THE COMPARISONS OF THE FRACTIONAL GAIN IN CONCEPTUAL LEARNING BY USING PEER INSTRUCTION

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ABSTRACT: Conventional, teacher centered teaching is not sufficient in science, technology, engineering and mathematics education at the present time. Therefore, new teaching strategies and methods have consistently been developed by the educators. One of the new developed teaching methods is peer instruction. Peer instruction is interactive teaching method. Peer instruction is quite easy and practical to implement therefore peer instruction might be adapted to different disciplines of science, social sciences, and engineering. The effectiveness of peer instruction and conventional, teacher centered teaching on students' conceptual learning were compared by calculating fractional gains with the help of some standardized tests including "Force Concept Inventory-FCI, Force and Motion Conceptual Evaluation-FMCE, Conceptual Survey of Electricity and Magnetism, CSEM" in this study. The normalized gains of studies performed and recorded between 1990 and 2016 were evaluated and discussed. When the examined studies were generally interpreted, students' conceptual understanding performance instructed with peer instruction was higher than students' conceptual learning performance instructed with conventional, teacher centered teaching.

Keywords: conceptual learning, peer instruction, standardized tests

INTRODUCTION

Conventional, teacher centered teaching is not efficient and useful to teach and to learn not only for instructors but also for students (Gok, 2014; Hake, 1998). Smith, Sheppard, Johnson & Johnson (2005, p.8) defined conventional, teacher centered teaching as "the information passes from the notes of the professor to the notes of the students without passing through the mind of either one." Many research (Gok, 2015; Gok & Gok, 2016; Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014; Preszler, Dawe, Shuster, & Shuster, 2007) reported that conventional, teacher centered teaching is not sufficiently effective on problem solving performance, conceptual understanding, attitude and self-efficacy of the students. The instructors teach actively and transfer needed information to the students; on the other hand, the students listen to the instructors passively in conventional, teacher centered teaching. Conversely, the roles of the instructors and students change in interactive-engagement courses based on active learning as presented in Figure 1.

Many physics instructors have been using alternative teaching strategies and different educational methods instead of conventional, teacher centered teaching in their courses recently. Therefore, new teaching methods and approaches are developed by the teaching experts. One of the new developed teaching methods is peer instruction. Peer instruction (PI) was developed by Eric Mazur (1997). Peer instruction is "an effective method that teaches the conceptual underpinnings in introductory physics and leads to better student performance on conventional problems" (p. 10, Mazur, 1997). The description of peer instruction according to Michinov, Morice, & Ferriéres (2015, p.1) is "an interactive student-centred instructional strategy for engaging students in class through a structured questioning process that improves the learning of the concepts of fundamental sciences." Peer instruction based on constructivist learning theory and social constructivism (Michinov et al., 2015; Yaoyuneyong & Thornton, 2011) is an interactive teaching method for the instructor and an active learning for the students in the classroom.

The main purpose of peer instruction is to provide students interaction during class and to focus the attention of the students on fundamental concept(s) and/or principle(s). Peer instruction was first conducted to introductory physics course at Harvard University. Mazur (1997) evaluated the conceptual learning of the students by using a standardized test, Force Concept Inventory (FCI). He reported that the conceptual learning performance of the students instructed with peer instruction was higher the conceptual learning of the students instructed with traditional instruction, "conventional, teacher centered teaching". Besides, many studies (Crouch & Mazur, 2001; Lasry, Charles, & Whittaker 2016; Suppapittayaporn, Emarat, & Arayathanitkul, 2010) have been revealed the effectiveness of peer instruction on students' conceptual learning, problem solving skills, critical and analytical skills in different disciplines (Biology, Engineering, Calculus, Chemistry, Philosophy, etc.) and courses relative to conventional, teacher centered teaching.

