ORIGINAL ARTICLE

Implementation of Peer Instruction Method on Teaching of Acids and Bases to 12th Grade Students: An Action Research¶

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Abstract: *This study aims to investigate the applicability and effectiveness of the peer instruction method on teaching the subject of acids and bases at the 12th-grade level. In addition, it aims to determine the effect of peer instruction on students' attitudes towards chemistry and in-class discussion, and to examine students' opinions regarding peer instruction post-implementation. The sample of the study consisted of 21 students studying in their 12th grade at a private high school. During the research process, the unit of acids and bases was covered by the researcher using the peer instruction method and the implementation was completed over a 5-week period. The study was designed as an action research, with both qualitative and quantitative data collected and examined. The study's quantitative data were collected through the Acids-Bases Concept Test (ABCT), Chemistry Attitude Scale (CAS), Argumentativeness Scale (AS), and concept questions, while the qualitative data were collected through the Method Opinion Scale (MOS), semi-structured interview, and observation. The analysis of the data was carried out using quantitative and qualitative methods. The results showed that there was a notable increase in the academic achievement of the students after the implementation. Furthermore, the results obtained from ABCT and semi-structured interviews indicated that peer instruction improved the students' conceptual learning, and was also effective in eliminating their misconceptions. Although the pretest-posttest scores of the CAS and AS did not demonstrate a considerable statistical difference, the observation and semi-structured interview data highlighted that the students' attitudes towards chemistry and in-class discussion increased positively. At the end of the implementation, it was observed that the stu-*

dents' attitudes towards the peer instruction method were positive and that the students considered it to be very useful and effective.

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***Keywords**: Peer Instruction, Acids-Bases, Conceptual Learning, In-Class Discussion, Attitude*

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Introduction

CHEMISTRY is taught as a core subject since it is one of the basic sciences and is encountered in many aspects of life. However, due to its abstract concepts and symbols, many students perceive chemistry as the most difficult science to learn (Coll, 2006). The subject of acids and bases, which has an important place in high school chemistry courses, is perceived as challenging by students due to its abstract nature that requires them to exhibit strong analytical skills, thus misconceptions can often occur (Nakhleh, 1992). Some of the misconceptions identified in the literature regarding acids and bases are as follows (Cartrette & Mayo, 2010; Kind, 2004; Muchtar, 2012; Ross & Munby, 1991):

- Acidic solutions do not contain OH- ions.
- Concentration is a measure of the strength of acidity of basicity.
- The equivalence point and the turning point are the same thing.
- For a substance to be acidic, it must contain H in its structure.
- In titrations, neutralization is not complete if either acid or base is weak.
- Misunderstanding the definition of amphoteric concept.
- Misconceptions about the arrangement of ions or molecules at the molecular level in acid-base solutions.
- Acidity strength depends on the number of hydrogen in the substance, and the strength of basicity depends on the number of hydroxides in the substance.
- The K_W value is always equal to 1.0×10^{-14}.
- The expression $K_W = [H]^+ \times [OH]^-$ is only valid for pure water.
- All solutions have the same pH value at the equivalence point.
- All acid-base titrations produce neutral solutions at the end point.

Formation of these misconceptions and the difficulties experienced by students in understanding these chemistry topics reveal inadequacy in their analysis and synthesis skills and that they try to understand the concepts based only on the words of their teacher under traditional lesson teaching methods (Birk & Kurtz, 1999). In addition, students frequently encountering acid-base terms in their daily lives (for example, pH values are clearly written on many cleaning, cosmetic, and beverage products) cause some of these misconceptions to be reinforced and unscientific inferences made. For these reasons, it is necessity to study teaching methods in which students examine acid-base topics in greater depth in order to internalize the concepts (Halakova & Proksa, 2007). It has been reported in the literature that students achieve more effective, permanent, and in-depth learning with active learning methods based on the constructivist approach, which encourages their participation and to take responsibility in lessons, directs them to think and make inferences, and includes the sharing of ideas (Dancy et al., 2016; Hake, 1998; Modell, 1996; Prince, 2004).

Active learning is described as cognitively engaging students through learning materials instead of them receiving knowledge passively (Bonwell & Eison, 1991). In an active learning environment, students are active participants and implement teaching activities planned and prepared by their teacher (Duch et al., 2001). In active learning, students test their hypotheses, share, have discussions within a framework determined by their teacher, are able to develop new products and ideas by working in groups, and are given the opportunity to make inferences by questioning; hence, it is suggested that such methods should be integrated more into teaching processes (Bonwell & Eison, 1991). Chi and Wylie (2014) referred to learning materials or activities (e.g., pre-reading, summarizing) selected for students to undertake during instructional activities. They identified three practical issues faced by teachers when developing active learning in lessons: 1) How to engage students meaningfully and cognitively; 2) Very few criteria exist for the design and implementation of active learning; and 3) Teachers possess no guidelines on how to modify current assignments for active learning. Chi and Wylie (2014) then proposed the ICAP framework, which empirically supports increasing active learning through four modes; interactive (I), constructive (C), active (A), and passive (P), based on the highest level of learning being from interactive to passive (I > C > A > P). Constructive modes can involve individual learners, whereas interactive modes may include collaborative or peer-to-peer discussion conditions. It has been reported in the literature that peer cooperation is an important supporter for the cognitive development of individuals (Cassidy et al., 2019). This taxonomy is deemed as effective and supportive in classifying cognitive engagement activities during active learning methods such as peer instruction. In addition to constructivism, peer instruction also supports the ICAP framework as its theoretical underpinning.

Peer instruction, which is a method used in active learning, aims to increase students' conceptual learning levels by partially changing and reorganizing traditional lessons (Mazur, 1997). Through this method, immediate feedback can be obtained to reveal and eliminate learners' misconceptions, and is aimed to motivate an entire class rather than just those eager to learn. In learning environments where peer instruction is applied, students are asked questions that challenge their minds to help them understand the concepts being taught to a greater depth. Moreover, students who are unable to sufficiently understand a subject from the teacher's perspective or style of expression and experience difficulties in answering questions are offered the opportunity to review and reevaluate the concepts through discussion with their peers (Crouch & Mazur, 2001; Watkins & Mazur, 2010). When the literature is examined, it can be seen that while there many studies approach chemistry subjects through different teaching methods at the high school level, published research examining the effects of peer instruction on the teaching of chemistry subjects has been very limited (Golde et al., 2006; Koretsky & Brooks, 2011). According to the literature reviewed for the current study, peer instruction can increase students' academic success (Porter et al., 2011), as well as their rate of attendance (Porter et al., 2013), improves their conceptual learning (Smith et al., 2011), develops a positive perception in students who are more motivated towards lessons (Gök, 2012), provides for a more effective discussion environment (Nielsen et al., 2016), and improves students' confidence in answering questions (Lasry et al., 2013) as well as their problem-solving skills (Cortright et al., 2005).

The aim of the current study was to investigate the effectiveness and applicability of peer instruction as a method to teach the acids and bases topic at the 12th-grade level. Peer instruction has been frequently used in physics teaching (Kudo et al., 2017) and has been shown to produce successful results. It is therefore considered that peer instruction, which encourages students to think, question, and discuss throughout the lesson, will also be an effective method to help students comprehend difficult chemistry subjects at the desired level (Brooks & Koretesky, 2011; Ergin et al., 2019; Lasry et al., 2008).

Research Questions

Can peer instruction be used as an effective method in teaching acids and bases?

Research Sub-Questions

- Considering the Acids-Bases Concept Test pretest–posttest mean scores, does a statistically significant difference exist between the academic achievement levels of students?
- How does teaching acids and bases with peer instruction affect students' conceptual learning levels?
- What effect do peer discussions during lessons have on students' understanding of a subject?
- Is there a statistically significant difference between students' attitudes towards chemistry lessons in terms of the Chemistry Attitude Scale pretest and posttest average scores?
- Is there a statistically significant difference between students' attitudes towards discussion in terms of their pretest–posttest Argumentativeness Scale average scores?
- What are the students' attitudes and views towards the peer instruction method?

