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Using CBA REACT Strategy Supported by Crossword Puzzle Game on the Topic of Acid-Base Titrations

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ABSTRACT This research investigates the effect of the context-based approach (CBA) 'Relating-Experiencing-Applying-Cooperating- Transferring' (REACT) strategy supported with crossword puzzles on achieving the associate degree students in the chemistry laboratory course on the topic of acid-base titrations. A crossword puzzle game and four contexts related to daily life upon acid-base titrations were developed and applied within this context. This study is a pre-test post-test research design with a control group, and the study group consists of second-year students studying in the Vocational School of Health Services Medical Laboratory Techniques (MLT) (n = 65) and Pharmacy Services (PS) (n = 65) programs at Zonguldak in Turkey. The experimental group was taught the relevant topic by the CBA REACT strategy supported with a crossword puzzle game, whereas the control group was taught by the CBA REACT strategy. The study result showed that the experimental group students' sound and partial understandings and academic achievements were higher than the control group students.

Keywords Acid-base Titrations, Context-based Approach, Crossword Puzzle, Gamification, Laboratory Chemistry, REACT Strategy

1. INTRODUCTION

Acid-base titrations in the chemistry laboratory course is a topic that students have difficulty understanding since it contains many abstract concepts and complex calculations (Kousathana, Demerouti, & Tsaparlis, 2005; Treagust, Harrison, & Vennile, 1996; Ural & Gencoglan, 2020). Acid-base titrations, especially in chemistry laboratory courses of the undergraduate level and the associate degree (it is a higher education based on secondary education, covering four semesters and aiming to train intermediate human resources, that is, forming the first stage of undergraduate education), is a topic based on quantitative analysis such as determining the concentration, titration type, and pH of samples containing acidic-basic substances; also contains the sub-topics of amphoteric substances, buffer solutions, and hydrolysis of salts (Baldwin & Orgill, 2019; Orgill & Sutherland, 2008; Sheppard, 2006; Supatmi, Setiawan, & Rahmawati, 2019; Widarti, Permanasari, & Mulyani, 2017).

When the literature is examined, it is noteworthy that many studies are showing that students at all levels have misconceptions about the concepts mentioned above due to the complex structure of the acid-base titrations topic (Azid, Yi Shi, Saad, Che Man, & Mei Heong, 2022; Sheppard, 2006; Widarti et al., 2017; Ozmen & Yıldırım, 2005). In general, these misconceptions of students include the species found in the solution before the equivalence point, at the equivalence point, and after the equivalence point in the titration, pH calculations, pH calculations of buffer solutions, acid-base indicators, pH concept showing the strength of the acid solution, the calculation of the equilibrium constants of acidity and alkalinity, that concentrated acid and base solutions are strong and diluted acid-base solutions are weak, that neutralization is defined as the breakdown of acid rather than an acid-base reaction, the degree of ionization and the titration curve (Aini & Silfianah, 2022; Artdej, Ratanaroutai, Coll, & Thongpancang, 2010; Cartrette & Mayo, 2011; Cooper, Kouyoumdjian, & Underwood, 2016; Damanhuri, Treagust, Won, & Chandrasegaran, 2016; Mubarokah, Mulyani, & Indriyanti, 2018; Salame, Montero, & Eschweiler, 2022).

It is known that conventional teaching, widely used in the education process, is insufficient in eliminating these misconceptions (Ayvacı & Ucmak, 2022; Celikler & Kara, 2016; Costu, Ayas, & Unal, 2007; Johnstone, 2010). For

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this reason, teachers should develop and implement alternative teaching strategies in which students can actively participate in the activities to reduce, prevent and identify misconceptions (Johnstone, 2010; Lin Lai & Lee, 2022; Nahum, Mamlok-Naaman, Hofstein, & Taber, 2010). These active learning environments must be environments where students can think like a scientist, conduct research, make inferences by asking questions, and transfer the topic of acid-base titrations to real situations in daily life (Akgun, Tokur, & Duruk, 2016; Demircioglu, Ozmen, & Ayas, 2004; Ural & Gencoglan, 2020).

In daily life, there are acid-base and salt solutions in foods and cleaning products. These solutions especially play an essential role in biological activities in the body. For this reason, the fact that events related to these concepts are very common in our daily lives and especially because it is a topic that includes submicroscopic concepts in general makes it important for learners to learn this topic correctly and to associate it with daily life. In this context, it is thought that the use of a context-based approach (CBA) associated with real situations and puzzles and gamification of crossword puzzles in teaching the topic of acid-base titrations can prevent the formation of misconceptions, reduce students' anxiety, provide meaningful learning in a fun environment involving group work, and increase their success.

CBA is an educational approach that focuses on inquiry-based laboratory investigation. It enables a learning environment in which real-life situations are used for students to have meaningful learning of scientific concepts and topics, and students are responsible for their learning and requirements (Bennett, Lubben, & Hogarth, 2007; de Putter, Nieveen, Taconis, & Jochems, 2022; Dori, Avargil, Kohen, & Saar, 2018; Prins, Bulte, & Pilot, 2018). REACT strategy is the most used one of the implementation strategies of the approach and consists of the 'Relating', 'Experiencing', 'Applying', 'Cooperating', and 'Transferring' stages (Crawford, 2001; Demircioglu, Vural, & Demircioglu, 2012; Karsli & Yigit, 2017). When the literature was examined, it was seen that there are a limited number of studies in which CBA and CBA REACT strategy used, especially on the topic of acid-base titrations in chemistry courses. For instance, in their study, Febiana, Partana, Wiyarsi, & Sulistyo (2019) examined the applicability of the chemistry module developed in accordance with CBA to chemistry teachers, experts, and students. The study's feedback from teachers, experts, and program students showed that the developed and applied situation could be used effectively.

In their study, Baran and Sozbilir (2018) examined the effect of context- and problem-based learning (C-PBL) concerning thermodynamics on students' achievement in medical laboratory and techniques associate degree programs. It was concluded that C-PBL increased the students' achievement in thermodynamics.

Majid and Rohaeti (2018) examined the effect of CBA on secondary school students learning about acid bases in their study. It was concluded that CBA increased the achievement of students on acid bases.

In their study, Ultay and Calik (2016) examined the effects of different teaching strategies (REACT strategy, 5E learning model, and traditional teaching) for the topic of acid-base in chemistry courses on science teacher candidates' concepts. In the research, a case for acid rains has been developed, and it was concluded that the REACT strategy was effective in teacher candidates' retention of the concepts in their long-term memories. At the same time, the 5E learning model was influential on their conceptual learning.