Figure 1. The Roles of Instructor and Student in Traditional (a) and Peer Instruction Courses (b)
Note: (These photographs were taken from the web-pages respectively
(a) http://study.com/articles/The_Differences_Between_Online_and_Traditional_Classroom_Educations.html
(b) http://perusersguide.org/guides/section.cfm?G=Peer_Instruction&S=What

Peer instruction is combined teaching and learning model. Peer instruction with *just in time teaching* (Novak, Gavrin, Christian, & Patterson, 1999) provides students to do warm-up exercises, peer instruction with *tutorials in introductory physics* (McDermott, Shaffer, & PEG at UW, 2002). It provides students to enhance their engagement toward physics courses and peer instruction with group-problem solving activities (Heller, Keith, & Anderson, 1992; Heller & Hollabaugh, 1992) provides students to solve qualitative and quantitative problem and so on.

Peer instruction has been conducted in associated with other interactive teaching and learning strategies (Gok, 2015; Michinov, Morice, & Ferriéres, 2015; Novak et al., 1999; Sayer, Marshman, Singh, 2016; Simon, Esper, Porter, & Cutts, 2013; Smith, Wood, Adams, Wieman, Knight, Guild, & Su, 2009; Wang & Murota, 2016) such as flipped classroom, just in time teaching, wikis, think pair share, problem solving strategy steps, structured inquiry and stepladder technique to be more effective, useful, and practicable.

The application procedures of peer instruction were explained step by step as follows:

1. Instructor presents brief lecture by using several short presentations in a course.
2. Instructor asks students a concept test question regarding each short presentation. An example of concept test question asked during the application procedure of peer instruction could be given in Figure 2.

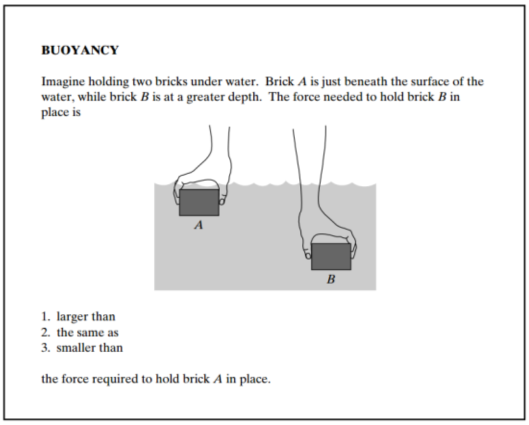
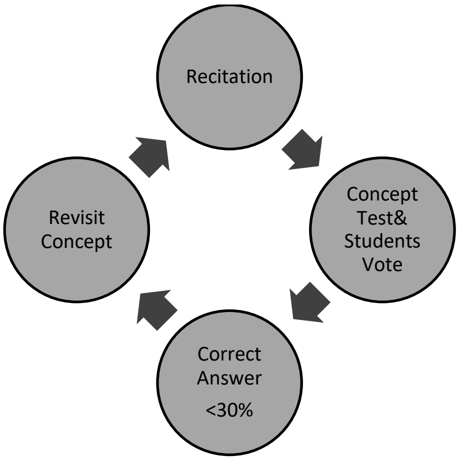


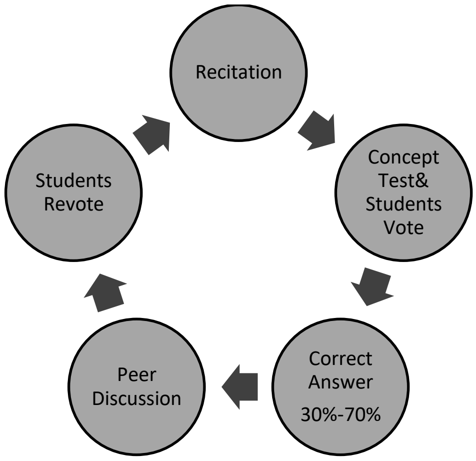
Figure 2. An Example of Concept Test Question on (Mazur, 1997, p.11)

3. Time is given to student about each concept test question.
4. Students record or report their answers individually.
5. Students show their answers by using low technological tool-flashcards (ABCDE) or high technological tools (classroom response systems, tablets etc.).
6. Instructor evaluates and analyzes their responses. The instructor comes across three circumstances for their answers as follows:
   a) If the students' performance is lower than 30%, the instructor repeats concept in question by using the same short presentation as shown in Figure 3a.