Peer Instruction Method

Peer instruction, which is described as an active learning method, is seen to increase students' individual participation in lessons, enabling them to learn by directing them towards discussion with their peers, and to take greater responsibility for their own learning (Zhu, 2007). Peer instruction was first developed by Eric Mazur in the 1990s (Mazur, 1997). In the implementation phase of the method, the teacher first divides learning units into small sections which include certain concepts so that these concepts can each be covered in small time periods. At the beginning of the lesson, students' reading assignments are checked by way of administering a quiz or by evaluating small assignments they completed prior to the lesson. The aim being to make students more familiar with concepts related to the subject being taught, and for teachers to shape their lesson preparations having seen their students' current knowledge level of a particular topic ahead of the lesson. During the lesson itself, the teacher sets a conceptual question which the students then attempt to answer through the use of appropriate flash (answer) cards. If approximately 90% or more of the class are able to answer correctly, the teacher moves on to the next small section. However, if only 30% of the students or less were able to answer correctly, the teacher reworks the topic in detail. Where the correct answer rate falls between these two ratios, the teacher tasks the students to discuss the question with their peers and then to update their answers accordingly. At the end of this process, the students' answers are reevaluated by the teacher and the next step is decided upon in accordance with the updated correct answer ratio of the class.

Methodology

In this study, the action research method was employed to determine the effect of peer instruction on the students' level of learning the concepts of acids and bases, as well as their attitudes towards the chemistry lessons. In action research studies, researchers take part as practitioners with the aim being to understand the dynamics of the process and its effect, to find solutions, and to generate new ideas (Johnson, 2014). In this classroom-based study, the first author designed a research based on their own classroom teaching as a high school chemistry teacher employed at a private high school, where the high performance of students is a significant focus. The school expects its teaching staff to employ student-centered methods and active teaching methodologies in order to promote student activity during the teaching-learning process. The researcher-teacher's aim was for students to effectively participate and learns in their chemistry lessons; however, based on prior experiences in the teaching of acids and bases at the 12th-grade level, students do

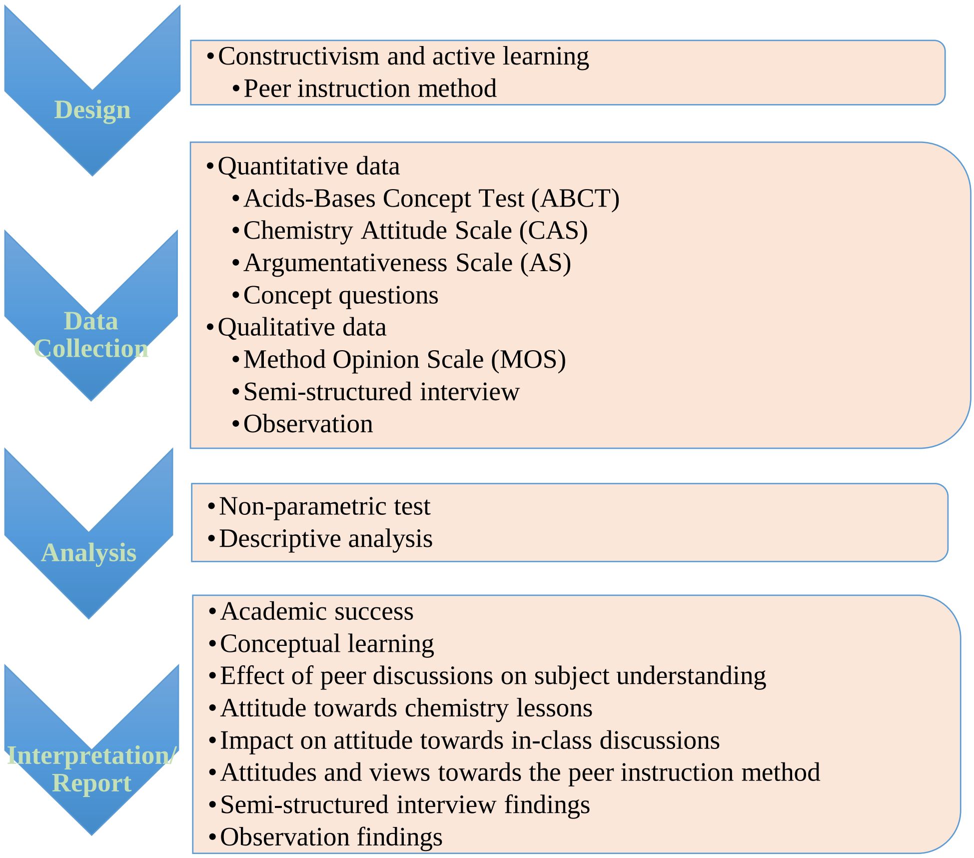

Figure 1. Action Research Process.

not actively participate during classes and held certain misconceptions about the concepts involved.

Not wanting their students simply to study with an exam-oriented focus, especially in the 12th grade with university entrance exams held at the end of their school year, the researcher-teacher wanted to break this general trend. After having interviewed other teaching colleagues, it was noted that they too experienced the same problems, and confirmed that active learning methods were never applied in 12th-grade classes at the school. The researcher-teacher held a doctoral degree and was familiar with active teaching strategies from their postgraduate education, and was therefore quite enthusiastic to use peer instruction as an active learning method. With the intention of trying to improve 12th-grade students' understanding of acids and bases content through a change of teaching style, the researcher-teacher reviewed the related literature and developed a plan to conduct the research. The research process and action plan was then shared with other researchers who joined the study. The processes of designing the study, collecting, analyzing, and interpreting the data, and then reporting the results (Glanz, 2014) (see the action research process illustrated in **Figure 1**) were predominantly under the responsibility of the researcher-teacher as first author of the current study.

Participants

The study group consisted of 21 students studying in their 12th grade at a private high school. Since the first author worked as a teacher at this institution, this action research study was conducted in their own 12th-grade chemistry class, utilizing convenience sampling as an appropriate means to access the target community. Both science and mathematics courses were taught in the English language at the school, and the academic level of the students, who are required to pass a special exam to attend the school, were very close to each other. The 12th-grade students who participated in the study had previously taken chemistry courses at the ninth, 10th, and 11th grade, and had therefore received basic level tuition on the topic of acids and bases in their 10th grade.

Data Collection Tools

Acids and Bases Concept Test

The Acids and Bases Concept Test (ABCT) was developed for use both as a pretest to measure the students' knowledge about acids and bases prior to being taught with the peer instruction method, and again as a posttest to measure their conceptual learning after the subject had been taught. The test was created by the researchers based on the current chemistry textbooks used at the school, past exam questions, and conceptual acid-base questions taken from the literature (Demerouti et al., 2004; Pınarbaşı & Canpolat, 2011; Ross & Munby, 1991). The ABCT consists of 30 multiple-choice questions, each with four options. Students were allowed 40 minutes to complete the test. The test is scored as 1 point for each correct answer and 0 points for any incorrect answers, with a maximum test score of 30 points.

In order to check whether or not the test questions sufficiently overlapped with the objectives to be measured (content validity), the expert opinion of the other researchers of the study and three chemistry teachers were sought. In addition, the ABCT was first developed as a pilot exercise, with 40 questions applied to 75 students at two different high schools. As a result of the post-pilot analysis, 10 questions that were deemed not to have any distinguishing features were subsequently removed from the finalized version of the test. The Cronbach's alpha reliability coefficient for the ABCT was found to be 0.71.

Method Opinion Scale

The Method Opinion Scale (MOS) was prepared by the researchers in order to evaluate the opinions and thoughts of the participant students regarding the effectiveness and efficiency of the peer instruction method after the subject had been taught. The MOS consists of seven open-ended questions. In their preparation, the questions were presented to two faculty members who were experts in their respective fields. In order to ensure that the questions were sufficiently short in length yet fully understandable, and also that they covered all aspects of the peer instruction method, and the researchers paid utmost attention to the experts' suggestions. During implementation of the MOS, the participant students were requested not to write their names on the answer sheet in order that they could respond without feeling undue pressure and to eliminate any thoughts of receiving negative feedback from their teacher if they gave any negative responses. The students were given 40 minutes to respond to the scale.