However, crossword puzzles consist of squares filled with words/numbers, with one letter/number per square (Dand, 2008). Because the crossword puzzles are effective in both learning new concepts and evaluating learning (Berry & Miller, 2008; Mshayisa, 2020; Nicol, 2020; Yesari, 2018; Yuriev, Capuano, & Short, 2016), they are used to strengthen the memory of learners and facilitate the recall of words and increase their achievement and performance in the teaching-learning process (Agarwal, Singhal, & Yadav, 2020; Cardozo, Miranda, Moura, & Marcondes, 2016). For this reason, crossword puzzles are considered one of the alternative games in the learning-teaching process. Since learners' participation is vital in the learning process, games and gamification are very effective in creating a learning environment based on curiosity, enthusiasm, and discovery instead of a learning environment based on fear and anxiety (Burgaz Uskan & Bozkus, 2019; Simsek, 2007). Therefore, gamification refers to the use of game elements to improve learning concerning texts that may be unenjoyable for students and provides active learning environments that increase learners' motivation and willingness to learn and that support their social interactions (Byusa, Kampire, & Mwesigye, 2022; da Silva Junior et al., 2020; Kim et al., 2018; Nieto-Escamez & Roldan-Tapia, 2021; Stojanovska, 2020). Educators with different areas of expertise have been determined to benefit from quizzes, board games, card games, and crossword puzzles as games in the teaching process (Abdulmajed, Park, & Tekian, 2015; Pearson, 2020). Especially in the field of chemistry education, only a few studies in which digital games were used to examine the conceptual understanding of learners on acid-base and salts (Belova & Zowada, 2020; Harman & Yenikalaycı, 2020). However, there are studies on chemistry education in which crossword puzzles as games are used effectively in learning, ensuring that learners enjoy the lesson and develop problem-solving and social skills (Fakokunde, 2021; Stojanovska, 2020). For example, Pearson (2020) examined undergraduate pharmacy students' opinions concerning online crossword puzzles developed on heteroaromatic chemistry in his study. This study showed that the students found the crosswords helpful, and some students increased confidence and engagement.

Ajayi and Ogbeba (2020) investigated the effect of three-dimensional puzzle-based (crossword, word search, and logic puzzles) instructional strategy on the students' engagement and academic performance in chemistry in their study. It was revealed that a three-dimensional puzzle-based instructional strategy improved the students' engagement and academic performance.

Kara (2019) developed and applied an activity on the elements and periodic table in the secondary school level chemistry course in his study. The result of the study showed that the activity increased the students' achievement in learning the places, names, symbols, atomic numbers, and usage areas of the elements in the periodic table.

The study by Yuriev et al. (2016) examined the effect of puzzles on students' meaningful learning and problem-solving in undergraduate-level physicochemistry courses. It was concluded that puzzles develop students' learning and problem-solving skills.

Joag (2014) developed and applied puzzles related to periodic table elements in the introduction to secondary school chemistry course in his study. The study showed that puzzles increase students' learning of periodic table elements, properties, and places in the table.

1.1 The Purpose and Importance of the Study

In the associate degree programs of medical laboratory techniques (MLT) and pharmacy services (PS) in the health field, chemistry laboratory courses mainly include the topic of acid-base and titrations. Because of the acidic-basic properties of the samples or simple drugs that students will prepare or analyze, they must know whether they are strong or weak, whether they are a buffer solution, and whether they can make a volumetric analysis. In addition, students need to know and comment that the regulation of acid-base balance in the body depends on a versatile acid-base buffering mechanism in which blood, cells, lungs, and kidneys participate, which is necessary for the maintenance of normal hydrogen ion concentration in both extracellular and intracellular fluids; they also need to know and comment on the pH, pO2, pCO2 levels in fluids (Demirel, 2013; Guyton & Hall, 1996). In this context, acid-base titration is an important topic with many mathematical operations and experiments.

As seen in the literature review mentioned above, it is natural for students to have many misconceptions about a topic involving such submicroscopic concepts as abstract and complex mathematical calculations. It has been determined that conventional teaching is insufficient in reducing misconceptions and preventing their formation and that students learn and understand more effectively in active learning environments where they feel comfortable, have fun, can work collaboratively, make laboratory applications, and associate the topics with daily life (da Silva Junior et al., 2020; Nieto-Escamez & Rolden-Tapia, 2021; Romero, 2017). Therefore, in this study, the CBA REACT strategy and gamification of crossword puzzles could positively affect students' understanding and achievement by providing the specified active learning environment. Moreover, even though it is a relative situation, it is thought that a good understanding of the topics to be learned at an early stage can affect students' achievement, and this initial understanding can lead to future learning processes (Majid & Rohaeti, 2018; Thompson & Zamboanga, 2004).

In addition, limited studies use CBA and CBA REACT strategies on acid-base titrations when the literature review is examined. In addition, there is no study in the literature in which crossword puzzles are used for the relevant topic.

This study examined the effect of the CBA REACT strategy supported by crossword puzzles on the students' academic achievements on acid-base titrations. Therefore, the research questions of this research are given as follows.

1. Is there any significant difference between the experimental and control groups regarding academic achievement for acid-base titrations in the chemistry laboratory course?
2. Is there any significant difference between the pre-test and post-test academic achievement scores of the experimental group in the acid-base titrations topic in the chemistry laboratory course?
3. Is there any significant difference between the pre-test and post-test academic achievement scores of the control group in the acid-base titrations topic in the chemistry laboratory course?

2. METHOD

2.1 Settings and Participants

The study used a semi-experimental matched random research design (pre-test and post-test with a control group) (Robson, 2015). The study group consists of second-grade undergraduate students (ages between 19-21 years old) studying in the Vocational School of Health Services MLT (n = 65) and PS Programs (n = 65) of a state university (N = 130). Since students taking an applied chemistry course on acid-base titrations were selected in the study, the purposive sampling method was used to determine the study group. In the study, students were not randomly assigned to these groups. However, they were randomly selected by drawing lots from two existing programs (MLT and PS) to be the experimental (EG) and control groups (CG). Four pieces of paper containing the two programs' names and EG and CG were placed in separate boxes. Then, an independent researcher drew first the program name and then a piece of paper indicating the experimental or control group. As a result of the draw, MLT Program was selected as the EG, and PS Program was selected as the CG. The EG students were taught the acid-base titrations topic with the CBA REACT strategy supported with crossword puzzles, and the CG students were taught the topic with the CBA REACT strategy.

The students who will graduate from these programs can perform simple drug applications and fundamental chemical analysis in a laboratory environment. Students theoretically studied the properties of acid-bases and salts, properties of strong and weak acids/bases, pH calculations, the concepts of buffer solutions, and hydrolysis in their first-year chemistry courses. MLT program students learned the relevant topics in the fall semester of the first year in the Laboratory Instruments course, and PS program students learned the topics in the same semester in the General Chemistry course. When the grade point averages of the midterm and final exams on these courses were examined, it was determined that the average grades of the two classes were close (average grade point for MLT = 58.02; average grade point for PS = 61.66).

In this context, students of MLT within MLT 225 Laboratory Chemistry and PS Program students within PS 207 Pharmacy Services Applications Laboratory I course will perform acid-base titration types and pH calculations in practice. This application aims to teach students acid-base titration types and pH calculation, pH calculation of buffer solution, hydrolysis event, and titration curve for these titrations depending on the type of the medium. The ethics committee's permission for this research was obtained from the local ethics committee with protocol no: 686. In addition, the written informed consent forms were collected from the EG and CG students before the application.