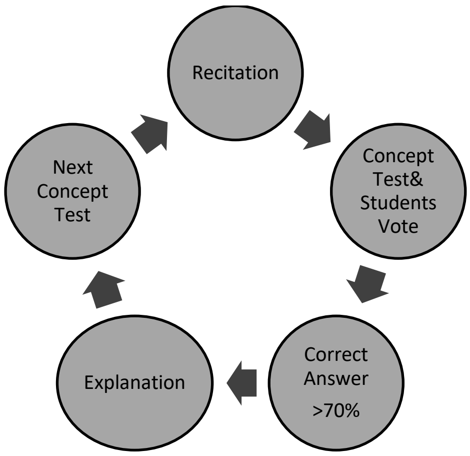
b) If the students' performance is between 30% and 70%, the instructor begins to discuss about concept test question among peers and the students try to convince each other on correct result. At the end of peers' discussion, the same concept test is voted again as indicated in Figure 3b.
c) If the students' performance is higher than 70%, the instructor shortly explains the correct results and then the instructor passes another concept test question or a new short presentation as demonstrated in Figure 3c.



(a)



(b)



(c)

Figure 3. The Application Procedures of Peer Instruction (Lasry, Mazur, & Watkins, 2008)

The given time for application procedures of peer instruction might be changed according to disciplines, courses, instructors, students and other factors.

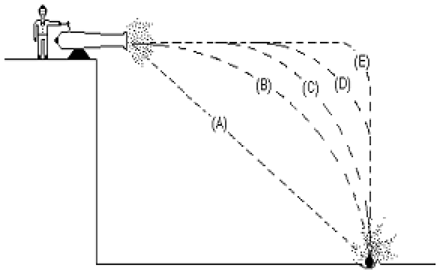
The main purpose of this study was to examine, compare and analyze the effectiveness of peer instruction and conventional, teacher centered teaching on students' conceptual learning. The results of some standardized tests "Force Concept Inventory-FCI, Force and Motion Conceptual Evaluation-FMCE, Conceptual Survey of Electricity and Magnetism, CSEM" between 1990 and 2016 were used for identifying students' conceptual learning with the help of fractional gain formula developed by Hake (1998).

METHODS

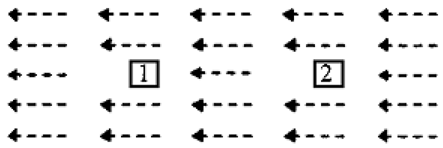
Some physics standardized tests between 1990 and 2016 were examined in order to compare the learning (fractional/normalized) gains of the students instructed with peer instruction and conventional, teacher centered teaching. Therefore, open access journals, proceedings, and dissertations were searched to obtain the data of the present study. Examined physics standardized tests were "Force Concept Inventory-FCI" (Hestenes, Wells, & Swackhamer, 1992), "Force and Motion Conceptual Evaluation-FMCE" (Thornton & Sokoloff, 1998), and "Conceptual Survey in Electricity and Magnetism-CSEM" (Maloney, O' Kuma, Hieggelke, Van Heuvelen, 2001).

Many researchers generally used indicated standardized tests in order to compare and evaluate the effectiveness of the developed educational strategies relative to conventional, teacher centered teaching; therefore, the author preferred to use these tests in the present study. Sample questions regarding standardized tests respectively were given in Figure 4.

A ball is fired by a cannon from the top of a cliff as shown in the figure below. Which of the paths would be cannon ball most closely follow?

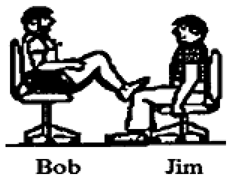


A positive charge might be placed at one of two different locations in a region where there is a uniform electric field, as shown below.



