Education and Science tedmem

Vol 44 (2019) No 199 127-147

An Investigation of the Effectiveness of the Peer Instruction Method on Teaching about Solutions at the High-School Level *

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Abstract

This study aimed to investigate the effect of the peer instruction method on students' conceptual understanding for teaching about solutions at the high-school level and to compare peer instruction with the existing method. Furthermore, the effect of the peer instruction method on students' attitudes toward chemistry class were also examined. A mixed-method design was employed in this study. Participants consisted of 59 eleventh graders from two different classes at Artvin İskebe Anatolian High-school during the 2016–2017 academic year. The study group was selected using the convenience sampling method and one of the classes was randomly assigned to be the experimental group and the other to be the control group. The peer instruction method was used in the experimental group and the existing method was used in the control group. The application stage lasted for four hours per week over the course of five weeks. The data for the study were collected using the Solutions Concept Test (SCT), Attitude Scale toward Chemistry Course (ASTCC), concept questions, semi-structured interviews, and observations. Independent group t-tests were used to analyze the data obtained from the SCT and ASTCC. Data obtained from semi-structured interviews and observations were analyzed descriptively. The average SCT post-test score of the students in the experimental group was higher than that of the students in the control group. The results of the independent t-test analysis revealed that this difference was statistically significant. According to these results, it can be argued that the peer instruction method is more effective than the existing method in promoting understanding of the concepts of chemical solutions, and the qualitative data obtained in the interviews also supported these findings. There were no statistically significant differences between the experimental group and control group in terms of students' attitudes. Despite this, it can be asserted that the students in the experimental group adapted to the peer instruction method throughout the application period and that they enjoyed participating in the lessons taught in this way. Based on in-class

Keywords

Attitudes
Chemistry Education
Conceptual Understanding
Discussion
Misconceptions
Peer Instruction
Solutions

Article Info

Received: 06.06.2018
Accepted: 02.21.2019
Online Published: 07.24.2019

DOI: 10.15390/EB.2019.7966

* This article is derived from Tamer Yıldırım's PhD dissertation entitled "The survey on the effectiveness of peer instruction method in teaching solutions at high school level", conducted under the supervision of Nurtaç Canpolat.

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observations, it can be argued that the students' in-class discussion skills improved. Overall, this study suggests that the peer instruction method is appropriate for promoting conceptual learning and correcting misconceptions.

Introduction

Countries are reviewing and restructuring their education systems in order to be competitive in the global economy, which is becoming globalized and knowledge-based. Discussion of approaches that promote effective and high-quality education and efforts to organize learning are on the rise (Çiftçi, 2015). Scientific knowledge gained during the information-age and the technologies developed based on this information are essential in raising the development level of countries, and innovations in the chemistry field influence these technological developments. It is known that students tend to be less successful in chemistry education than in other subjects in central exams, and international studies have indicated similar results. These studies state that students at all levels are generally unsuccessful despite making an effort to learn chemistry (Coll, 2006; De Jong, 2008; Nakhleh, 1992). The reasons for this failure are listed as the highly abstract nature of chemistry concepts, failure to learn the foundational concepts that undergird high-level concepts, and students' failure to adequately structure highly abstract chemistry concepts in their minds (Kavak & Yamak, 2015; Nakhleh, 1992; Pekdağ, 2010; Reid, 2000). It is known that students who can visualize concepts in their minds are more successful (Nakhleh & Mitchell, 1993). In order to manage chemistry learning effectively, it is necessary to disseminate the use of new teaching strategies, methods, and techniques that can help students overcome these learning difficulties by taking into account learning difficulties that have been revealed in previous researches (Coll, 2006; De Jong, 2008; Nakhleh & Krajcik, 1994). Chemistry teachers often state that their students tend to simply memorize mathematical equations rather than learning chemistry topics conceptually (Beall & Prescott, 1994; Akınoğlu & Tandoğan, 2007). Other studies report that there is a low correlation between success in solving mathematical chemistry problems and gaining a conceptual understanding of chemistry. (Halakova & Proksa, 2007; Nakhleh & Mitchell, 1993). Brooks & Koretsky (2011) state that students who do not achieve sufficient conceptual learning experience difficulties in solving problems and fail when they encounter different types of problems related to the same concepts, because they cannot use their knowledge functionally in new situations. Researchers (Coll, 2006; De Jong, 2008; Nakhleh, 1992) state that this occurs because the students who lack conceptual understanding fail to apply their existing knowledge when encountering new situations. Thus, it is very important to focus on students' conceptual learning in order to achieve success in chemistry teaching.

Achieving active learning, which is not based on memorization, requires the use of special teaching methods. It is reported in the literature that active learning promotes understanding and long-term retention of concepts (Açıkgöz, 2007; Bağcı Kılıç, 2001; Çelik, Şenocak, Bayrakçeken, Taşkesenligil, & Doymuş, 2005; Vazquez et al., 2012) Studies adapting constructivist theory to educational environments state that teaching via active learning methods as suggested by researchers, ensures conceptual learning while developing skills that are useful in many parts of students' lives (Açıkgöz, 2007; Bonwell & Eison, 1991; Marx, Blumenfeld, Krajcik, & Soloway, 1997; Prince, 2004; Silberman, 1996; Skamp & Peers, 2012). Through instruction based on this method, students are provided with the opportunity to configure their scientific knowledge themselves. However, within the scope of traditional teaching methods, students spend most of their class time either as passive listeners or reading information from books. Moreover, this information is not sufficient for understanding, and learning is based on memorization (Vazquez et al., 2012). However, a focus on teaching concepts and, accordingly, an interest in peer instruction that is oriented toward conceptual learning, has recently occurred in literature discussing active learning methods. Mazur (1997) has developed a peer instruction procedure based on Harvard University's practices and his experiences in his physics classes. Peer instruction is a teaching method whereby students think about conceptual questions and contribute to learning through participating in discussions while teachers present key concepts and guide the course. Peer instruction aims to help students learn problems and concepts related to the topic covered in classes through the aid of discussions with their peers (Crouch & Mazur, 2001). Peer instruction is effective for enabling interaction among students and for allowing them to question each other's and their own concepts. In addition, this teaching method makes classes more interesting for students. In the lessons taught by using this method, students have the opportunity to discuss and compare their ideas with their peers. Thus, students are able to restructure their understanding of the concepts (Mazur, 1997; Lucas, 2009; Simon & Cutts, 2012). The peer instruction method also better suited for use in crowded classes compared to other active learning methods, and it can effectively lead to conceptual learning in these settings (Crouch & Mazur, 2001). Discussions carried out by students to persuade their peers make classes engaging and direct students to conceptual concept questions and to apply their knowledge instead of presenting rote information.