2.2 Data Collection Tools

In the study, the Acid-Base Titration Applications Achievement Test (ABTAT), consisting of 20 open-ended questions on the topic of acid-base titrations, was developed by reviewing the relevant literature and taking expert opinions (Gunduz, 2008; Skoog, Holler, & West, 1996) (See App. 1). Question numbers related to specific subtopics are given in Table 1.

Since this study aimed at students learning these sub-topics, the questions concerning the developed contexts were not asked in the test. Therefore, the ABTAT is developed independently of the instructional team. The test was conducted as a pre-test and post-test to determine the achievement and understanding of the EG and CG students.

Open-ended questions in the test are among those asked within the scope of the chemistry laboratory course in MLT and PS Programs in previous years. In this context, the ABTAT was applied as a pilot test to sophomores who had previously taken the topic of acid-base titrations in the same programs in the spring semester (N = 145). Correct answers given by the students to open-ended questions (sound and partial understanding) "1 point"; wrong answers (misunderstanding, incomprehension, and unanswered) are scored as '0 points'. Item discrimination (r) and item difficulty (p) indices were calculated in data analysis. The average r-index was 0.75, the average p-index was 0.56, and the reliability coefficient of the test was 0.92.

2.3 Data Analysis

The analysis of the questions in the ABTAT was performed by content analysis. The questions in the test were classified and scored according to specific categories by two analytical chemists. The categories are sound understanding (SU), partial understanding (PU), misunderstanding (MU), incomprehension (IC), and unanswered (UA) (Nakiboglu & Nakiboglu, 2016) (Figure 1).

The highest score that can be obtained from the ABTAT is 60, and the lowest score is 0. The researcher read the students' answers to each question and coded them according to these categories. To ensure coding accuracy and reliability, 13 pre-test and 13 post-test samples were randomly selected and sent to a chemistry education expert. The researcher and the expert tried to convince each other by discussing the coding they disagreed on, and the researcher finalized this process. As a result of the expert opinion, pre-test and post-test agreement percentages were calculated as 0.95 and 0.90, respectively. In light of these data, it was determined that the reliability between the coders was at a valid level. It is stated that the consensus between the coders is expected to be at least 80% (Miles & Huberman, 1994). In addition, concerning the responses in the SU and PU categories, if the students only made some

Table 1 The subtopics and related question numbers of the ABTAT

Subtopics	Question Numbers
pH-pOH calculations of a weak acid	1
pH-pOH calculations of a weak base	16
pH-pOH calculations of basic and amphoteric salt	6, 7
pH-pOH calculations of a strong base	18
pH-pOH calculations in weak acid (monoprotic)-strong base titration and titration curve	2, 3, 4, 5
pH-pOH calculations in weak acid (diprotic)-strong base titration and titration curve	9, 10, 11, 12, 13, 14, 15
pH-pOH calculations in weak base-strong acid titration	17
H-pOH calculations in strong acid-strong base titration	19
The concentration of solute species in the titration of mixtures	8
Saponification number calculation	20

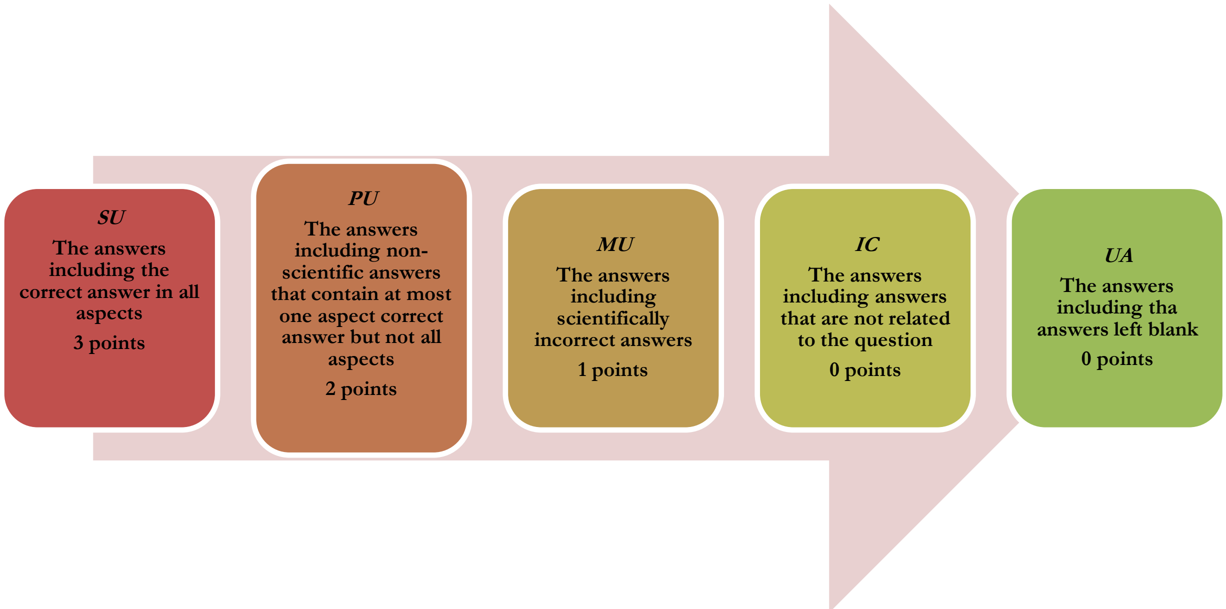

Figure 1 The categories and their explanations and scores

calculation errors but seemed to understand the problem, they were scored in the SU category.

Statistical analysis of all scores in ABTAT questions was done with the SPSS 19.0 package program. In order to determine which statistics to be used in the study, whether the academic achievement scores displayed a normal distribution was examined with the Kolmogorov-Smirnov Test. The Kolmogorov-Smirnov test results $p<.05$ showed that the score distributions did not exhibit a normal distribution. In this context, the Wilcoxon test was used to determine whether there was a significant difference within the groups in terms of pre-and post-test scores; while the Mann-Whitney U test was used to determine whether there was a significant difference between groups (Green & Salkind, 2003; Secer, 2015). In all statistical calculations, $p <.05$ results were considered statistically significant.

2.4 Creation and Application of Contexts

By reviewing the relevant literature and taking the opinions of two experts in the fields of chemistry education and analytical chemistry, four contexts titled 'I'm all balled up…', 'Two buddies' interesting chemistry assignment', 'Coral reefs are disappearing!', 'My hair is ace, get out of my face' concerning the topic of acid-base titrations has been developed (Gunduz, 2008; Skoog et al., 1996). The content of the contexts developed was the same as the subtopics in the ABTAT. In particular, contexts were developed in order to show how chemistry is used in daily life for the subtopics above in an exciting way and to carry out experiments through intragroup and intergroup discussions and brainstorming under the guidance of the instructor (de Putter et al., 2022; Dori et al., 2018). They were thus given in short narratives rather than long texts. Each stage of 'Relating', 'Experiencing', 'Applying', 'Cooperating', and 'Transferring' was carried out with the relevant contexts. The contexts are given in detail in App.2. Developed contexts, and their topics, aims, and experiments are explained in detail in Table 2.