How do the electric forces on the charge at positions 1 and 2 compare?
a) Force on the charge is greater at 1.
b) Force on the charge is greater at 2.
c) Force at both positions is zero.
d) Force at both positions is the same but not zero.
e) Force at both positions has the same magnitude but is in opposite directions.

Two students sit in identical office chairs facing each other. Bob has a mass of 95kg, while Jim has a mass of 77kg. Bob places his bare feet on Jim's knees, as shown to the right. Bob then suddenly pushes outward with his feet, causing both chairs to move. In this situation, while Bob's feet are in contact with Jim's knees,



a) Neither student exerts a force on the other.
b) Bob exerts a force on Jim, but Jim does not exert any force on Bob.
c) Each student exerts a force on the other, but Jim exerts the larger force.
d) Each student exerts a force on the other, but Bon exerts the larger force.
e) Each student exerts the same amount of force on the other.
j) None of these answers is correct.

Figure 4. Sample Questions: The First Question for FCI, The Second Question for FMCE and The Third Question for CSEM

The contents of the standardized tests were presented respectively as follows: The fundamental concepts of FCI including 29 items consist of "kinematics", "Newton's first law", "Newton's second law", "Newton's third law", "superposition principle", and "kinds of force". The fundamental concepts of FMCE including 43 items comprise of several application questions (force sled, cart on ramp, coin toss, force graph etc.) based on "force and motion" concepts. The fundamental concepts of CSEM including 32 items cover "charge distribution on conductors/insulators", "Coulomb's force law", "electric force and field superposition", "force caused by an electric field", "work, electric potential, field and force", induced charge and electric field", "magnetic force", "magnetic field caused by a current", "magnetic field superposition", "Faraday's law", and "Newton's third law".

The learning gains of the students were analyzed by using Hake's fractional gain formula as shown below. Hake (1998) developed a formula and then determined three specific intervals (high, medium, and low) for fractional gain. High gain-g is higher than 0.7; medium gain-g is between 0.7 and 0.3; low gain-g is lower than 0.3.

$$Fractional\ Gain < g > = \frac{posttest\% - pretest\%}{100\% - pretest\%}$$

Hake (1998) used Force Concept Inventory-FCI and Mechanics Diagnostic-MD test as standardized tests. The purpose of these tests was to determine the conceptual learning of students about Classical (Newtonian) Mechanics. He also used Mechanics Baseline (MB) test for testing problem solving skills of students. He compared the effectiveness of traditional introduction methods and interactive-engagement (IE) methods on students' conceptual learning and problem-solving skills. Hake (1998) defined interactive-engagement methods "designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors" (p.65).

Hake (1998) conducted to 6542 high school, college, and university students enrolled in 62 different introductory physics courses in order to be taken average normalized gain "g" by using above-mentioned standardized tests as pre-test and post-test. 62 introductory physics courses consisted of 14 high school-HS- (N=1113 students), 16 college-C- (N=597), and 32 university-U- (N=4832) courses. 14 physics courses of 62 introductory physics courses were instructed with traditional instruction methods with the participation of 2084 students. The other 48 physics courses were instructed by interactive-engagement methods with the participation of 4458 students.

The distribution of introductory physics courses instructed with interactive engagement methods were "Collaborative Peer Instruction" (Heller, Keith, Anderson, 1992; Heller & Hollabaugh, 1992; Johnson, Johnson, & Smith, 1991) in 48 courses, "Microcomputer-Based Labs" (Thornton & Sokoloff, 1990) in 35 courses, "Concept Tests" (Mazur, 1997) in 20 courses, "Modeling" (Wells, Hestenes, & Swackhamer, 1995) in 19 courses, "Active Learning Problem Sets (ALPS)" or "Overview Case Studies (OCS) Physics" (Van Heuvelen, 1991) in 17 courses, physics-education-research based text or no text in 13 courses, and "Socratic Dialogue Inducing (SDI) labs" (Hake, 1992) in 9 courses were conducted.