Chemistry Attitude Scale

The Chemistry Attitude Scale (CAS) was developed by Geban et al. (1994) and applied in the current study to measure the effect of the peer instruction method on students' approaches towards chemistry lessons. The CAS was first applied in the study prior to acids and bases being taught with the peer instruction method, and then reapplied again after the instruction. The scale, which is a 5-point, Likert-type instrument with anchors of 5 = *strongly agree*, 4 = *agree*, 3 = *undecided*, 2 = *disagree,* and 1 = *strongly disagree,* consists of 15 items in total. Responses to the CAS are scored from 5 to 1 for the items affirming the students' positive attitudes towards the lessons, and from 1 to 5 for the items dealing with negative attitudes, and the results then converted into numerical data. The Cronbach's reliability coefficient for the CAS was found to be 0.93.

Argumentativeness Scale

Infante and Rancer (1982) developed the Argumentativeness Scale (AS) to measure whether or not students' attitudes towards discussion change during lessons. The scale is presented as a 5-point, Likert-type instrument (5 = *always*, 4 = *often*, 3 = *I am indecisive*, 2 = *sometimes*, and 1 = *never*) and consists of 20 items in total. The AS was applied in the current study both before and after the acids and bases topic was taught using the peer instruction method. The Cronbach's internal consistency coefficient of the original scale was .91, and the scale's Turkish adaptation by Kaya and Kılıç (2008) presented a Cronbach's alpha reliability coefficient of 0.73.

Responses to the AS are scored from 5 to 1 for items that affirmed the students' positive attitudes towards discussion, and from 1 to 5 for items based on their negative attitudes, and the results were then converted into numerical data.

Semi-Structured Interview

According to the data obtained from the ABCT having been applied as a posttest, semi-structured interviews were conducted in order to gather more detailed information from which to examine the conceptual learning levels of the participant students and their views on the peer instruction method after the acids and bases topic had been taught using the peer instruction method. The interview questions were prepared by considering the answers given by the students to the ABCT and the events that emerged during the course of the lessons. The interviews were conducted with six students, with two volunteers chosen from among those who scored above average, average, and below average in the ABCT posttest.

The interview questions were applied in two parts. First, seven questions were asked that aimed to elicit the participant students' in-depth opinions about the peer instruction method. Second, the concepts that students often have misconceptions about regarding acids and bases were determined, and 10 open-ended concept questions were designed in order to examine their understanding of these topics and to reveal the reasons behind any misconceptions. Each semi-structured interview lasted for approximately 40 minutes and was audio recorded.

Observation

Detailed observation notes were taken by the researcher at the end of each lesson taught using the peer instruction method. The aim was to reach more reliable results by supporting the qualitative data obtained from the MOS and the semi-structured interviews with observations from the lessons. The students' motivation during the lessons taught with the peer instruction method were carefully observed and noted, as well as their readiness, their communication with their peers during the discussions, and the overall effect that the method had on their participation during each lesson.

Table 1. Concepts Related to Acids-Bases.

Concept		Planned Time
1.	Conjugated acid Conjugated base Amphoteric	80 minutes
2.	Neutralization Titration	80 minutes
3.	pH Autoionization of water	80 minutes
4.	Strong acids Strong bases Weak acids Weak bases	80 minutes
5.	Lewis acid Lewis base Nucleophile Electrophile	40 minutes
6.	Ionization of weak acids Ionization of weak bases	80 minutes
7.	Buffer solutions	40 minutes
8.	Hydrolysis	40 minutes
9.	pH curves End point Equivalence point	120 minutes
10.	Indicators	40 minutes

Concept Questions

Multiple-choice questions covering each concept in the acids and bases unit were first prepared. Students' misconceptions about acids and bases most frequently mentioned in the literature were taken into consideration during the preparation of the questions. The questions were then examined by two faculty members for content validity and any necessary improvements were applied in line with their opinions.

The participant students then answered the questions individually using an answer sheet. In cases where the percentage of correct answers in the class was between 30% and 90%, the students reviewed their answers by discussing them with their peers and then marked their new individual answers on their answer sheet. In this way, the responses to these questions also presented data regarding the peer instruction method application, as well as an opportunity to examine the contribution of the students' discussions to their conceptual learning levels.

Implementation

The peer instruction method application was completed over a 5-week duration, with five 40-minute lessons per week. Prior to commencing the lessons, detailed lesson plans were prepared by dividing the teaching unit into 10 compatible subtitles. Based on the nature of peer instruction, these subtitles were then subdivided into ten 12-minute time periods in which one or more of the concepts they contain (see **Table 1**) would be studied. It should be noted that the time allowed for answering and discussing the concept questions is excluded from these time periods.

As the subject of acids and bases was being taught using the peer instruction method, the subtitles to be covered in each upcoming lesson were given as textbook reading assignments in order for the students to arrive at the lesson having prepared in advance. In addition to these assignments, the students were tasked with answering reading quiz questions at home in order to gain familiarity with the required basic concepts and terminology. These assignments were collected from the students before the start of each lesson, quickly examined, and general preliminary information about the relevant section provided. This approach was employed to help the students gain familiarity with the concepts to be covered in the lesson, identify any points with which they experienced difficulties in understanding, and to then focus more on those areas during the upcoming lesson.

The lesson process started with the teacher explaining the objectives of the subject to be covered and the content of the lesson. Then, as an introductory activity, a thought-provoking question was asked to the students about the textbook chapter they would discuss, and their answers noted. Next, the subject was discussed based on a detailed explanation provided about the question. For example, considering acid-base theories, as a thought-provoking question, the students were asked, "What do the terms acid and base mean to you?" After a reflection period of about 2 minutes, some of the students volunteered their answers. Afterwards, the meaning of the terms was briefly explained and then the Arrhenius acid-base theory was discussed, followed by an examination of the historical development process of acids and bases.

According to Arrhenius, acids are substances that increase the H^+ ion concentration in their aqueous solutions, while alkalis, as soluble bases, are substances that increase the OH^- ion concentration in their aqueous solutions. These expressions were explained by showing the equations of acids and bases in their aqueous solutions with examples on the classroom whiteboard. Afterwards, the limitations of this theory were emphasized, along with how it helps in forming the foundations for new theories. Thus, the content was attempted to be associated with the nature of science. For example, Equation 1 was presented on the whiteboard, emphasizing that the reaction between a weak base, ammonia, and hydrogen chloride gas cannot be explained by this theory since ammonia does not contain OH- ions.

$$HCl(g) + NH_3(g) \rightarrow NH_4Cl(s) \quad (1)$$

Figure 2. Students Holding Up Flashcards during Application.

Second, the Brønsted–Lowry acid–base theory was discussed. According to this theory, Equations 2-4 can be used to explain that acids are proton donors and bases are proton acceptors. It was also stated that in aqueous solutions, a proton can be represented as H^+ or as a hydronium ion H_3O^+.

$$HCl(aq) + H_2O\,(l) \rightarrow H_3O^+(aq) + Cl^-(aq) \quad (2)$$
$$CH_3COOH(l) + H_2O\,(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq) \quad (3)$$
$$NH_3\,(aq) + H_2O\,(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq) \quad (4)$$

In order to draw the students' attention to the misconception that "water cannot act as an acid or a base, it is just a solvent," which is frequently encountered in the literature, the question "Can pure water with a pH of 7 at 25°C act as an acid or a base?" was asked. The students were then given about 2 minutes to think before their answers were taken. Afterwards, the teacher gave a detailed explanation of the problem. From Equations 2-4, it can be stated that water behaves as a base by accepting a proton when it reacts with acids, and acts as an acid when it reacts with bases by donating protons. Therefore, substances that can act as both Brønsted–Lowry acid and Brønsted–Lowry base are classified as amphoteric substances.