Through an examination of the literature, it can be seen that a considerable majority of the studies exploring the applicability and efficiency of peer instruction in teaching environments have focused on teaching physics. These studies found that peer instruction practices were more successful in teaching concepts and in improving academic achievement while having positive effects on the attitudes of the students towards the lesson (Allison, 2012; Crouch & Mazur, 2001; Doğru, 2013; Eryılmaz, 2004; Gök, 2013; Suppapittayaporn, Emarat, & Arayathanitkul, 2010; Özcan, 2017; Şekercioğlu Çirkinoğlu, 2011; Tokgöz, 2007; Yeşiloğlu, 2015). In a study carried out by Nicol & Boyle (2003), discussions among the whole class and those within small groups were compared, and the discussions within the small groups were found to be more effective. In this study, the attitudes of the students were also compared, but it was found out that there was no statistically significant difference between the groups. In the studies carried out by Yeşiloğlu (2015) and Özcan (2017), student misconceptions on the respective subject were examined and it was detected that the rate of misconceptions was lowered when the peer instruction method was applied. However, Allison (2012) and Doğru (2013) found that the peer instruction method did not have a significant effect on the motivation of students. In research conducted by Brooks & Koretesky (2011), the peer instruction method was used in a chemical thermodynamics class. In this study, after peer discussion, the relationship between the ratio of changing their previous answers and students' self-confidence was examined. The findings revealed that the students generally preferred the the most commonly given answer after the discussions. Furthermore, it was determined that when the student group was informed about the general answer ratio of the class, the self-confidence level of the students was affected negatively. In this study, the concept questions with a lower percentage of correct answers were reported to be more effective in teaching the subject. Based on this literature review, it can be seen that there are very few studies on peer instruction, and that the majority of these existing studies are on teaching physics. In short, the number of studies wherein the peer instruction method is applied on teaching chemistry, is quite limited. Therefore, the efficacy of the peer instruction method on teaching chemistry was examined within the scope of this study. The study analyzed the applicability of the peer instruction method in teaching about chemical solutions, one of the fundamental concepts of chemistry and the source of many misconceptions.

It is essential that students learn about the subject of solutions since it consists of key concepts that are necessary to comprehend other concepts in the field of chemistry. The studies conducted on the subject of solutions note that students displayed common misconceptions and had comprehension difficulties. Some of the common misconceptions about concepts related to solutions are the following (Akgün, Gönen, & Yılmaz, 2005; Azizoğlu, Alkan, & Geban, 2006; Karamustafaoğlu, Ayas, & Coştu, 2002; Pınarbaşı & Canpolat, 2003; Çalık & Ayas, 2004; Kalın & Arıkıl, 2010; Pınarbaşı, Sözbilir, & Canpolat, 2009; Tezcan & Bilgin, 2004):

- A solution is formed when a dissolved substance melts in a solvent.
- A solvent transforms the dissolved substance into its own form.

- A solution is formed when a substance is decomposed in another substance.
- A dissolution comes into existence when a dissolved substance fills the gaps in a solvent.
- A solution cannot be solid, it can only be in liquid form.
- Dissolved substances are deposited in the air spaces within the solvent.
- Solubility is increased by mixing.
- As the contact area increases, the amount of the dissolved substance increases.
- Boiling point rises and freezing point decreases depend on the type of particles in the solution.
- Dissolved molecules prevents the solvent molecules from moving away from the solution by holding the solvent molecules.
- As solutions' boiling point increases, their vapor pressure decreases.
- A pure solvent and a solution of it have different vapor pressures under the same atmospheric pressure.
- Because of the attractive forces between solute particles and solvent particles, the vapor pressure of a solution is less than that of the pure solvent.
- The bubbles in boiling water are a result of gases dissolved in the water.
- When the temperature increases, the solubility of all solid substances increases.
- Many heterogeneous mixtures are labeled as homogeneous, as the concept of homogeneity is not well understood.
- Substances only dissolve through ionization.

Dissolution, which is one of the basic concepts related to solutions, occurs at the microscopic level. It is essential that concepts concerning solutions be well understood in order to grasp chemical phenomena and to understand the subsequent subjects better. Thus, special instruction methods should be used to eliminate these misconceptions and comprehension difficulties. Many studies have examined the effect of active learning methods on learning about the concepts related to solutions (Adadan & Savasci, 2012; Avinç Akpınar, 2010; Bayrakçeken et al., 2009; Çalık, 2006; Çalık & Ayas, 2005; Demirbaş, Tanrıverdi, Altınışık, & Şahintürk, 2011; Karamustafaoğlu et al., 2002; Pınarbaşı, Canpolat, Bayrakçeken, & Geban, 2006; Şimşek, 2009; Tosun & Taşkesenligil, 2011a; Ültay, Durukan, & Ültay, 2015). Avinç Akpınar (2010) developed active learning materials and applied them by using the "5 E" learning model, and Çalık, Ayas, & Coll, (2007), Sevim (2007), and Pınarbaşı et al. (2006) used the conceptual modification model, Tosun & Taşkesenligil (2011a) used the problem-based learning approach, Şimşek (2009) used the collaborative learning approach, Ültay, Durukan, & Ültay (2015) used conceptual modification texts, and Karamustafaoğlu et al. (2002) used the concept map technique. In almost all of these studies, it was reported that active learning methods were more successful than traditional instruction. However, despite the employment of these active learning methods, some misconceptions persisted in these studies (Demircioğlu, Demircioğlu, & Ayas, 2004; Pınarbaşı et al., 2006). While active teaching methods can be more effective than traditional methods, it is challenging to apply many active learning methods in crowded classrooms. The literature suggests that the peer instruction method is more conveniently applied in crowded classrooms than other active learning methods, such as the problem-based learning method and the project-based learning method, and it is also suggested that the peer instruction method aims at teaching concepts directly (Crouch & Mazur, 2001; Mazur, 1997; Simon & Cutts, 2012).