Hake (1998) averagely calculated the fraction gains at the end of the research. The fractional gain was found as g=0.23±0.04 (low-g $(< g >) < 0.3$) for traditional instruction methods while the fractional gain was calculated as g=0.48±0.14 (medium-g. $0.7 > (< g >) \geq 0.3$) for interactive-engagement methods. Average fractional gain of traditional courses was found as low-g ($< g > = 0.23$). Fractional gain of IE courses were calculated as $< g_{10HS} > = 0.55 \pm 0.11, < g_{13C} > = 0.48 \pm 0.12, < g_{25U} > = 0.45 \pm 0.15$ respectively. The difference between interactive engagement methods and traditional instruction methods ($< g_{48IE} > - < g_{14TI} > = 0.25$) is 1.8 standard deviations of IE courses and 6.2 standard deviations of traditional courses. Consequently, interactive engagement methods were more than twice ($< g_{IE} > = 2.1 \ < g_{TI} >$) as effective in constructing fundamental concepts as traditional introduction methods.

He also compared the achievement of the students' problem solving for both interactive engagement courses and traditional courses by using MB test. At the end of the research, the problem-solving achievement of the students instructed with IE courses had higher problem solving achievement of the students instructed with traditional methods. These results were supported by Mazur’s (1997) research.

The results obtained from research were analyzed and interpreted in consideration of Hake's findings and assumptions in the present study.

RESULTS AND FINDINGS

The comparison of some specific characteristics (pre-test and post-test score percentages, the differences between pre-test and post-test, fractional gains of the tests and the number of the students) between peer instruction and traditional instruction was given in Table 1. Many physics researchers generally use the physics standardized tests " Force Concept Inventory-FCI, Force and Motion Conceptual Evaluation-FMCE, Conceptual Survey in Electricity and Magnetism-CSEM" which were statistically analyzed the validity and reliability of them. Researchers prefer to use these tests for comparing the effectiveness of a new educational method on students' performance and problem-solving skills. The given data in Table 1 was examined and interpreted in three categories (FCI, CSEM, and FMCE) as follows:

FCI

Crouch & Mazur (2001) revealed the effectiveness of peer instruction from 1991 to 2000. They calculated the fractional gain of introductory physics course as low-g "0.25" for traditional instruction methods. After they instructed the introductory physics courses with peer instruction, the fractional gains of introductory physics courses were found between 0.40 and 0.74. The fractional gains of peer instruction are referred medium-g. The fractional gain of peer instruction was only obtained high-g in 1997.

The research on calculating of fractional gain with the help of peer instruction between 2000 and 2008 could not be encountered in open access database. Lasry (2008) published a research paper. He compared and examined the effectiveness of peer instruction by using higher technological tool (classroom response system) and flashcards. He calculated the fractional gain for both classroom response system and flashcards as medium-g. Kalman, Milner-Bolotin, & Antimirova (2010) modified peer instruction (M-PI) approach and they compared the effectiveness of modified peer instruction and collaborative group. At the end of the research they reported the fractional gains for both modified peer instruction and collaborative group as medium-g.

The examined results were supported by the results of Antwi, Raheem, & Aboagye (2016), Gok (2012b, 2014) and Nishimura & Nitta (2014). But Harvey (2013) reported the fractional gains for both peer instruction and traditional instruction as low-g. Recently Lasry et al., (2016) analyzed the conceptual learning performance of students by using FCI. They revealed the similar fractional gain of traditional instruction and peer instruction as medium -g.