After the explanation, the first multiple-choice conceptual question was asked to the students, who were then given 2 minutes to answer the question individually. When the time was up, the students were asked to show their answers using flashcards (cards with options A, B, C, and D; see **Figure 2**) that had previously been left on their desks by the teacher.

The teacher tallied up the students’ answers and determined the class percentage of correct answers before moving to the next phase of the peer instruction process based on this percentage.

Following this, the concept of conjugate acid-base pair and amphoteric substances were studied for a period of 10-12 minutes. It was emphasized that there is only one hydrogen atom difference between a conjugate acid-base pair, and it was stated that amphoteric substances can act as either a Brønsted–Lowry acid or a Brønsted–Lowry base, depending on their reaction. These concepts were then explained on the whiteboard using Equations 5-7.

$$H_2PO_4^-(aq) + OH^-(aq) \rightarrow HPO_4^{2-}(aq) + H_2O(l) \quad (5)$$
$$H_2CO_3(aq) + OH^-(aq) \rightarrow HCO_3^-(aq) + H_2O(l) \quad (6)$$
$$HCO_3^-(aq) + S^{2-}(aq) \rightleftharpoons HS^-(aq) + CO_3^{2-}(aq) \quad (7)$$

The multiple-choice concept questions prepared for this section were directed to the students and the same steps of the peer instruction method were then repeated.

The misconceptions most frequently encountered in the literature were associated with the relevant sections and asked to the students in the form of questions throughout the course of the lesson in order to draw their attention to these misconceptions. These questions were also embedded in the lesson plans. In order to eliminate these potential student-held misconceptions, the teacher gave detailed explanations and examples once the students’ answers had been received. The remaining sections were then treated in the same manner as explained here for the first section.

Data Analysis and Ethical Considerations

For the analysis of the quantitative data obtained from the research, non-parametric tests were performed using IBM’s SPSS program. Data from the ABCT’s pretest and posttest applications were analyzed by applying the Wilcoxon signed-sum test, which is the non-parametric equivalent of the dependent (paired) group t-test and is recommended for use in cases where the number of participants is less than 25 (Gravetter & Wallnau, 2015). In the analysis quantitative data generated from the CAS and AS applications, Wilcoxon signed-sum test was used in order to determine whether or not a statistically significant difference existed from before and after the application. Results from the concept questions, as another form of quantitative data collection, were presented separately for each subtitle by calculating the individual correct answer percentages of the students before and after the discussion.

The qualitative data obtained from the MOS, researcher observations, and semi-structured interviews were reviewed according to descriptive analysis techniques and coded using appropriate categories. Direct quotations from the study's semi-structured interviews were frequently selected to support interpretations and inferences and to facilitate the reader's interpretation of the results. In addition, the researcher-teacher analyzed the data by consulting with another researcher in the study, who was an expert in the area of peer instruction, for the purposes of consensus. Both qualitative and quantitative approaches were used together in the current research, which was designed within the framework of an action research study. It has been stated in the literature that inferences obtained based on the use of qualitative and quantitative methods together can be more explanatory and enlightening (McMillan & Schumacher, 1997). The data obtained from the quiz questions and researcher observation notes were evaluated as supportive and complementary to the data obtained with other data collection tools. Thus, data triangulation was attempted to be provided.

All students participating in the study were administered the same peer instruction practices under the same conditions and by the same teacher. The researcher-teacher made the application and observations without prejudice, to the best of their knowledge. The participating students had not previously been taught with the peer instruction method. Six volunteer students were selected for the semi-structured interviews, and attention was paid to the interviews being conducted during the week following the end of the application in order to ensure the students' retention of information about the application and its process. The collected data were evaluated according to both positive and negative results in terms of dependability. The findings obtained from the theoretical framework were compared with the findings of similar studies from the current literature. The current research study was conducted according to the permission received from the researchers' university ethics committee. In addition, the students' parents were duly informed about the nature of the study, and parental permission and student participation forms were collected prior to commencement of the application. While presenting the data, in place of the participants' real names being used, pseudonym participant codes of S1, S2… were used instead.

Findings

Effect of Peer Instruction on Academic Achievement

According to the results of the ABCT's application, a statistically significant difference was found to exist between the students' pretest and posttest scores ($z = -4.020$, $p < 0.05$). It was determined that the students' pretest

Table 2. Wilcoxon Test Results.

	Ranks	n	z	p
Pretest-posttest scores	Negative Ranks	0a	-4.020	0.000
	Positive Ranks	21b		
	Ties	0c		
	Total	21		

a. Posttest Score < Pretest Score
b. Posttest Score > Pretest Score
c. Posttest Score = Pretest Score

Table 3. Misconception Analysis Results.

Misconception*		Pretest %	Posttest %
1	For a substance to be acidic, it must contain H in its structure.	85.7	52.4
2	Misrecognition of the definition of the concept of amphoterism.	81.0	38.1
3	Misconception about the arrangement of ions or molecules at the molecular level in acid-base solutions.	57.1	42.8
4	In titrations, if either acid or base is weak, neutralization does not occur completely.	71.4	28.6
5	KW value is always equal to 1.0 x 10-14	28.6	0.0
6	The expression KW = $[H]^+ \times [OH]^-$ is valid only for pure water.	76.2	28.6
7	Acidic solutions do not contain OH^- ions.	19.0	0.0
8	Acidity strength depends on the number of hydrogens in the substance, and the basicity strength depends on the number of hydroxides in the substance.	90.5	90.5
9	Concentration is a measure of acidity or basicity strength.	14.3	4.8
10	Equivalence point and turning point are the same thing.	90.5	38.1
11	All solutions have the same pH value at the equivalence point.	76.2	4.8
12	All acid-base titrations form neutral solutions at the end point.	57.1	23.8

*Includes misconceptions with a prevalence of more than 10%.

score average was 10.10 out of a possible 30 points, and that the posttest score average was 19.52. The Wilcoxon test results are presented in **Table 2**.

From the Wilcoxon signed-sum test, the difference between the mean scores was revealed as being statistically significant, with the difference in favor of the posttest. In other words, the academic achievement levels of the students had increased significantly by the end of the implementation.

Effect of Peer Instruction on Conceptual Learning

Table 3 presents the students' misconceptions based on data analyzed from the ABCT application, which was prepared considering well-known misconceptions on the subject, and applied both as a pretest and a posttest.

According to **Table 3**, there was a significant improvement seen in eliminating misconceptions that the students held prior to the application, except for one (misconception 8). The following question tests this misconception:

Which of the following is a weak acid?

- H_2SO_4
- H_3PO_4
- HNO_3
- $HClO_4$

Considering the answers given by the students to this question, it was determined that 15 of the students chose option D in both their pretest and posttest, and that a high percentage (90.5%) of the students held this misconception in both test applications. It was concluded that the students continued to associate the acidic strength in direct proportion to the number of hydrogens in the substance at the end of the implementation. Since both H_2SO_4 and HNO_3 are acids that are frequently given as examples in both the students' resources and lectures, it is notable that of the students who selected option B or D, option B (H_3PO_4) was preferred as the strong acid, which has a high hydrogen number.

Table 3 shows that there was significant elimination of eight misconceptions based on comparing the students' posttest scores to their pretest (misconceptions 1, 2, 4, 6, 9, 10, 11, and 12) and that some were completely eliminated (misconceptions 7 and 5). However, despite this change, it can be seen that some of the students' misconceptions persisted even after the study application (misconceptions 3 and 8) and that these were quite resistant to change. Based on the answer given to the question in which misconceptions 1 and 7 were tested, it was understood that the students did not consider Lewis acids when considering acids. Teaching a large part of the acid-base unit on the basis of the Brønsted-Lowry theory and usually giving the examples of known acids and bases may have been affective in the formation of these misconceptions.