The example of the application concerning the context of "Two Buddies' Interesting Chemistry Assignment" consisted of two sections following the CBA REACT strategy is given in Table 3.

2.5 Creation and Application of Crossword Puzzles

A crossword puzzle was developed by taking the opinions of two analytical chemists and based on the developed contexts (See App.3). The content of the puzzle is the same as the ABTAT and the subtopics of acid-base titration applications. In the crossword puzzle, the answers to the questions between 1-21 are in the horizontal rows, and the answers to questions 22-37 are in the vertical columns. There are both verbal and numerical questions within the puzzle. The answers to the numerical questions will be written in words. The developed puzzle is placed within a game. The game includes small colored cards with questions, dice, and a stop sign on the game board (Figure 2). The dice are used to determine the first person to start the game. In the step sign, steps are taken according to the number of letters of the known words. Different colors in some boxes in the puzzle show the number to be added to the number of letters of the known word and the number of steps is determined accordingly. Groups of 5 people play the game.

In this study, thirteen groups of EG students from groups of 5 played the first round of the game (40 minutes). Of the 13 winners at the end of the first round, three groups were formed from two groups of 5 people and one group of 3. These three groups played the second round (20 minutes). While these groups played this round, the other students in class supported their groupmates by

Table 2 The contexts, topics, aims, and experiments

Contexts	Topics	Aims	Experiments
I'm All Balled Up…	The context, which consisted of two sections, was based on a young girl who learns that the reason for her grandmother's fragrant and beautiful hair is that she uses soft soap, which she can make easily at home.	The students learn the chemical reaction of soap formation and its type, the differences between the formation of soft soap and white soap, the calculation of the saponification number, the calculation of pH and pOH of a strong base, and how to titrate a strong mono base with a strong monoacid.	The students carried out the white soap experiment at the 'Experiencing' stage in the first section, whereas they carried out the strong acid-strong base titration (hydrochloric acid 'HCl'- sodium hydroxide 'NaOH') experiment at the same stage in the second section.
Two Buddies' Interesting Chemistry Assignment	In this context, which consisted of two sections, two classmates were inspired by the movie 'The Mummy' to research the mummification process for their chemistry project. Their project was based on researching the bitumen substance and natron solution used in the mummification process and the formalin solution used in the autopsy process.	The students learn the pH-pOH calculation of a weak monoacid, the titration of a weak monoacid-strong mono base, the pH-pOH calculation of a basic salt and amphoteric salt, and the titration of mixtures.	A single experiment was performed in the 'Experiencing' stage for both sections. The students performed the weak monoacid-strong mono base (acetic acid 'CH3COOH'- sodium hydroxide 'NaOH') titration experiment under the guidance of their instructor.
Coral Reefs are Disappearing!	The context, consisting of three sections, was based on the fact that coral reefs are being destroyed due to acidification caused by global warming as the carbonate in their skeletal structures is converted into carbonic acid.	While the students solved questions about the titration of a weak monoacid with a strong mono base in the context of the 'Two buddies' interesting chemistry assignment' context, the aim was that they would solve questions about the titration of a weak diacid solution with a strong mono base solution and draw the titration curve in this context.	In the same way, the weak acid-strong base titration experiment, which was carried out in the context of the 'Two buddies' interesting chemistry assignment', was referred to again in the 'Experiencing' stage. In addition, the students were informed about the difference between weak monoacid-strong monobase titration and weak diacid-strong monobase titration.
My Hair is Ace, Get out of My Face!	The context, which consisted of two sections, was based on a young girl who wanted to dye her hair but saw that the dye was made up of an ammonium compound while examining the can. Therefore, she decided not to dye her hair and asked her uncle about this since he was a chemist, and she knew that ammonia is a basic, poisonous, and corrosive substance.	The students learn about weak monobase-strong monoacid titration. The students were asked how to calculate the pH of ammonia (NH3) in the hair dye and how to titrate the ammonia solution, which is a weak base, with a hydrochloric acid, which is a strong acid.	In terms of laboratory safety precautions, the titration experiment of ammonia solution with a hydrochloric acid solution was not conducted with the students, although the students were told how to conduct this experiment in the 'Experiencing' stage. Ammonia vapor is harmful to the eyes and respiratory tract.

watching their friends playing quietly. Finally, the three winners played the last round of the game (15 minutes). The one ahead of the step sign won within the specified time. Its rules and the way of playing are as follows.

In the first round;

- Five people take turns rolling the dice. The student with the highest score on the dice is the first to begin the game, while the student with the lowest score is the last to begin.
- The highest scorer starts the game and draws one of the small colored cards. The question on the card is hidden from other players.
- If the player knows the right answer, s/he writes the answer to the question on the card in the appropriate and correct place in the puzzle. Then s/he moves

Table 3 An example of the application according to the stages

Relating (R)	The first section starts with the students' curiosity about the mummification process for their chemistry project assignments after getting influenced by the movie "Mummy". This section is aimed at the students learning the bitumen substance and the natron solution. Then, within and between groups, the students discuss what these items could be. Afterward, students are given the second section of the context for making discussions. In the second section, they learn that the natron solution is mainly composed of sodium carbonate (Na2CO3) salt and sodium bicarbonate (NaHCO3), sodium sulfate (Na2SO4), sodium chloride (NaCl), and that it is a basic salt solution.
Experiencing (E)	The students are reminded of basic, acidic, neutral, and amphoteric salts. It is mentioned that the sodium carbonate in the natron solution is a basic salt and can occur at a particular stage of weak acid-strong base titration. In this context, students prepare weak acid and strong base titration. 10 mL of vinegar, 40 mL of distilled water, and a few drops of phenolphthalein (pp) indicator are placed in a conical flask with the help of a straw or graduated cylinder. The burette is filled with 0.1 M sodium hydroxide solution and attached to the ring stand. The titration process begins. Calculations are made by stopping titration at the turning point. In our experiment, the students are told that the active ingredient of vinegar is acetic acid and that vinegar is used instead of acetic acid to make the experiment more reliable. In addition, in the experimental calculations, the students were asked to discover how much acetic acid active ingredient in vinegar is.
Applying (A)	For the second section of the context, the students tried to solve the questions about the pH-pOH calculation of the weak acid, the calculation of pH-pOH as a result of adding specific volumes of titrant in the weak acid-strong base titration, the titration curve drawing, the calculation of basic salt and amphoteric salt pH-pOH, the titration of the mixtures.
Cooperating (C)	The instructor gives the students the research topics related to the sub-topics of the questions in the second section of the context. Then, in the next lesson, the students made presentations for the research topics and discussed them in class.
Transferring (T)	After the application of all contexts was completed, the instructor asked the students what the buffer systems in the body are, the properties of acids, bases, and salts in these buffer systems, and how they could be titrated.