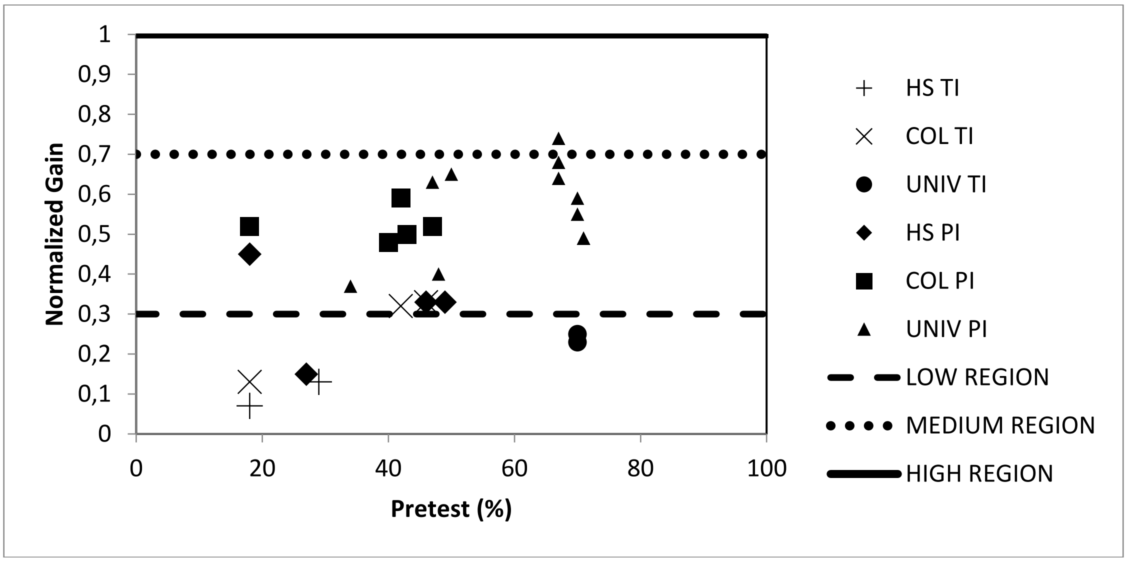


Figure 5. The Relationship between Normalized Gains and Pre-Test Scores on Force Concept Inventory
Note: HS: High School; COL: College; UNIV: University; TI: Traditional Instruction; PI: Peer Instruction

The relationships between normalized gains and pre-test scores on Force Concept Inventory were presented in Figure 5. The relationships were determined according to Hake (1998)' fractional gains (low-g, medium-g, and high-g). The pre-test scores of university students for both peer instruction and traditional instruction were mostly higher than the pre-test scores college and high school students. Therefore, the normalized gains of university students were slightly lower than the gains of college and high school students.

This is because university students learnt the fundamental concepts of introductory physics course when they came to that level. High school students' pre-test scores according to university students' pre-test scores were quite low because of having not sufficient knowledge. Consequently, the raise of high school students' fractional gain was considerable.
The learning gains of university, high school and college students instructed with peer instruction were usually found in medium-g region $(0.7 > (< g >) \geq 0.3)$. The learning gains of university, high school and college students instructed with traditional instruction were generally calculated in low-g region $\left((< g >) < 0.3\right)$. The learning gains of students taught with traditional instruction for each level were eventually low according to the learning gains of the students instructed with peer instruction. In light of these findings it could be said that the traditional instruction methods are not sufficient not only to teach the fundamental principles of introductory physics courses for instructor but also to learn the fundamental concepts of physics for students.

CSEM

Gok (2011) compared the effectiveness of peer instruction by using classroom response system with respect to flashcard on students' conceptual understanding about the principles of electricity and magnetism with the help of Conceptual Survey of Electricity and Magnetism (CSEM). He calculated the fractional gains as g=0.54 (medium-g) for classroom response system and g=0.29 (low-g) for flashcard. When the results were compared for both classroom approaches, it could be said that the effectiveness of peer instruction with classroom response system on students' conceptual learning was higher than the usage of flashcard. Gok (2012a) examined the difference between peer instruction and traditional instruction in students' conceptual learning by using CSEM. At the end of this research, the fractional gain (medium-g "0.62") of peer instruction was found higher than the fractional gain (low-g "0.36") of traditional instruction.