In light of this literature, the objective of this study is to analyze the effect of the peer instruction method on conceptual understanding within the scope of teaching the subject "solutions" to high-school students and to compare this approach with the traditional teaching method. In addition, the effect of peer instruction method on the attitudes towards chemistry class is analyzed.

For this purpose, the following research questions were sought to be answered in the study:

1. Is there a statistically significant difference between the SCT post-test scores of the experimental group where the peer instruction method is used and the control group where the traditional (currently-used) method is used?
2. How does the peer instruction method affect students' conceptual understanding of solutions?
3. Is there a statistically significant difference between the experimental group where the peer instruction is applied and the control group where the traditional (currently-used) method is applied in terms of final test scores on the Attitude Scale toward Chemistry Course?

As stated before, the limited number of chemistry-oriented national and foreign studies on the peer instruction method makes this research more important and unique. It is thought that this research will provide an alternative teaching method for educational directors and planners while contributing to the literature of the field.

Method

This was based on a mixed-method research model. Mixed-method design is a research model that uses both quantitative and qualitative data collection, and was preferred because it provides data diversity and can be used to seek answers for different types of research questions. Mixed-method research models can be applied in four different ways, namely triangulated, embedded, explanatory, and exploratory (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, & Demirel, 2012; Creswell & Plano Clark, 2007; McMillan & Schumacher, 2010). In all variants, data are collected both quantitatively and qualitatively. Once the data has been collected and determined to support each other, the method aims to expand the quantitative results with qualitative data (Büyüköztürk et al., 2012; Creswell & Plano Clark, 2007). In order to obtain more reliable results, triangulation has been used in this study.

In this study, quantitative data collection tools were used to compare the effects of two different methods (the peer instruction method and existing method) on students' conceptual learning achievement and attitudes towards the course. Quantitative research was used with the aim of establishing cause-and-effect relationships between variables (McMillan & Schumacher, 2010). Qualitative data were collected through interviews and observation. Qualitative research uses data collection methods including observation, interviews, and document analyses and serves as a process for revealing perceptions and events in a realistic and holistic natural setting (Yıldırım & Şimşek, 2013).

Research Group

The study group consisted of 59 students attending two different 11th-grade classes at Artvin Iskebe Anatolian High School in 2016–2017. The researchers obtained the required research permission from the MONE (Ministry of National Education). One of the classes was randomly designated as the experimental group (N=31) and the other as the control group (N=28). The study group was selected through the convenience sampling method, which is a non-random sampling method, as it was considered that the applicability of the peer instruction method in the selected sample should be appropriate and convenient for selecting this sampling method. The advantage of the appropriate sampling method is that the selection of the sample is easily accessed, appropriate, and convenient for the study that is to be conducted (McMillan & Schumacher, 2010). In addition, this sampling method was selected as it caused little loss of time, money, and productivity (Büyüköztürk et al., 2012). One of the most important factors in the selection of the research group was the fact that both classes were similar in terms of academic achievement, as students were selected to attend the school through a central examination, thereby resulting in a relatively narrow range of academic achievement. Other important factors were the students' interest in the course and the technological and laboratory facilities of the school.

Data Collection Tools

Both qualitative and quantitative data collection tools were used in this study. These included the Solutions Concept Test (SCT), the Attitude Scale Toward Chemistry Course (ASTCC), semi-structured interviews, and observations. The use of different types of data collection tools improves the reliability of the collected findings of the study (McMillan & Schumacher, 2010; Yıldırım & Şimşek, 2013).

Solutions Concept Test (SCT)

The SCT is designed to measure the level of conceptual learning about solutions by 11th-grade high-school students. In the test development process, first the 11th-grade chemistry curriculum determined by the Ministry of National Education was examined and a concept list and course outcomes were determined. The concepts and outcomes were accounted for in the creation of the test items. In this process, national and international theses, articles, general chemistry books, chemistry lessons, and auxiliary test books (Canpolat et al., 2009; Çalık & Ayas, 2003; Demirbaş, Tanrıverdi, Altınışık, & Şahintürk, 2011; Kalın & Arıkıl, 2010; Pınarbaşı & Canpolat, 2003; Tosun & Taşkesenligil, 2011b) were reviewed, and a 36-item test was generated. The test was reviewed by two professors and two PhD students, one of whom is also a chemistry teacher, and the relevance of the test items to the learning outcomes was evaluated. As a result of this validation process, some questions were deleted from the test and other necessary changes were made. In this multiple-choice test, the misconceptions frequently encountered by students were used as distractors. In the academic year 2015–2016, when the topic of solutions was studied previously, the test was applied to a group of 70 people who attended the 12th grade. After this application, based on students' answers, some questions that required algorithmically-based mathematical problems were deleted and the number of questions in the test was reduced to 29, as the students found the number of questions too high. Reliability analysis of the 29-item test showed that Cronbach's alpha coefficient was 0.71. Thus, it can be said that the test is reliable (Kline, 1999). The finalized SCT was applied to both the experimental and control groups as a pre-test and post-test. Two of the questions in the final form of the test were as follows:

Example question: Which one of the following statements is true concerning the formation of a solution?

A) It forms after the solute material melts within the solvent.

B) It forms after the solute material is placed in the air pockets within the solvent.

C) The solute material is lost within the solvent.

D) The solvent converts the solute material into its own structure.

E) It occurs after the interaction of solvent and solute particles.

Example question: Under same temperature, the vapor pressure of the salt-water is higher than the pure water. Please specify the correct explanation(s), which are stated below:

I. The attraction between the salt ions and water molecules prevents the water molecules from being withdrawn from the solution.

II. Since the number of water molecules over the solution's unit face is reduced compared to the pure water, the vapor pressure reduces.