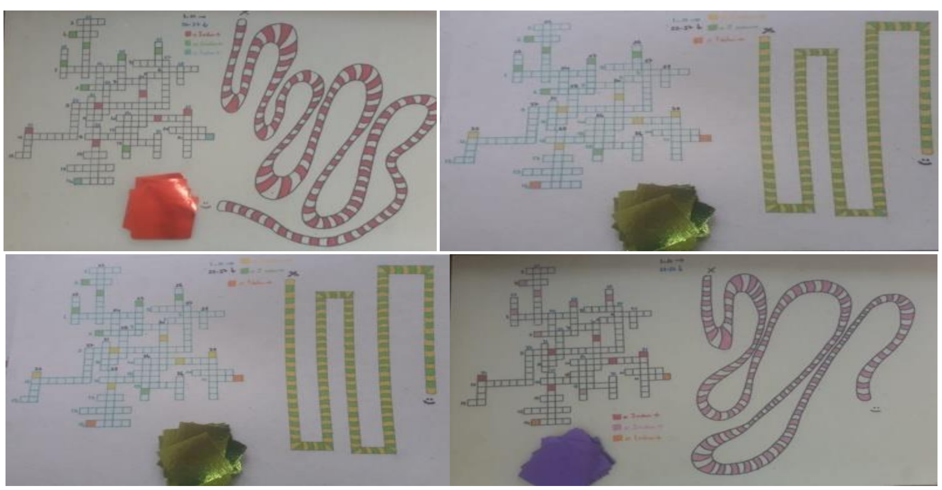

Figure 2 Colored cards with questions and a stop sign on the game board

forward by the number of letters in the word on the step sign. If there is a colored box within the boxes containing the word, the number of steps is checked according to the box's color. S/he proceeds in the step sign by adding this step number to the number of letters in the word. For example, the player randomly draws card number 1, which has a question concerning the complex organic compounds that color depending on the pH of the solution. Suppose the player knows the answer to this question, the 'Indicator' ['İndikatör' in Turkish]. In that case, s/he writes the word in the area indicated by the number 1 and shown horizontally in the puzzle. Since there are nine letters, s/he advances nine steps on the step sign. However, the first box in the area where the word is written is colored orange. The orange color is shown as two more steps forward at the bottom of the game board. So the player advances 11 steps on the step sign.

- If the colored box belongs to two or three words, the number of steps indicated in the colored box will be used only once. In other words, if the player knows the word in the colored box and uses the total number of steps on the step sign, other players cannot use this number of steps even if they know other words that this colored box overlaps. So, for instance, if the cor rect answer (the indicator word) to the question on the first number card is written in the puzzle and the advantage of the first orange box is used (more than two steps), the advantage of the orange color cannot be used again when writing the answer of the question on the 23rd card, where the first orange box overlaps.

- The players have one minute to answer each question. If the player correctly answers the question on the card s/he drew, the same player draws another card. If the player says "Pass", the game passes to the next player.
- If the answer to the question on the colored cards is unknown, it is returned to be retracted in a closed form.
- The game continues in this way.
- The first round of the game lasts for 40 minutes. After 40 minutes, the player who has advanced the most steps wins. The winner is not defined as the one with the most points but as the one ahead on the step sign.
- In the second round;
- After the first round, new groups of five people are formed among the winners. Then, the newly formed groups begin to play the game among themselves. This constitutes the second round of the game. The duration of the second round is 20 minutes. After 20 minutes, the winners are ahead on the step sign.
- In the third round;
- The game goes on like this until only one group is left in the last round. The last round lasted 15 minutes. After 15 minutes, the person who is ahead on the step sign wins.

In addition, after completing the entire implementation process in both groups, crossword puzzles were played with the CG students.

2.5 The Implementation Process

Before the application, the EG and CG students were informed about the CBA REACT strategy, the application process, and the roles of the instructor and the students. After the ABTAT pre-test was applied for both groups (1-course hour), random groups of five people were formed from both groups. Next, the application was implemented based on the stages of the REACT strategy for both groups (18-course hours). Then, the ABTAT post-test was applied for both groups (1-course hour). Finally, the crossword puzzle game was implemented for only EG group students (3-course hours). After the implementation, the game crossword puzzle was played with the CG. The game was also applied to CG students to avoid discrimination between EG and CG students at the end of the application.

3. RESULT

3.1 Results Concerning the Content Analysis of ABTAT

The ABTAT pre- and post-test content analysis of both groups in terms of total frequency were shown in Figure 3-4.

In the pre-test content analysis of the groups (Figure 3), the fact that the majority of both groups gave answers in the UA category shows that the students did not know the topic of acid-base titrations. As seen in Figure 4, the result of the post-test content analysis revealed that the response frequencies of the SU and PU categories of the EG were higher than those of the CG. In comparison, the response frequencies of the EG in the MU and UA categories were lower than the CG's response frequencies in the relevant categories. Therefore, it was concluded that the response frequencies of the EG in the IC category were higher than that of the CG in the same category.

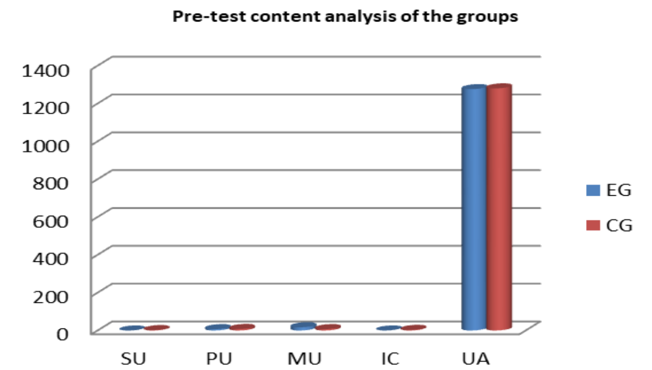

Figure 3 Pre-test content analysis of the groups

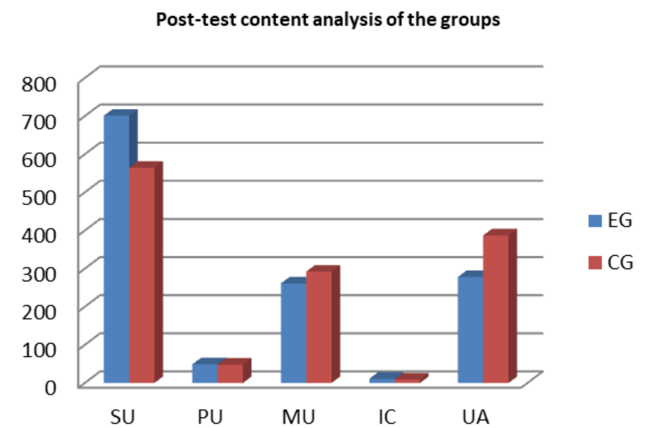

Figure 4 Post-test content analysis of the groups

These findings show that the EG's sound and partial understanding increased in the post-test compared to the CG, and their misunderstanding and unanswered questions decreased (Figure 4). In addition, the reason why the EG's answers in the IC category were slightly higher compared to the CG can be explained by the fact that the EG engaged in writing answers unrelated to the question instead of leaving some answers blank.