Specific to misconception 2, it was determined that there were seven students who thought that a substance could not act as both a Bronsted-Lowry acid and a Bronsted-Lowry base in both their pretest and posttest responses. In the question regarding misconception 4, the students are required to know in which forms ethanol and hydrogen chloride exist in aqueous solutions; however, the findings revealed that the students were unable to sufficiently visualize the dissolution of ethanol and hydrogen chloride in water at the molecular level. There was a significant improvement seen for misconception 4, but following the application, six students still thought that a strong acid could not be completely neutralized with a weak base. The results for misconception 5 revealed that the majority of the students understood that the value of K_W changes at different temperatures and thus the pH values of pure water can also change. For misconception 6, following the application, most of the students understood that the expression $K_W = [H]^+$.

Table 4. Findings of Concept Questions.

Topic	Concept Question	Pre-Discussion Answers (%)		Post-Discussion Answers (%)	
		True	False	True	False
Acid-Base Theories	1.	85.7	14.3	100.0	0.0
	2.	71.4	28.6	85.7	14.3
	3.	95.2	4.8	-	-
	4.	95.2	4.8	-	-
	5.	90.5	9.5	-	-
	6.	90.5	9.5	-	-
	7.	81.0	19.0	90.5	9.5
	8.	90.5	9.5	-	-
Properties of Acid-Bases and pH Scale	1.	85.7	14.3	100.0	0.0
	2.	71.4	28.6	81.0	19.0
	3.	23.8	76.2	57.7	42.3
	4.	71.4	28.6	95.2	4.8
	5.	95.2	4.8	-	-
	6.	66.7	33.3	90.5	9.5
Strong/Weak Acids and Bases	1.	66.7	33.3	90.5	9.5
	2.	85.7	14.3	100.0	0.0
	3.	76.2	23.8	85.7	14.3
	4.	81.0	19.0	100.0	0.0
	5.	76.2	23.8	95.2	4.8
	6.	52.4	47.6	66.7	33.3
Acid-Base Calculations	1.	33.3	66.7	61.9	38.1
	2.	81.0	19.0	95.2	4.8
	3.	76.2	23.8	100.0	0.0
Ka, Kb Values for Conjugated Acid-Base Pairs, Relationship of Kw Value with Temp., pKa, pKb	1.	66.7	33.3	95.2	4.8
	2.	81.0	19.0	100.0	0.0
	3.	23.8	76.2	90.5	9.5
	4.	76.2	23.8	100.0	0.0
	5.	95.2	4.8	-	-
	6.	85.7	14.3	95.2	4.8
Buffer Solutions	1.	42.9	57.1	95.2	4.8
	2.	61.9	38.1	71.4	28.6
	3.	90.5	9.5	-	-
	4.	33.3	66.7	90.5	9.5
Salt Hydrolysis	1.	52.4	47.6	100.0	0.0
	2.	14.3	85.7	71.4	28.6
	3.	76.2	23.8	95.2	4.8
pH Curves	1.	57.2	42.8	95.2	4.8
	2.	38.1	61.9	61.9	38.1
	3.	57.2	43.8	100.0	0.0
	4.	61.9	38.1	100.0	0.0
Indicators	1.	57.2	42.8	71.4	28.6
	2.	61.9	38.1	81.0	19.0
	3.	66.7	33.3	100.0	0.0
	4.	85.7	14.3	100.0	0.0
	5.	76.2	23.8	95.2	4.8
	6.	66.7	33.3	95.2	4.8

$[OH]^-$ was valid not only for pure water but for all aqueous solutions. Regarding misconception 9, it appears that the students ignored the need to understand the solution concentrations whilst comparing acidic strengths using the solution pH values. In addition, an unlisted (additional) misconception was also identified, that "acids in solutions with lower pH, are stronger."

A significant improvement was seen regarding misconception 10, although eight of the students still held this same misconception even after having received the instruction. Both the pretest and posttest results for misconception 11 showed that the students understood that the pH values at the equivalence point can change according to the strengths of neutralized acids and bases. Finally, although there was a noticeable improvement between the pretest and posttest scores regarding misconception 12, five of the students who selected incorrect options following the application failed to understand that the pH value at the equivalence point should be less than 7 at the end of a weak base-strong acid titration.

Effect of Peer Discussions on Understanding the Subject

Table 4 presents the percentages of the students' correct and incorrect answers for the concept questions for each subtitle, with both their first individual answers (pre-discussion) and the again after the peer discussion activity. In questions where the students' individual answers were correct by 90% or more, no discussion was held, hence no post-discussion percentages are shown.

According to **Table 4**, when the percentages of incorrect first individual answers are compared with the incorrect answers determined after the discussion, it can be seen that a significant improvement exists for those questions that were discussed. In some cases, although there was a notable improvement in the students' individual answers to the concept questions after the discussion, where this improvement still failed to meet the desired level, new tests were conducted with different concept questions after having been explained in detail. When the answers given to these concept questions asked based on new tests were examined after the discussion, it can be seen that the percentage of incorrect answers was 10% or below.

Effect of Peer Instruction on Attitudes towards Chemistry

Since the scores obtained from the Chemistry Attitude Scale did not show normal distribution, the Wilcoxon signed-sum test was employed. The analysis results showed that there was no statistically significant difference be-

Table 5. Wilcoxon Test Results.

	Ranks	n	z	p
Pretest-Posttest test scores	Negative Ranks	7a	-1.008	0.313
	Positive Ranks	13b		
	Ties	1c		
	Total	21		

a. Posttest Score < Pretest Score
b. Posttest Score > Pretest Score
c. Posttest Score = Pretest Score

Table 6. Wilcoxon Test Results.

	Ranks	n	z	p
Pretest-Posttest scores	Negative Ranks	4a	-1.874	0.061
	Positive Ranks	14b		
	Ties	3c		
	Total	21		

a. Posttest Score < Pretest Score
b. Posttest Score > Pretest Score
c. Posttest Score = Pretest Score

tween the students' pretest and posttest mean scores ($z = -1.008$, $p < 0.313$). According to the descriptive results, the students' pretest mean score was 54.19 out of a possible 75, whilst the posttest mean score was 57.48. The Wilcoxon test results are presented in **Table 5**.

According to **Table 5**, the difference between the mean scores was not found to be statistically significant according to the results of the Wilcoxon signed-sum test. However, as can be seen, the posttest means score was higher than that of the pretest.

Effect of Peer Instruction on Attitudes towards Argument

It was determined that the Argumentativeness Scale data did not show a normal distribution, and therefore the Wilcoxon signed-sum test was applied. The analysis results revealed that there was no statistically significant difference found between the students' pretest and posttest scores ($z = -1.874$, $p < 0.061$). According to the descriptive results, the students' pretest mean score was 70.3 out of a possible 100, whilst the posttest mean score was 76.0. The Wilcoxon test results are presented in **Table 6**.

Table 7. Attitudes and Opinions of Students Towards Peer Instruction.

Question	Excerpts from the students' responses	f	%
How did the peer instruction teaching method used for acids and bases affect your interest in the course?	"My interest in the lesson increased." "It helped reinforce the subject, increased my motivation, and helped me see my mistakes.", "It made the lesson more efficient."	21	100.0
How would you compare the way in which the acids and bases topic was handled in this course with the way that other topics were handled in terms of your understanding of the subject?	"It was more effective than the way other subjects are handled in terms of understanding the subject." "I understood the subject better this way." "It saves time."	17	81.0
	"There was no perceived difference between the methods."	4	19.0
How did the way the acids and bases topic was handled affect your participation in the course?	"It positively affected my participation in the course."	19	90.4
	"It did not affect my participation."	1	4.8
	"It reduced my participation."	1	4.8
Did the classroom peer discussions have any impact on your understanding of the acids and bases topic?	"The discussions helped me understand the topic better, added a different dimension and perspective to the way I learned the topic, and increased the permanence of my learning."	19	90.4
	"It didn't have any effect on my understanding of the subject."	2	9.6
Were the reading quizzes considered as helpful?	"It was helpful."	14	66.7
	"Its contribution was limited."	4	19.0
	"It didn't help."	3	14.3
Did the way the acids and bases topic was handled make you enjoy classroom discussions?	"The discussions held during the course were effective and productive, and for this reason, I participated in the discussions with pleasure, realized any mistakes I had made through discussing with my peers, and had the opportunity to see different perspectives from these discussions."	17	81.0
	"No, it did not make me like [the subject]."	4	19.0
Did you find that the reading assignments for the acids and bases topic useful to your learning of the subject?	"I found the reading assignments to be useful since when we arrived at the lesson, we already had an idea about the subject, which increased our participation in the lesson."	15	71.4
	"It partially helped my learning."	4	19.0
	"I don't think it helped."	2	9.6

According to **Table 6**, it was determined that the difference between the students' Argumentativeness Scale pretest and posttest scores was not statistically significant. However, the posttest means score of the students was found to be higher than the pretest mean score.