III. Since the vapor pressure rate is higher in salt-water, the vapor pressure reduces.

A) Only I B) Only II C) Only III D) II and III E) I and III

Attitude Scale Toward Chemistry Course

It can be stated that positive attitude of the students towards a lesson and their school would have a positive impact on their learning. If students do not have the desired attitude towards school and the course, measures should be taken to improve their attitudes (Özer, 1998; Simpson & Oliver, 1990). In this study, the attitudes of the students in experimental and control groups towards chemistry courses were measured using the Attitude Scale toward Chemistry Course developed by Kan & Akbaş (2005). Kan & Akbaş (2005) developed the ASTCC to measure the attitudes of high-school students towards chemistry courses. The scale consists of 22 items in three categories. These include positive attitudes towards chemistry, negative attitudes towards chemistry, and active participation in chemistry courses. The reliability of the scale was determined by Kan & Akbaş (2005), who calculated the Cronbach alpha value for the scale as 0.92. Using a 5-point Likert-type scale, ASTCC's items were rated as "1 = I don't agree at all, 2 = I agree somewhat, 3 = I agree moderately, 4 = I agree strongly, 5 = I agree completely". It was applied as a pre-test and post-test for the students in the study group.

Protocol of Semi-structured Interviews

Semi-structured interviews were conducted to determine in detail the conceptual understanding and misconceptions, if any, of students in the study group. An interview form consisting of 11 questions was prepared by the researchers. During the preparation of the questions, the MONE chemistry curriculum outcomes and misconceptions described in the literature were taken into consideration. During the interviews, the students were asked to draw figures and graphs in responding to some questions and therefore, pencils and paper were provided during the interview. Following the completion of the application, semi-structured interviews were held with six students selected from each group (the experimental group and the control group) whose success in learning solutions concepts was intermediate according to their final SCT score. The interviews were recorded with a voice recorder, and each interview lasted approximately 20 minutes.

Observation

In order to determine the active participation of the students in the lesson, their adaptation to the method, and their participation in peer discussions, observations were made by the first researcher. In this study, an unstructured observation approach was used. Unstructured observation is made with the participation of the researcher in the natural setting of the behavior with the observation of the participants (Yıldırım & Şimşek, 2013). Observations were made for five weeks in the experimental group lessons by the first researcher, .and at the end of the lessons, the results of the observations were noted by the researcher without using any structured sheets.

Peer Instruction Course Activities

Lesson plans and appropriate concept questions were prepared for each lesson to be applied in the experimental group where the peer instruction method was used, and an application covering a total of 20 lesson hours, or four hours of lessons per week for five weeks, was carried out. When the lesson plans were prepared, the topics included in the MONE's 11th-grade chemistry curriculum's solutions unit (solvent-dissolved interactions, concentration units, colligative properties, solubility, factors effecting solubility, separation and purification techniques) and the length of the class period served as guidelines. First, the outcomes determined by the MONE were considered as the main objectives, and then nine separate course plans were developed, in which the topics, outcomes, course content, and concept questions would be discussed within an 80-minute period, divided into two 40-minute blocks. When the lesson plans were prepared, two consecutive periods of 40-minutes were divided into three sections (approximately 25 minutes), and within these periods, each concept would receive 8–10 minutes of discussion. According to the peer instruction method, two concept questions would initially be posed to the students According to the rate of correct answers to these concept questions, alternative concept questions were used if needed as necessitated by the peer instruction method. Thus, 80-minute block lessons were designed to include an average of 6–8 concept questions and accompanying peer discussions. Two professors who specialized in the field and a doctoral student, who was a chemistry teacher, evaluated the prepared plans and reviewed them together. Necessary corrections were made to the lesson plans and concept questions during this expert examination. A pilot application was carried out in an 11th-grade class consisting of 27 students at Artvin Iskebe Anatolian High School in the 2015–2016 academic year. As a result of the pilot application, several improvements were made to the lesson plans, resulting in the versions used in the study.

Teaching Implementation

The implementation in the experimental group was carried out by the first researcher in accordance with the design proposed by Mazur (1997) and shown in Figure 1. As shown in Figure 1, the tests for the reading assignments that were given earlier were collected at the beginning of the lesson with the intent of preparing the students for the lesson. At the beginning of the lesson, students were given flash cards, answer keys, and ballpoint pens, and these were collected at the end of the lesson. The 80 minute class time was divided into three sections each to allow time to explain each concept for the day. The topics/concepts were explained for 8–10 minutes each, and during this time, occasional questions were posed to the students and brainstorming was encouraged. Subsequently, the first concept question included in the lesson plans was directed to the students, and one or two minutes were provided to allow students time to think. Students were asked to write their individual answers on their flash cards and show them to the class. If the correct answer rate was above 85%, the next concept was initiated. If the correct answer rate was between 30% and 85%, students would discuss the reasons for their answers with their peers next to them for about 3–4 minutes. Peer groups were not formed in any specific way; each student was paired with the student sitting next to him or her and the two students had peer discussions. If there is no student sitting next to a student, he or she was included in the discussion of the peers in front of him or her. Observations were made during this discussion by walking between the student chairs, and guidance was provided to the students when necessary. At the end of the discussion, students were asked to revise their answers and fill out the answer form again. If the correct answer rate was 85% or greater, the next topic was initiated. If the correct answer rate remained below 30%, the topic/concept was re-explained and an alternative concept question was posed for the same concept. The practice process continued in this way until all of the subjects/concepts related to solutions were covered. In the experimental group, a practice covering 20 class periods was executed for 5 weeks based on the lesson plans that were prepared as appropriate for peer instruction.