In addition, when the content analysis of the ABTAT post-test questions in both groups was examined (Figure 5-6), while the questions with the highest response frequencies in the SU category were generally the same in both groups, in addition to these questions, the response frequencies in the SU category were higher in the EG than those in other categories between questions 10 and 13. This finding showed that the EG students also had a sound

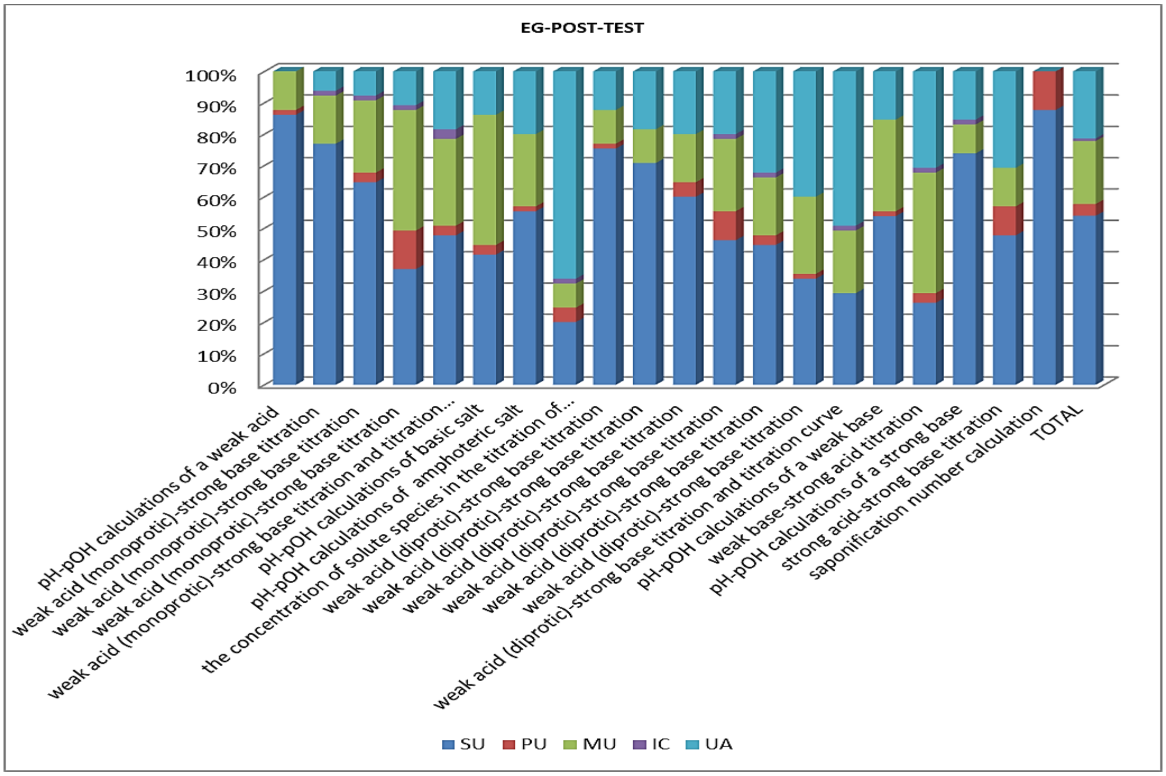

Figure 5 The content analysis of the ABTAT post-test questions in the EG

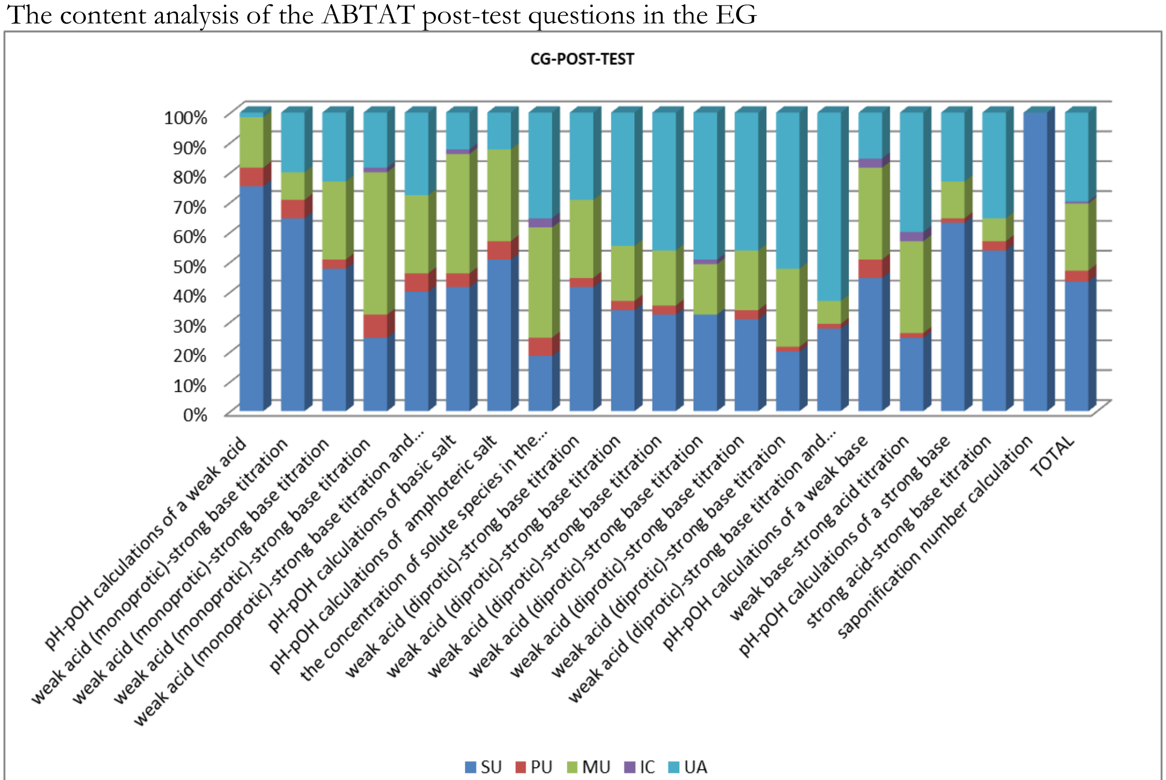

Figure 6 The content analysis of the ABTAT post-test questions in the CG

understanding of the initial pH calculation of the medium before the titration of H2CO3-NaOH, the calculation of the pH-pOH of the medium before the first equivalence point, the medium at the first equivalence point, and the medium before the second equivalence point of the same titration.