Students' Attitudes and Opinions towards Peer Instruction

Table 7 presents the seven questions about the attitudes and opinions of the students towards the peer instruction method together with excerpts from their answers. According to the results, the students considered that peer instruction helped to increase their motivation. Those students who answered that there was no difference between the traditional and peer instruction methods considered that they had the opportunity to reinforce what they had learned, and that although this helped in their success, it did not change their level of understanding of the subject. Except for one student, all of the participants stated that the teaching of the acids and bases subject using peer instruction had positively affected their participation in the lessons. One student who responded negatively determined that their motivation sometimes decreased whilst waiting for the questions to be asked. It was observed that students responded positively when questioned about the effect of peer discussions being held in the classroom regarding their understanding of acids and bases. Two of the students stated that the discussions had no effect on their understanding of the subject, and mentioned that they preferred not to change their answers post-discussion where they were still unsure about their answers.

A small number of the participants indicated that the contribution of the reading quizzes was limited or none, and that, in addition, these tests created unnecessary stress for the students. Those students who found the tests to be of no benefit also stated that it was difficult to solve questions in situations that required them to provide detailed information. These results show that reading quizzes positively impacted the majority of the participating students as a pre-lesson preparation tool.

Most of the students stated that the discussions held as part of their course were effective and productive. On the other hand, those who negatively responded did so with simple, short answers such as “no, it [the discussion] didn’t make them like it [presumably, the subject]” without elaborating with any further explanation. The majority of the students found the reading assignments they were given to complete before the lessons were prepared in a way that was useful to the learning of the subject. A few of the students considered the reading assignments to be of limited benefit, and stated that they were seen as useful in terms of attending lessons already prepared, but that they were insufficient in terms of fully understanding the main concepts of the subject. Those participants who did not find the reading assignments to be useful did not consider that the subject could be understood through reading unless a teacher then also explained the subject.

Semi-Structured Interview Findings

Opinions about the Peer Instruction Method

It was determined that the answers given by the students to the seven semi-structured interview questions about the peer instruction method coincided with their explanations given in the Method Opinion Scale, and that they were mostly positive.

From the analysis of the answers given to the question about the advantages of teaching with peer instruction, the students said that they felt they understood the subject better, participated more in the lessons, were able to appreciate different ideas and perspectives, take note of and correct their own mistakes during the discussions, arrive at the lesson more prepared, and that it reinforced their understanding of the topic.

With regards to any disadvantages of teaching with the peer instruction method, the students did not express much in the way of negativity, although they did identify certain disadvantages; that peer discussions can sometimes get tough, the application takes longer, concept test questions can be difficult, leading to the thought that some students would not be able to learn the topic.

The interviewed students responded positively when asked, “How did the peer instruction teaching method used for acids and bases affect your interest in the course?” They mentioned that their interest level increased, that they were more motivated during the lessons, and that the discussions were enjoyable.

The concept test questions projected on to the whiteboard were considered by the students to be useful in terms of learning the subject. These questions were found to be effective in terms of understanding the subject, and that they were thought-provoking and positive in terms of increasing the permanence of the topic being taught.

It was indicated that discussing the concept test questions with their peers had a positive effect on the students’ learning. The students’ responses of the relevant semi-structured interview question revealed that they were able to comprehend the topic better through seeing different perspectives, that they were able to express themselves better, that their answers were attempted to be attributed to a reason, and that the discussions led the students to think more deeply and increased the permanence of the subject in their minds.

All but one of the interviewed students stated that the application of peer instruction for other chemistry topics could also be effective and beneficial. They also mentioned that the method provided them with the opportunity to participate in the lesson more actively and to correct their mistakes promptly. On the other hand, one student stated that the effectiveness of the method may differ from one topic to another.

The last of the seven questions posed during the first part of the semi-structured interview examined the effect of reading quizzes on the students’ learning of the topic. All of the students stated that the quizzes had a positive effect on their learning, that they had understood the basic points of the topic, which points they needed to study more carefully, and that they came to the lesson with a better idea about the topic and thereby felt more prepared.

Misconceptions about Acids and Bases

The 10 questions that formed the second part of the semi-structured interviews attempted to determine the students' level of understanding of the concepts related to the acids and bases topic that was being taught.

When the students were asked "How do you define acids and bases?" it was seen that five students defined acids and bases according to the Bronsted-Lowry theory, which was a correct means of definition. Two of the students stated that it could be defined according to three theories, with one student correctly remembering the Arrhenius theory. All of the students made definitions according to Lewis's theory, and that only one student remembered this theory incorrectly. An example of one student's answer is as follows:

We defined acids and bases according to three theories. Let's start with Arrhenius first; acids give hydrogen ions when dissolved in water, while bases give hydroxide ions. According to Bronsted-Lowry, acids donate protons and bases accept protons. According to Lewis, acids are electron pair acceptors and bases are electron pair donors. [S4]

The students were then asked, "What can be said about the acidity-basicity of water?" When their answers were examined, it was seen that the students first answered that water was neutral. Five of the students correctly mentioned the amphoteric property of water, stating that it can act as an acid or a base against different substances. One of the students said that, "Since the acid concentration in lakes can increase due to acid rain, these waters are called acidic" (S2), which was incorrect. On the other hand, concerning the question about the acidity-basicity of $Al(OH)_3$, all of the students responded that the material would also exhibit amphoteric properties since Al metal is amphoteric. An example of a student's answer to this question, together with their interaction with the teacher, is as follows:

The Kw value of the water is 10^{-14}. This indicates that the water is neutral because its pH and pOH values are 7. [S1]

Can't water act as an acid or a base? [Teacher]

We can decide this according to the substance with which water reacts. For example, if we compare it with HCl, water becomes a base, if we compare it with NaOH, water becomes an acid. It is amphoteric. [S1]

What can you say about the acidity-basicity of $Al(OH)_3$? [Teacher]

It is also an amphoteric substance; it can show both acidic and basic properties. Al(OH)3 may appear as a base but it can behave as an acid in reaction with NaOH. [S1]

With regards to the question, “What do you understand by the strength of acidity-basicity?” four of the students answered correctly. One student attempted to explain the question with Ka-Kb, pKa-pKb values, and the researcher asked a second question to further probe the student’s understanding, and although the students offered a correct explanation the expected answer was not obtained. Another student first tried to answer the question using the concept of pH, but gave the wrong answer to the researcher’s second question. However, the correct answer was given when the researcher asked for a new explanation using a third question that included a clue (as follows):

We can explain it by the concentration of H^+ or OH^- ions that an acid or base contains. As the H^+ ion increases, the pH value decreases and we consider this as a stronger acid. The opposite is true for bases. [S2]

How would you explain the concept of strong acid vs. weak acid? [Teacher]

By neutralization reactions. For example, if we can neutralize a strong base only with a strong acid, it is called a strong acid. If the base is weak, the neutralized acid is called a weak acid. [S2]

Can we explain it according to their dissociation in water? [Teacher]

If it is completely ionized in water, it is considered as a strong acid or base, while if it is partially ionized, it is called a weak acid-base. So we look at the degree of ionization in the water. [S2]