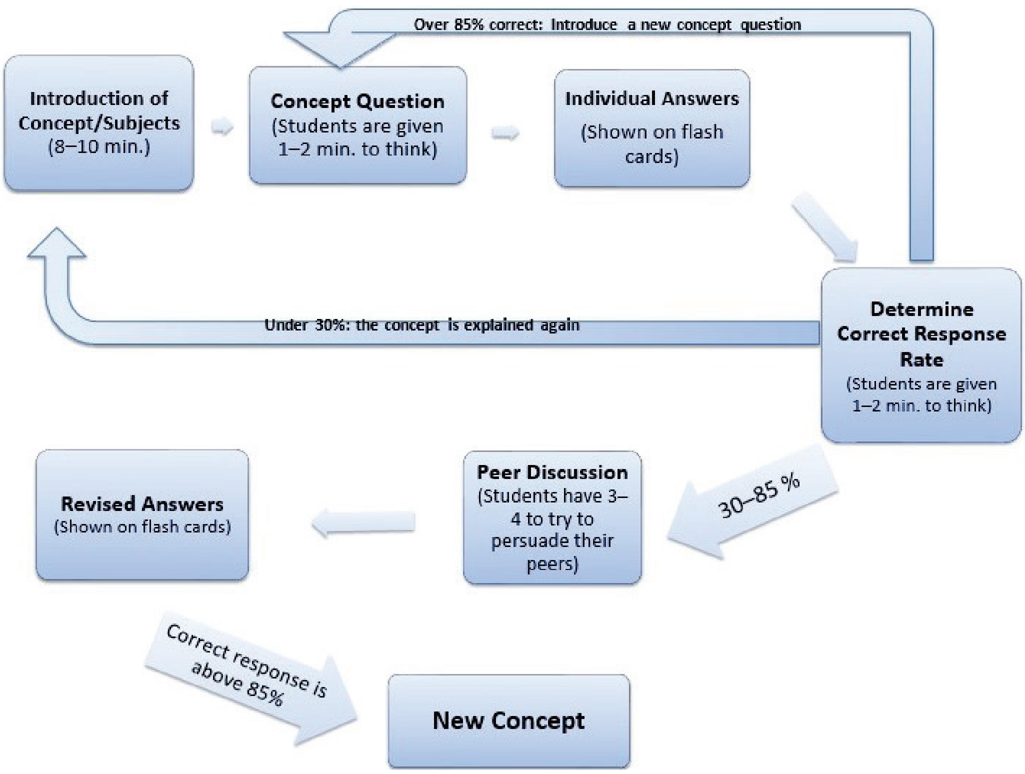

Figure 1. Peer Instruction Design

In the control group, the lessons were again taught by the first researcher and the topics were presented in a teacher-centered lecture style. The topics were presented without the use of concept questions for five weeks and without peer discussions. However, the researcher asked the students thought-provoking questions to introduce each topic to encourage brainstorming. If there was a misconception about the covered topics, necessary explanations were provided. Following the explanations, sample question(s) related to the topics were solved on the board. Afterwards, many sample questions were solved together with the students. Visual materials such as graphics, pictures, and animations that were used in lessons in the experimental group were also used in the control group. Whereas few mathematical questions were included in the experimental group classes, this type of question was frequently solved in the control group classes.

Data Analysis

The data obtained through use of the SCT and ASTCC were analyzed in a predictive statistical manner. The SPSS 18 software package was used for statistical analysis of the data obtained from these tests. The ASTCC and SCT were applied as a pre-test and post-test for both the experimental group and the control group. After the tests were applied, it was determined whether the score distribution for each test showed normality. It was noted in the normality study of the data that the mean, mode, and the median values were close to one another and that the skewness and kurtosis values were in the +1 to -1 range. As the data showed normal distribution, parametric tests were used to analyze the test results. An independent groups t-test was used in order to determine whether there was a statistically significant difference between the SCT and ASTCC pre- and post-test scores. The predictive statistical analyses of this study were tested at a significance level of 0.05. The misconceptions of the experimental and the control group students in the SCT post-test were determined and subjected to a percentage analysis.

Qualitative data analysis methods were used in the analysis of data obtained through semi-structured interviews to determine the level of conceptual understanding of the students about solutions. The data obtained through the interviews were analyzed through content analysis, and the results obtained were presented in tables and supported with descriptions. The interview data were transcribed by the researchers, and content analysis was conducted on these texts. The main categories of student responses and their frequencies were determined based on the interview data and presented in Table 3. A content analysis was also carried out for the observation notes prepared by the first researcher after the lessons. Findings obtained through analysis of the observation data are listed as observation results.

Results

In order to determine the effect of the peer instruction method on learning concepts related to the topic of solutions, the SCT was applied both in the experimental group and control group as a pre-test and post-test. Since both the pre-test and post-test scores of the two groups showed normal distribution, an independent groups t-test was performed in order to determine whether there was a statistically significant difference between the pre-test and post-test scores in each group. The independent groups t-test results for the pre-test and post-test scores of the SCT are shown in Table 1.

Table 1. Independent Groups t-Test Results for The SCT Pre-Test and Post-Test Scores

	Group	**n**	$\bar{X}$	**SD**	**DF**	**t**	**p**	**r**
Pre-Test	Experimental	31	4.87	2.10	57	-0.75	.46	0,10
	Control	28	5.42	3.27				
Post-Test	Experimental	31	16.90	2.85	57	5.75	.00	0,61
	Control	28	12.82	2.48				

n = the number of the students, **X** = mean, SD = standard deviation, DF= degree of freedom

Table 1 showed that the mean of the pre-test scores of the experimental group was 4.87 and the pre-test mean of the control group was 5.42, and there was no statistically significant difference between the SCT pre-test score averages ($t\ (57) = -0.750$, $p > .05$). According to these results, it can be said that the groups were identical in terms of their success in grasping concepts related to solutions prior to the study implementation. Examination of the post-test score averages showed that the average of the experimental group was 16.90 and the average of the control group was 12.82, and a statistically significant difference was found between the averages ($t\ (57) = 5.748$, $p < .05$). These results showed that the experimental group was more successful than the control group in terms of their conceptual understanding of the subject of solutions. Accordingly, it can be said that the peer instruction method is more effective than the existing teaching method in promoting an understanding of concepts related to solutions. This is also demonstrated by the percentages of misconceptions displayed by students in the experimental and control groups in their SCT post-tests as shown in Table 2.

Table 2. Misconception Percentages of Students in the Experimental and Control Groups in the SCT Post-test

Misconceptions	Percentage	
	Experimental Group	Control Group
Dissolved substance is deposited in the air spaces within the solvent.	38	32
Dissolved molecules prevents the dissolved solvent molecules from moving away from the solution by holding the solvent molecules.	23	54
The concentration of the solution increases when a solute is added in a saturated solution.	19	38
Solutions consisting of solids at the bottom are excessively saturated solutions.	16	60
Solubility increases by mixing.	48	57
As the contact area increases, the amount of the dissolved substance increases.	48	71
Boiling point rises and freezing point decreases depends on the type of particles in the solution.	90	75

Table 2, which details the responses on the SCT post-test, shows that the percentage of misconceptions of the students in the control group is generally higher than that of the experimental group. Despite both teaching approaches, misconceptions such as

- *The boiling point increase and freezing point decrease depend on the type of particles in the solution.*
- *As the contact surface increases, the amount of the dissolved substance increases.*
- *Solubility increases by mixing.*

seem to have continued at a high rate in both the experimental and control groups.