The response frequencies were lowest in the SU category, especially in the 8th question concerning the titration of the NaHCO3-Na2CO3 mixture solution. Most of the experimental group left this question blank, whereas most of the control group misunderstood it. This finding showed that most students did not know or misunderstood the 'titration of mixtures' subtopic. In this context, it was found that the students did not consider both the amount of Na2CO3 coming from NaHCO3 and the amount of Na2CO3 in the mixture. Instead, they equalized the amount of mmol HCl spent in the titration up to the turning point to NaHCO3 in the mixture, and the amount of mmol HCl spent in the titration up to the turning point with the amount of Na2CO3 in the mixture.

The response frequency in the MU category was highest for the 6th question in the experimental group and the 4th question in the control group among the questions. This finding indicated that most students misunderstood the equivalence point pH and pOH calculation of weak monoacid-strong monobase titration and a basic salt's pH-pOH calculation. Most students misunderstood that the pH and pOH of the medium at the equivalence point of the weak acid-strong base titration is seven, as in a neutral salt. They calculated the pH thinking of basic salt as a strong acid solution.

Moreover, the highest response frequency in the UA category was for the 8th question in the experimental group and the 15th question in the control group among the questions. This finding showed that most students in the control group did not know the calculation of pH-pOH of the medium after the second equivalence point of the H2CO3-NaOH titration and the plot of the titration curve.

In summary, it was concluded that the CBA REACT strategy supported by the crossword puzzles increased the sound and partial understanding and decreased the misunderstandings on acid-base titrations in the chemistry laboratory course.

3.2 Results Concerning the Statistical Analysis of ABTAT

The results of the Mann-Whitney U Test and the Wilcoxon Test, respectively, are shown in Table 4-5.

When the data are examined, there is no statistically significant difference between the ABTAT pre-test achievement scores of the EG and CG. However, there is a significant difference between the ABTAT post-test scores in favor of the EG. The Wilcoxon test results show a statistically significant difference between the pre-and post-test scores of both groups. In addition, the effect size of this difference obtained in both groups was calculated ($r = Z/\sqrt{n}$) (Field, 2009). The effect size of this difference was r = 0.615, indicating that the difference had a significant effect, and 37.83% of the total variance was explained by education. In addition, the effect size calculated using the G.Power-3.1.9.2 program was calculated as 2.6668 in the EG and 2.0793 in the CG. This finding has shown that the post-test scores of both groups were higher than the pre-test scores, but this increase was higher in the EG compared to the CG. In light of these findings, it was concluded that the CBA REACT strategy supported with crossword puzzles increased the students' academic achievement in the chemistry laboratory course acid-base titrations topic.

4. DISCUSSION

Since students' thoughts, feelings, and practices enable them to learn a topic in a meaningful way (Bretz, 2001), and since the topic of acid-base titrations is complex and contains abstract concepts, it was considered appropriate to use the CBA REACT strategy supported by a crossword puzzle game in this study. This integrated learning strategy was implemented in a university-level chemistry laboratory course. With the implementation, students had the opportunity to experience titration types (strong acid/strong base, weak acid/strong base, weak base/ strong acid), buffer solutions, hydrolysis, and pH-pOH calculations in a fun and brainstorming environment with contexts related to daily life, laboratory experiments and crossword puzzle game in the topic of acid-base titrations. In the study, it was concluded that the achievement of the EG in which the CBA REACT strategy supported with crossword puzzles was applied and the CG in which only the CBA REACT strategy was applied increased significantly at the end of the application process and that the application had a significant effect on both groups. However, since the mean achievement score of the EG was slightly higher than that of the CG, it can be said that the CBA REACT strategy supported with crossword puzzles effectively increased students' achievement in acid-base titrations. Likewise, the study's findings showed that the EG students' sound and partial understanding of the relevant topic was higher than the CG.

Some studies in the literature show that CBA and CBA REACT strategy increases students' learning on the

Table 4 Mann whitney u test results of ABTAT pre-and post-test scores of the EG and CG (p<.05)

	EG (n = 65)	CG (n = 65)			
ABTAT	Median (Minimum-Maximum)	Median (Minimum-Maximum)	U	p	Effect Size
Pre-test	0.4769 (0.00-4.00)	0.4000 (0.00-3.00)	2002	.503	
Post-test	37.8462 (9.00-60.00)	32.2000 (4.00-60.00)	1657	.034	0.3783

Table 5 Wilcoxon Test Results of ABTAT Pre- and Post-test Changes of the EG and CG (p<.05)

Groups	Pre-test	Post-test	z	p	Effect Size
EG	0.4769 (0.00-4.00)	37.8462 (9.00-60.00)	-7.009	<.001	2.6668
CG	0.4000 (0.00-3.00)	32.2000 (4.00-60.00)	-7.010	<.001	2.0793

relevant topic. In the study carried out by Jabessa (2019), it was concluded that CBA applied to the topic of acids-based indicators increased the students' achievement, and the students were more successful in organizing and carrying out the experiments performed during the laboratory sessions.

On the other hand, no studies use crossword puzzles on the same topic. However, studies show that crossword puzzles increase academic performance, achievement, and learning on chemistry topics.

As a result of the content analysis of the study, it was found that students had misunderstandings that their pH and pOH of neutralization reactions are always 7, the titration curve is linear or concave, the pH of the strong acid or base is solved as a weak acid or base pH calculation or vice versa, they confuse with acidic and basic buffers, they confuse with the Henderson-Hasselbalch equation, and that they also confused acidity and basicity equilibrium constants. Some studies in the literature support these findings. The study by Sheppard (2006) showed that the general misconceptions include acid-base strength, neutralization, titrations and pH calculations, indicators, acid-base equilibrium, and buffers. However, it was also determined that the students had misconceptions concerning the neutralization, conjugate acid-base pairs, and the Bronsted theory in the literature (Drechsler & Schmidt, 2005; Schmidt & Chemie, 1995).; Sheppard, 2006).

In the study of Widarti et al. (2017), they concluded that the prospective chemistry teachers had misconceptions about the species which existed in the solution before the equivalent point, the calculation of pH in an acid-base titration, microscopic description of species in the process of titration of a weak acid and strong base and the content sample.

Ivanoska and Stojanovska (2021) investigated the misconceptions among primary school students concerning their research's acids and bases concepts. They revealed that the students had misconceptions that an acid-base indicator is a substance that is red in acidic and blue in basic solution. Instead, the medium is always neutral at complete neutralization of any acid and any base.

Salame et al. (2022) expressed in their research that acid-base titrations could be a difficult and complex process for students because of the nature of acids/bases, stoichiometric calculations, moles and molarity changes, mathematical manipulations involving algebraic, and logarithmicones.

Aini and Silfianah (2022) concluded in their study that most students had misconceptions concerning acid-base indicators, acid strength (pH), acid-base ionization (Ka-Kb), calculation of solution pH, the pH in the environment concept, acid-base materials, acid-base theory concept.