The students were then asked “Can you compare the pH values of pure water at 25°C with pure water at 100°C?” All of the students responded that the pH values of pure water would differ at the two temperatures. Two of the students incorrectly answered, having stated that the pH value of pure water at 100℃ would be greater than 7 and would show basic properties. Other students correctly answered, saying that the H^+ and OH^- concentrations would be equal in pure water at different temperatures, that the pH value would decrease at high temperatures, but pure water would be neutral at all temperatures. An example of one of the student’s response is as follows:

We can say that they are both neutral, but we cannot say that the pH values of both are the same. This is because, as the temperature increases, *the H^+ and OH^- concentrations also increase. While these values are 10-7 at 25°C, and let's say 10-6 at 100 ℃, then the pH value of the water will be 6. [S3]*

What can be said about the acidity-basicity of water at these temperatures? [Teacher]

Water is neutral at both temperatures, but the pH values will differ. [S3]

From the question, "How can the change in the pH value at the equivalence point be explained according to the acid-base strength used in the titration? (give examples)," two of the students stated that since strong acids are fully ionized and weak bases are partially ionized, the pH is less than 7 at the equivalence point of their titration. Another student stated that since the initial pH of strong and weak acids differs, titrations with the same base will result in a different pH at the equivalence point. The researcher then asked, "Can you explain that in another way?" to which four students stated that there would be salt hydrolysis, but only one student gave the correct explanation. An example dialogue is as follows:

When weak acids or weak bases are titrated with a strong acid–strong base, the pH value will be different from 7 at the equivalence point. The salt formed is either acidic or basic. [S6]

How would you explain that? [Teacher]

For example, in acidic salt, conjugate acid of the weak base is present. In its reaction with water, H^+ is formed. Salt hydrolysis occurs. [S6]

The students were then asked, "Can you draw the NaOH–CH_3COOH titration graph?" and it was determined that six students drew the correct graph in response. Their graphs showed the approximately correct pH values at the start, end, and equivalence points, and were accepted as correct. The students showed that the initial pH of acetic acid was 3-5 since it is a weak acid, with a pH at the end of the titration of 12-13 since NaOH is a strong base, and the pH at the equivalence point was greater than 7. In addition, the students were asked to choose an indicator for this titration, and it was observed that all of the students chose the correct indicator in the appropriate pH range.

Next, the students were asked, "Can you show the variation of hydroxide and hydrogen ions in a solution with respect to each other on a graph?" Four of the students drew a correct graph, showing that the amounts of H^+ and OH^- ions changed inversely proportional to each other, but that the concentration of either could not be 0, while two of the students failed to provide the correct response.

The students were also asked, “What can be said about the acidity–basicity of sodium acetate and ammonium chloride salt?” It was seen that five of the students classified the two salts correctly, whilst one student failed to make the correct classification. The students were additionally required to explain their answers using reaction equations, with three students providing the correct equations. However, three other students wrote down the ionization of these salts in water, but could not remember the hydrolysis reaction of the ions from a weak acid–weak base with water. An example answer is as follows:

The solution of sodium acetate salt becomes basic. This is because the salt is formed from the reaction of a weak acid such as acetic acid and a strong base such as sodium hydroxide. When dissolved in water, it decomposes into acetate and sodium ions. OH^- ions are formed from the reaction of acetate ion with water, which makes the solution basic. Ammonium chloride is an acidic salt. H^+ ions are formed from the reaction of the ammonium ion with water, making the solution acidic. [S4]

Next, there followed a question, “How do you prepare a solution that can resist pH change?” All of the students knew that a buffer solution should be prepared in order for a solution to be resistant to pH change and they also correctly stated the components of a buffer solution. The teacher then asked, “How does it resist pH change when we add a small amount of strong acid to a buffer solution?” It was determined that five of the students answered the question correctly, whilst one could not provide the correct explanation. The following is an example response:

Buffer solutions can show resistance to pH changes, and these can be prepared by mixing a weak acid and its salt or a weak base and its salt. [S6]

How does the buffer resist the pH change when we add a small amount of strong acid to the solution? [Teacher]

There is a weak acid and its conjugate base in the solution. This conjugate base neutralizes it by reacting with the added acid. [S6]

Finally, the students were asked, “Can you explain using equations how an acid-base indicator gets different colors at different pH values?” Five of the students gave the correct answer, whilst one student was unable to provide an answer to the question. It was observed that the students who answered correctly also wrote the desired reaction equation as $HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$, and added that the weak acid indicators and their conjugate bases gave different colors. An example of the students' answers is as follows:

Colors change according to the change in the concentrations of a weak acid indicator and its conjugate base in a solution. Since the HIn concentration will increase when acid is added, the color it gives becomes more dominant and this is the color that we see. [S5]

Observation Findings

From the researcher's observations, it was noted that the teacher did not talk all the time during the lessons and that the students were afforded the opportunity to discuss topics among themselves which contributed considerably to their active participation in the lessons. It was also noted that those students who willingly participated in the peer discussions when solving the concept questions tried to persuade each other by giving different examples. The students participated in the discussions from the beginning to the end of the lessons, and appeared to easily ask questions that they may have otherwise been afraid to ask their teacher directly. However, it was also observed that some of the students, albeit limited in number, avoided taking part in any classroom peer discussion, particularly during the initial weeks of the application.

It was observed that some of the students completed their reading assignment homework by preparing a summary, whist others only read the relevant section. It was also noted that those students who prepared a summary were able to grasp the subject more quickly and that they participated in the lessons more willingly. The teacher walked among the students during the peer discussions, and noted that those students who understood the concepts well seemed openly willing to explain their opinions to their peers.

It was notably only very rarely observed that students whose first individual answer was correct changed their answers following a peer discussion. The case of students holding on to an incorrect answer and not changing it following a peer discussion was also not observed very frequently. It was observed, however, that the students thought longer about and made reasoning for those concept questions that were asked in the form of "…which or which ones are true?"

Conclusion and Discussion

In order to measure the effect of the peer instruction method on the academic achievement levels of the participant students, the Acids-Bases Concept Test was developed and used as both a pretest and posttest. When the ABCT results were analyzed, it was determined that the students' academic success had increased significantly. These findings are also consistent with similar studies from the literature, e.g., Crouch and Mazur (2001), James (2006), Lasry et al. (2008, 2016), Perez et al. (2010), Schell and Butler (2018), and Zingaro and Porter (2014). It can be said that the students' active participation in the lesson by solving the concept test questions, discussing them with their peers, and having the opportunity to reevaluate any elements of the concepts that they did not understand based on their peers' ideas was seen to positively affect their academic achievement levels. The researcher-teacher observed that the concept questions seemed quite challenging for the students to answer, leading them to think more deeply. However, the peer discussions regarding these questions were seen to positively affect the permanence of the knowledge they gained. These results also are consistent with data obtained from the students' semi-structured interviews. In addition, it was considered that the students arrived at their classes having already become familiarized with the topic that would be studied due to their reading assignments and follow-up reading quizzes, which made it easier for the students to understand the topic of study.

During the in-class peer discussions, the teacher participated by walking around the class, helping the students to think more deeply and discuss the appropriate concepts, to move discussions in the right direction by asking crucial questions where they had become stalled, and to provide the students with clues that effectively drew demotivated groups back into the discussion. It may be said that these factors also positively affected the academic achievement level of the participant students. Turpen and Finkelstein (2009) obtained similar results from research undertaken at the University of Colorado, in which they observed the practices of six physics instructors who taught using the peer instruction method within the same department. The authors stated that in classes where the student-teacher interaction was high, the students participated in their lessons more willingly, and not only answered the questions correctly but also expressed their reasoning more clearly.

It has been frequently stated in the literature that conceptual learning directly affects academic success (Petres, 2008). In terms of the current study, a significant increase was observed in the conceptual learning levels of the participant students, with visible improvement noted in the resolving of misconceptions in parallel with their increased academic achievement. However, it has also been frequently stated that special teaching methods are required to reduce or eradicate learners' misconceptions, and that traditional teaching methods are deemed insufficient to achieve this outcome (Kaya, 2011; Schmidt, 1997). Connected to this, in research by both Lasry et al. (2013) and Zhang et al. (2017), it was reported that peer instruction practices help improve students' conceptual learning levels.