FMCE

Suppapittayaporn et al. (2010) investigated the difference between peer instruction and traditional instruction in students' learning gains about Newtonian Mechanics by using Force and Motion Conceptual Evaluation-FMCE. The study revealed that the students' conceptual learning gain (medium-g "0.45") instructed with peer instruction was higher than the students' conceptual learning gain (low-g "0.14") taught with traditional instruction. But Harvey (2013) presented that the fractional gains of peer instruction and traditional instruction were calculated as low-g<0.30 by using different standardized tests (FCI and FMCE).

Table 1. The Comparisons (Pre-Test, Post-Test, and Fractional Gains) of the Some Standardized Tests (FCI, FMCE, and CSEM) according to Peer Instruction and Traditional Instruction

Year	Author(s)	Standardized Test	Method	N	Pre-Test	Post-Test	Difference	Gain
1990	Crouch &Mazur	FCI	TI	121	70%	78%	8%	0.25
1991			PI	177	71%	85%	14%	0.49
1993			PI	158	70%	86%	16%	0.55
1994			PI	216	70%	88%	18%	0.59
1995			PI	181	67%	88%	21%	0.64
1996			PI	153	67%	89%	22%	0.68
1997			PI	117	67%	92%	25%	0.74
1998			PI	246	50%	83%	33%	0.65
1999			PI	129	48%	69%	21%	0.40
2000			PI	126	47%	80%	33%	0.63
2008	Lasry, N.	FCI	PI/CRS	35	40%	67%	27%	0.48
			PI/FC	34	47%	70%	23%	0.52
2008	Cummings & Roberts	FCI	TI	N/A	N/A	N/A	N/A	0.24
			PI	N/A	N/A	N/A	N/A	0.40
2008	Lasry et al.	FCI	TI-COL	22	46%	63%	17%	0.33
			PI-COL	69	43%	69%	26%	0.50
		FCI	TI-UNIV	127	70%	77%	7%	0.23
			PI-UNIV	187	71%	85%	14%	0.49
2010	Kalman et al.	FCI	M-PI	54	34%	58%	24%	0.37
			CG	77	29%	55%	26%	0.37
2010	Suppapittayaporn et al.	FMCE	TI	119	16%	28%	12%	0.14
			PI	156	18%	55%	37%	0.45
2011	Gok, T.	CSEM	PI/CRS	35	37%	72%	35%	0.54
			PI/FC	33	37%	56%	19%	0.29
2012a	Gok, T.	CSEM	TI	34	41%	63%	22%	0.36
			PI	37	41%	78%	37%	0.62
2012b	Gok, T.	FCI	TI	31	42%	61%	19%	0.32
			PI	32	42%	76%	34%	0.59
2012	Nishimura & Nitta	FCI	PI	N/A	46%	64%	18%	0.33
2013			PI	N/A	49%	65%	16%	0.33
2013	Harvey, C.	FCI	TI	62	29%	38%	9%	0.13
			PI	83	27%	38%	11%	0.15
		FMCE	TI	80	18%	20%	2%	0.02
			PI	62	17%	25%	8%	0.09
2014	Gok. T.	FCI	TI	56	18%	30%	12%	0.13
			PI	42	18%	66%	48%	0.52
2016	Antwi et al.	FCI	TI	37	18%	24%	6%	0.07
			PI	37	18%	54%	36%	0.45
2016	Lasry et al.	FCI	TI	22	N/A	N/A	N/A	0.33
			PI	86	N/A	N/A	N/A	0.47

Note: CG: Collaborative Group; CRS: Classroom Response System; COL: College; CSEM: Conceptual Survey of Electricity and Magnetism; Difference: Pre-Test- Post-Test; FC: Flashcard; FCI: Force Concept Inventory; FMCE: Force and Motion Conceptual Evaluation; MPI: Modified Peer Instruction; N; The Number of Student; PI: Peer Instruction; N/A: Not Available; TI: Traditional Instruction; UNIV: University

CONCLUSION

It was quite different to analyze and interpret conceptual understanding of the students according to the contents and fundamental concept(s)/principle(s) of the standardized tests in the present study. Because the pre and post-test results of examined studies were only presented in the literature, the conceptual learning of the students was generally evaluated instead of performing deep analysis of the test results.