Semi-structured interviews were held with six students from both the experimental group and control group using a semi-structured interview form consisting of open-ended concept questions about the subject of solutions in order to examine conceptual understanding of the students in greater detail. The findings from the analysis of the interviews are shown in Table 3.

Table 3. Semi-Structured Interview Results

Questions	The experimental group students' answers	f	The control group students' answers	f
-What is dissolution? What kind of events occurs during the dissolution process?	• Associating dissolution with interactions between the particles • The assimilation of the dissolving by the solvent.	5 1	• Creating a homogeneous mixture • Breaking of intramolecular bonds • Solute disappears • Moving of solute to pores within the solvent • Creation of new substance	2 1 1 1 1
-What can be done to increase the concentration of solution to a given concentration?	• First, the dissolved solute is placed in the solution vessel and then as much solvent as needed to reach the total volume is added on top of it.	6	• Place the solute in the solution vessel and then add the liquid solvent until the total volume of the solution is reached.	6
-Would you briefly explain the process of solution preparation at a given concentration?	• The amount of solute can be increased, and the solvent can be reduced.	6	• Increasing the amount of solute and reducing the solvent	6
-What is solubility? Please explain. (What is the relationship between a saturated solution and solubility)?	• Each liquid has a certain saturation limit. This is called solubility. • Student did not know and provided no answer	2 4	• Each liquid has a specific solubility limit. This is called solubility. • Unable to relate saturated solution with solubility, despite knowing about saturated solutions.	1 5
-How does the solubility of solids and gases change with increasing temperatures?	• It increases in solids and it decreases in gases.	5	• Solubility of solids increases, and solubility of gases decreases. • It increases both in solids and in gases. • No effect	2 3 1
-How do you explain why salt is being thrown on snowy and icy roads during the winter months?	• A decreased freezing point is caused by creating a salt solution.	6	• Salt forms a soluteand decreases the freezing point. • Salt melts the ice.	3 3
-Can drinking water be obtained from sea water? How do you explain this process?	• Accurately explained the process of desalination. through forward osmosis • Student did not know and provided no answer	4 2	• Accurately explained the process of desalination. through forward osmosis • Student did not know and provided no answer	3 3
-Which separation method is used in the process of obtaining sugar from sugar beets? Could you explain the process briefly?	• Expressing that sugar is extracted from sugar beet by means of a solvent in the form of hot water, which is called extraction • Knowing the term "extraction" but not remembering the process	1 5	• Transfer of sugars to the water with the aid of the water • Knowing the term "extraction" but not remembering the process • Student declared that he/she did not know.	1 1 4

When Table 3 is examined, it is seen that the answers of students in the experimental group to the solutions topic are mostly scientifically acceptable and close to true, except regarding the concept of solubility and the extraction process.

In Table 3, considering the control group's responses, it can be seen that the students cannot associate the dissolution phenomenon with the solvent-dissolved solute interaction, do not fully understand the dissolution process, do not associate solubility with saturated solutions, have misconceptions about the effect of temperature on solubility, and were not able to learn about colligative properties and the extraction phenomenon adequately.

In order to determine the effect of the peer instruction method on the attitudes of the students towards chemistry lessons, the ASTCC was applied to both groups as a pre-test and post-test. Independent t-tests was used to determine whether there was statistically significant difference between the pre-test and post-test scores of the groups because it was understood that both the pre-test and post-test scores of the two groups showed normal distribution. Results of the independent t-test performed for the ASTCC pre-test scores and post-test scores are given in Table 4.

Table 4. Independent Grops t-Test Results for ASTCC Pre-Test and Post-Test Scores

	Group	n	$\bar{X}$	SD	DF	t	p	r
Pre-Test	Experimental	26	54.88	7.03	48	0.26	.96	0,12
	Control	24	54.79	7.28				
Post-Test	Experimental	30	57.20	9.09	54	-0.73	.47	0,10
	Control	26	58.88	7.94				

Table 4 showed that there was not a statistically significant difference between the average scores of the experimental and control groups on the pre-test ($t(48) = 0.26$; $p > .05$). Furthermore, there was no statistically significant difference between the groups in terms of the ASTCC post-test scores ($t(54) = -0.73$; $p > .47$). According to the results of the analysis, it can be said that the peer instruction method did not lead to a statistically significant change in the attitudes of the students towards the chemistry course.

After the 80-minute lessons (40+40), the researcher noted his observations about the delivery of the lessons in the class. Some important points in the observation notes were as follows:

- Students had difficulty adapting to the method in the first week, but after the second week, it was observed that they adapted to the method completely.
- It was observed that some students avoided participating in discussions and they were encouraged to participate by the researcher.
- It was observed that the students had difficulty returning their attention to the lessons after the discussion of the concept questions.
- During the discussion, it was observed that the students lost class discipline.
- The correct response rate always increased after the discussion of the concept questions.
- As the subjects progressed through the application, it was observed that the satisfaction and discussion skills of the students gradually improved.
- It was observed that some students who were reluctant to participate in the class asked, “When will this method be complete?"
- It was observed that the willing students were more satisfied by having the chance to actively participate and that they were interested in the class.
- It was observed that some students used statements such as, "I wish we could use this method in other classes as well."

Discussion and Conclusion

The data shown in Table 1 indicates that the peer instruction method is more effective than the existing instruction method in promoting understanding of concepts related to the topic of solutions. This conclusion is also supported by the percentages of students displaying misconceptions shown in Table 2. In general, it was found that the percentages of experimental group students having misconceptions on the post-test of the SCT were lower than those of the control group. Furthermore, findings obtained in semi-structured interviews held with the experimental and control group students also showed similar results. When the answers that students in the experimental group and control group provided to the questions asked in the semi-structured interviews were compared, it was seen that the students in the experimental group gave more detailed and scientifically acceptable answers than the students in the control group, the conceptual understanding of the experimental group students was better, and the control group students frequently revealed misconceptions by giving shallow answers (Table 3). These results are consistent with the results obtained in other studies in the literature and in other studies which investigated the effect of the peer instruction method on learning in different subject areas (Allison, 2012; Crouch & Mazur, 2001; Cortright, Colins, & Di Carlo, 2005; Demirel, 2013; Smith et al., 2009; Şekercioğlu Çirkinoğlu, 2011; Tokgöz, 2007; Yeşiloğlu, 2015). These studies also report that the peer instruction improves the conceptual understanding of students.

