav, J. B. (2016). How the initial thinking period affects student argumentation during peer instruction: Students' experiences versus observations. *Studies in Higher Education, 41(1)*, 124-138.	Introductory Physics	x	x	"The initial thinking period was found to increase argumentation time during discussion, consistent with students' own experiences. However, while students felt that the initial thinking period increased participation and contribution of

				ideas among all group members" (p.124).
Sayer, R., Marshman, E., & Singh, C. (2016a). Case study evaluating just-in-time-teaching and peer instruction using clickers in a quantum mechanics course. *Physical Review Physics Education Research, 12*(020133), 1-23.	Quantum Mechanic	x	-	Asking questions after the lecture enhanced student performance compared to reading quizzes. After group discussion following individual responses, the performance of the students on the clicker questions also increased.
Sayer, R., Marshman, E., & Singh, C. (2016b). The impact of peer interaction on the responses to clicker questions in an upper-level quantum mechanics course. *Proceedings of the 2016 Physics Education Research Conference*, 304-307 CA: Sacramento, US.	Quantum Mechanics	x	-	The performance on the clicker questions was improved after interaction with peers following individual clicker responses.
Al- Hebaishi, S. M. (2017). The effect of peer instruction method on pre-service teachers' conceptual comprehension of methodology course. *Journal of Education and Learning, 6*(3), 70-82.	Teaching Methodology	x	x	PI enhanced conceptual comprehension and was efficient on attitude of the students positively.
Zhang, P., Ding, L., & Mazur, E. (2017). Peer instruction in introductory physics: A method to bring about positive changes in students' attitudes and beliefs. *Physical Review Physics Education Research, 113*(010104), 1-9.	Physics	-	x	The belief and attitude of the students on physics and physics learning enhanced in peer instruction groups of the research. The results of the fixed group were more positive relative to the results of the variable groups. Besides, female students in the peer instruction groups were higher the belief and attitude about physics learning than male students.