The comparison of fractional gains with Hake (1998)'s research result was conducted in this research. When the pre-test and post-test scores of the students were evaluated for both peer instructional and traditional instruction "conventional, teacher centered teaching", the differences between peer instruction and traditional instruction showed in favor of peer instruction, and the fractional gains supported the achievement of the peer instruction according to years.

When the examined research results were generally interpreted and discussed from the viewpoint of peer instruction and traditional instruction, it could be said that according to Hake (1998)'s fractional gain ranges, the fractional gains of peer instruction were higher than the fractional gains of traditional instruction. The fractional gain of peer instruction is medium-g without using low technology or high technology, having professional experience of the instructors, and also having academic background of the students while the fractional gain of traditional instruction is low-g.

RECOMMENDATIONS

Some suggestions concerning the research's findings could be presented as follows: a) more studies are needed to confirm the effectiveness of peer instruction on students' conceptual learning in different disciplines by using different standardized (diagnostic) tests and the other educational tools, b) the studies could be more conducted to high school students, more data is especially needed to interpret the findings for this level, c) the effectiveness of peer instruction on students' metacognitive skills and critical analytical thinking could be examined and compared with traditional instruction, d) the demographics of the students and instructors could also be investigated in further studies, e) the performances of the students' conceptual learning, problem solving etc. by using fractional gain formula could be investigated with the help of different educational methods apart from peer instruction.

NOTE

Some parts of this research were presented at ICEMST (International Conference on Education in Mathematics, Science and Technology) 2016

REFERENCES

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.

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

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.

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.

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.
Hake, R. R. (1992). Socratic pedagogy in the introductory physics lab. *Physics Teacher, 30*, 546-552.
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*, 627-636.
Heller, P., & Hollabaugh, M. (1992). Teaching problem solving through cooperative grouping. Part 2. Designing problems and structuring groups. *American Journal of Physics, 60*, 637-644.
Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher, 30*, 141-158.
Johnson, D. W., Johnson, R. T., &. Smith, K. A. (1991). *Cooperative Learning: Increasing College Faculty Instructional Productivity.* ASHE-ERIC Higher Education Report 20(4), Washington DC: George Washington University Graduate School of Education and Human Development.
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.
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. (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.
Mazur, E. (1997). *Peer instruction: A user's manual*. Upper Saddle River, NJ: Prentice Hall.
Maloney, D. P., O' Kuma, T. L., Hieggelke, C. J., & Van Heuvelen, A. (2001). Surveying students' conceptual knowledge of electricity and magnetism. *American Journal of Physics, 69*(7), S12-S23.
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.
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.
Novak, G., Gavrin, A., Patterson, E., & Christian, W. (1999). *Just-in Time Teaching: Blending active learning with web technology*. New Jersey: Prentice Hall.
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.
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.
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.
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.
Thornton, R. K., & Sokoloff, D. R. (1990). Learning motion concepts using real-time microcomputer-based laboratory tools. *American Journal of Physics, 58*, 858-867.
Thornton, K., & Sokoloff, D. R. (1998). Assessing student learning of Newton's Laws: The force and motion conceptual evaluation and the evaluation of active learning laboratory and lecture curricula. *American*

Journal of Physics, *66*(4), 338-352.
Van Heuvelen, A. (1991). Overview, case study physics. *American Journal of Physics*, *59*, 898-907.
Wang, S., & Murota, M. (2016). Possibilities and limitations of integrating peer instruction into technical creativity education. *Instructional Science, 44*, 501-525.
Wells, M., Hestenes, D., & Swackhamer, G. (1995). A modeling method for high school physics instruction. *American Journal of Physics, 63*, 606-619.
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.