In the experimental group, it can be said that active participation in discussions with their peers after the students answered conceptual questions and that instructor-guided re-evaluation of their misunderstandings with were effective in improving their conceptual understanding. It is thought that the concept questions used during the lesson encourage the students to think deeply, which helps them retain knowledge by stimulating their minds. This is analogous to Brooks & Koretesky’s (2011) conclusion that effective concept questions encourage better learning of a subject, even if the wrong-answer rate of the concept questions is high. In addition, it can be said that when the students performed preliminary readings prior to the lessons, this could lead them to have a command of the subject, interpret the concept questions more correctly, and participate in peer discussions more effectively. During the semi-structured interviews, students clearly stated that doing preliminary reading before the lessons enabled them to have an idea about the subject and made it easier for them to participate in the lesson.

It is also evident from the observations made in the classroom that peer discussions lead to a more effective teacher involvement in the classroom. Teachers keep discussions alive during the class period, provide contributions to keep students engaged in the discussion, help students avoid forming misconceptions, and guide for the discussion to prevent it from growing dull. This is thought to be another factor positively affecting conceptual learning. Indeed, in an active learning environment, the teacher facilitates student learning by playing a guiding role (Açıkgöz, 2007). It is important that pupils realize that the discussions and social interactions they participate in contribute significantly to their learning. The students in the experimental group participated in discussion more willingly with their peers, behaved more comfortably in class, and developed an improved sense that the peer instruction method, and social environment affected their learning positively. Thus, it can be said that the students will be encouraged to participate more and will make considerable progress in their discussion skills, provided that this method is maintained for a longer term. Therefore, the conceptual understanding skills of the students would be expected to improve, as well. In the studies carried out by Smith et al. (2009), Yeşiloğlu (2015) and Özcan (2017), it was inferred that the peer discussions improve the active participation of students and their discussion abilities.

Vygostky, the most prominent name in social constructivism, emphasizes the importance of learners’ social interactions for their learning and the formation of conceptual structures in their minds (Weir, 2004). Kaptan (1999) notes that in the learning environment, students learn through interacting with each other and sharing their knowledge with their peers. Moreover, it can be said that students who have misconceptions after these discussions are able to their misconceptions. In the present study, it can be considered that addressing related misconceptions during the discussion of the concepts in classes taught using the peer instruction methodology also positively contributed to learning and to the discussions. Moreover, it can be said that sharing different suggestions and questioning different opinions during peer discussions helped effect changes in students' conceptual misunderstandings of subjects and helped students consolidate the learned information.

On the other hand, in addition to the above-mentioned results that generally favored the peer instruction method in general, some contrary results were also observed. For example, some of the SCT questions were more often answered correctly by students in the control group. However, it is noteworthy that these questions included numerical calculations. This result can be considered normal, as the classes in the control group were instructed according to the existing method, which places greater emphasis on solving mathematical questions.

In the data related to misconception percentages on the SCT test shown in Table 2, it is seen that despite the higher rate of some misconceptions in the experimental group. Particularly noteworthy was the misconception that a "significant increase in boiling point and decrease in freezing point depended on the particles of the solution." In order to investigate the cause of this misconception, the students were asked to explain their understanding of particle types in the interviews held with the students who had misconceptions. Based on students' answers, it was seen that they thought about particle type as the number of ions that the dissolved substances contributed to the solution, for example, salt ionizes and sugar does not ionize, which therefore decreases the freezing point at different rate. While this understanding was correct, in a case where the number of particles in the solution is equal, students were not able to deduce that sugar and salt will cause the same amount of change. This may be attributable to the instructor not underlining this detail sufficiently during the implementation phase. Underlining for students the fact that what matters is not the number of moles before dissolution, but the number of particles in the solution after dissolution, and that it does not matter whether the particles in the solution are ions or molecules, would help prevent students from developing this misconception. Another misconception in the experimental group was that the "dissolved substance is trapped in air spaces in the solvent." This result may be related to the students' understanding of the fact that volumes are not pooled while dissolving. Through students' answers to interviews questions regarding the preparation of solutions, it was determined that the students in the experimental group knew that volumes could not be pooled, but the students in the control group paid little attention to this fact. The students in the experimental group knew that the solution volume after the dissolving process was smaller than the sum of the separate volumes of the solvent and solute and determined that this situation could only be explained by the fact that the particles of the solute filled air cavities in the solvent. In a similar study conducted by Çalık & Ayas (2005), it was found that some students thought that the solute fills the gaps in the solvent or fills air cavities in a solid material. In addition, in both groups, it is shown that the students were not able to distinguish completely between the dissolution rate and the concept of solubility concept, based on their ideas that "solubility increases by mixing and as the contact area increases, the amount of the solute increases." It is thought that students without a solid foundation for their knowledge may have run into a contradiction in this regard. The students mistake the mixing phenomenon for the amount of solute. This result correlates with the results of Çalık et al. (2007) and Sevim (2007). It can be assumed that this misconception is caused by the fact that sugar dissolves faster when it is mixed with a tea spoon in daily life, and similarly, that powdered sugar dissolves more rapidly than sugar cubes. In spite of instruction, it is reported in the literature that misconceptions in this regard continue at a significant level (Pınarbaşı et al., 2006).

In the interviews questions regarding how dissolution occurs (described in Table 3), it is seen that the students in the experimental group gave more detailed answers, and the students in the control group had misconceptions, such as that during dissolution, intermolecular bonds broke, the solute disappeared, a new substance is generated, and the solute was placed in cavities within the solvent. In the interview questions and on the conceptual examinations posed to the students in the experimental group, discussion of various misconceptions was encouraged. In these activities, it was seen that conceptual questions and peer discussions were more effective than the existing method for eliminating misconceptions. Based on this, it can be inferred that the discussions of errors are important in eliminating such errors. The results obtained in the studies of Özcan (2017), Şekercioğlu Çirkinoğlu (2011), and Yeşiloğlu (2015), which found that the peer instruction decreased misconceptions, support this conclusion.