As can be seen in **Table 4**, upon comparing the percentages of individual correct answers given by the participant students to the concept questions before and after the discussions, a significant increase was observed after the peer discussion had taken place. The researcher-teacher also observed that the students made greater efforts to understand the concepts by extending their mental activities across a larger part of each lesson, along with working on the solution of concept questions and peer discussions during the lessons. Additionally, the answers given by the students to the semi-structured interview questions notably coincided with these same observations. As stated in the literature, scientific discussion undertaken during lessons can positively affect students' conceptual learning (Erduran et al., 2004; Naylor et al., 2007). As an example that supports this finding, the percentages of correct answers given by the students in the current study to the second concept question in the seventh subtitle (see as follows) before and after the peer discussions are presented:

Which salts will dissolve in water to give solutions with a pH above 7?

I. Na_2CO_3
II. CH_3COONa
III. Na_2SO_4

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

It was determined that the majority of the participant students answered this question incorrectly prior to their peer discussions (three answered correctly, 18 were incorrect). However, after the discussions, there was a remarkable improvement noted with 15 of the students choosing the correct option (D), and the number of students who answered incorrectly correspondingly decreased from 18 down to six. At this point, it can be seen from their individual answers prior to the discussion that the students thought that SO_4^{2-} ion does not result in a hydrolysis reaction with water since it comes from a strong acid. In fact, although it is accepted that this ion does not undergo hydrolysis with water, by making rough assumptions as seen in many classroom textbooks, students may think sensitively and in greater detail during peer discussions and come to realize that SO_4^{2-} ion has a Kb value and conjugate base of HSO_4^- ion, and therefore may undergo hydrolysis with water. This demonstrates how the students' discussions significantly affected their understanding of the subject, and that this interaction should be considered an important factor in the structuring of student knowledge (Tullis, 2018). It was observed by the researcher-teacher that the students appeared to easily ask questions to their peers during these discussions which they would perhaps otherwise have been reticent to ask their teachers or would not have felt the need to ask. The written answers provided by the students to the questions in the Method Opinion Scale also coincided with these observations. In addition, the students received instant feedback from their peers or teachers during the discussions. Self-evaluations made in this way are deemed important since students gain the opportunity to review any points that they may have previously misunderstood (Kirschner et al., 2015).

According to Piaget, an individual's effective learning is possible with a dynamic balance that should take place between the dimensions of assimilation and regulation (Fosnot & Perry, 2005). The emergence and sustainability of this balance seems more possible with the creation of learning environments that increase the individual's intrinsic motivation and where they can be actively involved (McKeachie, 2002). The observations made by the teacher during the practice in the current study show that the learning environments in which the peer instruction method was applied conformed to this definition.

Students' attitudes towards a course are one factor that can affect their academic success (Schibeci, 1984). It is thought that students who have a positive attitude towards a course will have higher intrinsic motivation, and that this may affect their academic success. When the effect of peer instruction on students' attitudes towards chemistry was examined in the current study, it was seen that no statistically significant difference existed between the pretest and posttest mean scores of the Chemistry Attitude Scale, although the posttest mean score was shown to be higher. In addition, when this finding was evaluated together with the results of the Method Opinion Scale, an improvement was noted in the students' attitudes. The findings revealed that all 21 of the participant students stated that the application conducted with peer instruction increased their interest in the lesson, helped to reinforce their learning, was a source of motivation, helped them see their own mistakes, kept their interest fresh, and made the lesson more productive. The observations made by the teacher during the lessons also supported this noted improvement in the students' attitudes towards their lessons. It may therefore be said that a clear relationship exists between positive developments in student attitude towards their lessons and the peer instruction method (Zhang et al., 2017). The first two questions of the semi-structured interviews also examined the participant students' opinions towards peer instruction. When the students' responses to these questions were examined, it was seen that they were mostly positive and considered the method to be useful in their learning. In addition, the teacher observed that some of the students who were initially hesitant when the application started, increasingly adopted the method as the course progressed, and more willingly participated in the lessons.

Discussion has been described as an opportunity for teachers to observe students' misconceptions and their communication skills, and to then provide appropriate feedback (Arends, 2007). Discussion within the classroom environment can be used to develop students' thinking and problem-solving skills by creating a learning environment in which they can actively participate together through discussion, which is a known means of effective communication (Erduran & Jiménez-Aleixandre, 2008). Teaching methods that help students to enjoy discussion as a learning aid provide learners with importance opportunities to acquire a culture of discussion. In the current study, it was observed that the differences between the pretest and posttest scores of the Argumentativeness Scale were not statistically significant, although the mean posttest score was notably higher. In addition, considering the results obtained from the Method Opinion Scale, the majority of the participant students responded that their in-class discussions based on the peer instruction method were considered to be effective and productive, and therefore the students happily participated, came to realize their own mistakes during discussions with their peers, and had the opportunity to see different perspectives in problem solving. The teacher also observed that the students participated more willingly in discussions during lessons taught with peer instruction.

The study also determined that some students, albeit small in number, stated that the peer instruction method had not helped them in liking the concept of in-class discussion. The teacher observed that some students particularly avoided discussion in the lessons. Upon further examination, the teacher established that these same students also did not participate in discussions within other lessons either, preferring instead to remain silent, maintaining only limited social interaction with their peers, and were generally unwilling to talk in the classroom.

Limitations, Implications and Suggestions

The current study applied the peer instruction method over duration of 5 weeks. There are some opinions in the literature that this timeframe would be insufficient for behavioral changes to be observed in variables such as attitude since they require deep investigation, and that considerably more time than 5 weeks would be needed (Fernández, 2017). For this reason, it should be considered that more extensive results could be obtained with a longer-term study in order to observe clear changes in students' attitudes towards their course of study. It is therefore suggested that future studies in which changes in students' attitudes towards chemistry are to be observed should be conducted with peer instruction applications over an extended period of time.

The current study's application was limited to 21 participant 12th-grade students at a private high school in Turkey, where the first author was employed as a teacher. Whilst action research is predominantly conducted using small study groups, and considering that the researcher was also a practitioner, the current study was not aimed at generalizing results applicable to other group sizes or types (Johnson, 2014). Among the suggestions put forward by the current study is the use of experimental-control group research as an approach that can handle greater participant numbers, where the effectiveness of the method itself is scientifically measured, and where generalizable results can be obtained.

The current study is one of the first of its kind in Turkey to apply peer instruction as a teaching and learning method in high school chemistry lessons. The study showed that peer instruction was an applicable method, suitable as a personal teaching style, and that it may be used with other subjects and different teaching methods. This finding is also noted in the literature, with peer instruction considered a flexible method of teaching (Dancy et al., 2016). Based on the teacher's experience in the practical process itself during the current study, instruction could be given to students on how to answer reading quiz questions used to measure their level of reading assignment fulfillment. In addition, writing summaries or web-based assignments could be used in place of reading quizzes. In terms of the peer instruction method, careful preparation and planning should be undertaken prior to classroom lessons, and due attention paid to the preparation of lesson plans and concept questions that cover the whole teaching unit before the application takes place. During peer discussion, the teacher should circulate among the students in order to check that their discussions are being conducted in accordance with the intended purpose. Through the development of activities to introduce peer instruction as a method that can be used by teachers, it should be ensured that they gain the requisite knowledge and skills regarding the application of this method. As such, similar studies could be conducted in the future that examine the effectiveness of peer instruction in the teaching of other chemistry topics.

It may be said that the current study will act as a useful resource for teachers wanting to learn about peer instruction as a method of teaching and its application for chemistry subjects in particular. It is considered that peer instruction is a teaching method that can provide teachers with opportunities to improve their classroom practices due to its effectiveness in terms of applicability without any additional cost being incurred or need for additional physical equipment.

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