Considering the interview findings on the solution concept, it was concluded that although the answers of the students in the experimental group were closer to the truth, neither of the groups could associate the concepts of saturated solutions and solubility. This is due to the absence of relational learning. Thus, it can be said that relational learning should be emphasized more during the teaching process. The matter that solubility and concentration in saturated solutions correspond to each other should be discoursed in a more detailed manner. Considering the figures depicting the temperature curves of the solutions drawn by the students during the interviews, it was seen that the answers of the students in the experimental group were more accurate, although they lacked some details. The curves drawn by the students in the control group did not contain any indication that the boiling point of the saturated solution will remain constant, implying that the conceptual aspects of this subject was not understood adequately. Still, it can be said that the conceptual comprehension of this subject is not at the desired level in the experimental group, despite their stronger answers. This can be explained by the students' lack of knowledge and of skills in drawing and reading graphics. This situation is in parallel with the result of the study of Çalık, Ayas, & Coll (2007), where the students had difficulty to drawing their thoughts. The students were asked in the interview to show the dissolution of an ionic salt, such as NaCl, in water at the particle level by drawing a figure, and it was seen that their drawing was inadequate. It can be said that the students were not able to fully understand the granular structure of materials and that they could not sufficiently visualize microscopic phenomena in their mind. Similar results are reported in the literature (Canpolat, Pınarbaşı, Bayrakçeken, & Geban, 2004; Ebenezer, 2001; Kabapınar, 2001).

The student responses concerning the concept of extraction seem to be inadequate in both groups. The reason for this may be that the students did not learn about the concept of extraction in previous years and did not study the subject repeatedly. The students who were educated according to a spiral curriculum studied basic concepts about solvents in previous years, but they encountered the concept of extraction for the first time in the 11th grade, and it seems that they did not understand it adequately within the two hours of instruction time. Therefore, it is concluded that the level current knowledge and prior exposure to subjects on an appropriate level is important for learning.

In general, the reasons why the courses taught through peer instruction methods are more successful at promoting understanding at the conceptual level than courses taught through traditional methods are:

- students arrive at class having completed pre-reading,
- students' attention is engaged by posing an interesting question when starting lessons,
- common misconceptions seen in students are discussion during the class period,
- participation of all students is ensured by showing answers with flash cards,

- after a brief summary of the topic, it is reinforced with concept questions,
- students are made aware of their mistakes through discussions with some of their peers,
- knowledge is reinforced when the teacher by provides the correct answer following the peer discussion.

The third research question asked whether there was a statistically significant difference between the post-test score averages of the experimental and control groups in terms of their attitudes towards chemistry lessons. Considering the results on the ASTCC post-test (shown in Table 4), it is seen that there was no statistically significant difference between the experimental group and the control group in their pre-test and post-test scores. These results show that there is no difference between the peer instruction method and exiting method in terms of the development of particular attitudes towards chemistry lessons. According to these quantitative findings, it can be said that peer instruction does not significantly contribute to the development of students' attitudes towards chemistry lessons. This result of the study is consistent with the results of various studies in the literature which state that the peer instruction method does not significantly affect student attitudes towards the course (Demirel, 2013; Eryılmaz, 2004; Şekercioğlu Çirkinoğlu, 2011; Tokgöz, 2007; Yavuz, 2014; Yeşiloğlu, 2015). In the literature, practices that were maintained for a longer term lead attitude changes within certain studies (Pınarbaşı et al., 2006). However, this study's five-week implementation phase was not enough to lead to an attitude change.

The literature states that having positive attitude towards the course is one factor that affects the students' learning and academic achievement (Özer, 1998; Simpson & Oliver, 1990). Therefore, it is important to develop and implement teaching methods that will improve students' attitudes towards the course, because the students who have positive attitudes towards the course will have higher degrees of internal motivation. The fact that the peer instruction method is a novel method for the study group and the fact that such active learning approaches have not become widespread in schools may have led the outcome that the students' attitudes towards the course did not change. It is well known that students who are accustomed to existing methods generally resist change. The fact that the application period was limited can be seen as a factor in this outcome. In fact, the observational findings showed that the students gradually adapted to the method during the application process. This indicates the possibility of improving their attitudes, provided the practices are maintained for a longer period.

Discussions raise students' interest level and encourage students to become more active in class. It encourages students to make better comments and offers students and teachers various opportunities to re-evaluate and solve their own mistakes. For this reason, it is important to apply teaching methods that give students the opportunity to discuss and to develop critical-thinking skills (Gültepe & Kılıç, 2013; Yeşioğlu, 2015). In Toulmin's discussion model, students are encouraged to develop discussion skills through the use of language by strengthening their mental capacities and demonstrating reasoning abilities (Şekerci & Canpolat, 2017).

Peer discussions sim to support students' scientific thinking, enable the development of critical-thinking skills, and achieve more permanent and functional learning. During the application period, it was observed that students avoided participating in discussions during the first lessons, but in the following weeks, they adapted to the method and actively participated in peer discussions and tried to persuade each other by criticizing others' viewpoints. However, it was observed that some students avoided discussions during the class period, and these students were identified to be reluctant students who were more resistant to attending classes. Similarly, in the study conducted by Yeşiloğlu (2015), it was reported that the peer instruction method made important contributions to the development of students' discussion skills.

According to the results of this study, it can be said that this method is ideal in terms of promoting conceptual learning and correcting students' misconceptions. However, these results are limited to the topic of solutions. Thus, similar studies must be conducted on other chemistry topics where misconceptions and concept-learning challenges are present in order to evaluate the peer instruction method in a more detailed manner. Additionally, providing highly detailed explanations of the commonly misunderstood concepts is of crucial importance in correcting these errors. It can be argued that in explaining concepts during lessons, it is very helpful to emphasize misconceptions and the reasons for them in order to correct these misconceptions. Furthermore, peer-instruction practices should be maintained for longer periods in order to improve student attitudes towards chemistry courses.

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