5. CONCLUSION AND IMPLICATION

In summary, it was concluded that the CBA REACT strategy supported by the crossword puzzles increased academic achievements and the sound and partial understanding of the students on the topic of acid-base titrations in the chemistry laboratory course in this research. The findings of this study are also thought to shed light on future research and close the gap in the literature since there is no study in the literature regarding the effect of the CBA REACT strategy supported with crossword puzzles on acid-base titrations in the chemistry laboratory course and especially on the academic achievement of students at the associate degree level in the health field. Furthermore, this study contributes significantly to science education by uncovering the effect of embedding a crossword puzzle game into CBA REACT for learning acid and base titrations. Especially in this study, students gained current information about the mummification process, the destruction of coral reefs, the use of ammonium compound as a dye fixative in hair dyes, and made soap.

In addition, these combined activities effectively provide meaningful learning of the relevant topic by activating the right and left hemispheres of the brain. We need to provide these interactive learning environments to develop students' learning, collaborative work, and solving problems they may encounter professionally. Therefore, students will grow confident as they experience collaborating and competing moments in their chemistry learning.

To expand the study's findings in future studies, it is planned to add another CG to the study, in which the course is taught compared to traditional laboratory practice only on acid-base titrations. In addition, further studies could investigate to what extent the CBA REACT strategy and the CBA REACT strategy supported with crossword puzzles promote students' conceptual learning. Finally, the absence of a different independent variable in the study is among the limitations of the study.

REFERENCES

Abdulmajed, H., Park, Y. S., & Tekian, A. (2015). Assessment of educational games for health professions: a systematic review of trends and outcomes. *Medical Teacher*, *37*(Suppl.1), 27-32.

Ayvacı, H. S., & Ucmak, C. (2022). Comparison of science teacher candidates' theoretical knowledge about matter state change and daily life contexts. *Journal of Instructional Technologies and Teacher Education*, *11*(1), 1-15.

Agarwal, H. K., Singhal, A., & Yadav, A. K. (2020). Crossword puzzle: An innovative assessment tool to improve learning of students in forensic medicine. *Medico-legal Update*, *20*(1), 18-22.

Aini, F., & Silfianah, I. (2022). Identification of students' misconceptions on acid-base using four tier diagnostic tests. *Jurnal Pembelajaran Kimia*, *7*(1), 33-43.

Ajayi, V. O., & Ogbeba, J. (2020). Possibility of improving students' engagement and academic performance in chemistry using three-dimensional puzzle-based instructional strategy: A field report. *Kogi Journal of Education and Pedagogy*, *1*(1), 142- 152.

Akgun, A., Tokur, F., & Duruk, U. (2016). Associating conceptions in science teaching with daily life: Water chemistry and water

treatment. *Adıyaman University Journal of Educational Sciences*, *6*(1), 161-178.
Artdej, R., Ratanaroutai, T., Coll, R. K., & Thongpancang, T. (2010). Thai grade 11 students' alternative conceptions for acid-base chemistry. *Research in Science and Technological Education*, *28*(2), 167-183.
Azid, N., Yi Shi, L., Saad, A., Che Man, S., & Mei Heong, Y. (2022). The COVID-19 pandemic: Web 2.0 tools as an alternative instruction for science in secondary schools. *International Journal of Information and Education Technology*, *12*(6), 467-475.
Baldwin, N., & Orgill, M. K. (2019). Relationship between teaching assistants' perceptions of student learning challenges and their use of external representations when teaching acid-base titrations in introductory chemistry laboratory courses. *Chemistry Education Research and Practice*, *20*(4), 821-836.
Baran, M., & Sozbilir, M. (2018). An application of context- and problem-based learning (C-PBL) into teaching thermodynamics. *Research in Science Education*, *48*, 663-689.
Belova, N., & Zowada, C. (2020). Innovating higher education via game-based learning on misconceptions. *Education Sciences*, *10*(9), 221-231.
Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: a synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, *91*, 347–370.
Berry, D., & Miller, M. (2008). Crossword puzzles as a tool to enhance athletic training student learning: Part 2. *Athletic Therapy Today*, *13*(1), 32-34.
Bretz, S. L. (2001). Novak's theory of education: Human constructivism and meaningful learning. *Journal of Chemical Education*, *78*(8), 1107.
Burgaz Uskan, S., & Bozkus, T. (2019). Place of play in education. *International Journal of Contemporary Educational Studies*, *5*(2), 123-131.
Byusa, E., Kampire, E., & Mwesigye, A. R. (2022). Game-based learning approach on students' motivation and understanding of chemistry concepts: A systematic review of literature. *Heliyon*, *8*(5), e09541.
Cardozo, L. T., Miranda, A. S., Moura, M. J. C. S., & Marcondes, F. K. (2016). Effect of a puzzle on the process of students' learning about cardiac physiology. *Advance Physiology Education*, *40*, 425-431.
Cartrette, D. P., & Mayo, P. M. (2011). Students' understanding of acids/bases as organic chemistry contexts. *Chemistry Education Research and Practice*, *12*(1), 29-39.
Celikler, D., & Kara, F. (2016). Determining the Readiness Level of 5th Grade Students' on Relating Their Knowledge about "Change of Matter" Unit to Daily Life Experiences. *Kafkas University Journal of the Institute of Social Sciences*, *17*, 21-39.
Cooper, M. M., Kouyoumdjian, H., & Underwood, S. M. (2016). Investigating students' reasoning about acid-base reactions. *Journal of Chemical Education*, *93*(10), 1703-1712.
Costu, B., Ayas, A., & Unal, S. (2007). Misconceptions about boiling and their possible reasons. *Kastamonu Education Journal*, *15*(1), 123-136.
Crawford, M. L. (2001). *Teaching contextually: Research, rationale, and techniques for improving student motivation and achievement in mathematics and science.* Waco, TX: CCI Publishing.
da Silva Junior, J. N., de Sousa Oliveira, J. M., Winum, J. Y., MeloLeite, A. J. Jr., Alexandre, S. O. F., do Nascimento, D. M., de Sousa, U. S., Pimenta, A. T. A., & Monteiro, A. J. (2020). Interactions 500: Design, implementation, and evaluation of a hybrid board game for aiding students in the review of intermolecular forces during the COVID-19 pandemic. *Journal of Chemical Education*, *97*(11), 4049-4054.
Damanhuri, M. I. M., Treagust, D. F., Won, M., & Chandrasegaran, A. L. (2016). High school students' understanding of acid-base concepts: An ongoing challenge for teachers. *International Journal of Environmental & Science Education*, *11*(1), 9-27.
Dand, H. (2008). *Techniques of Teaching*. New Delhi: APH Publishing Corporation.
de Putter, L. G. A., Nieveen, S. N. M., Taconis, R., & Jochems, W. (2022). A one-year teacher Professional development programme towards context-based science education using a concerns- based approach. *Professional Development in Education*, *48*(3), 523-539.
Demircioglu, H., Vural, S., & Demircioglu, G. (2012). The Effect of A Teaching Material Developed Based On 'REACT' Strategy On Gifted Students' Achievement. *Ondokuz Mayıs University Journal of Education Faculty*, *31*(2), 101-144.
Demircioglu, G., Ozmen, H., & Ayas, A. (2004). Some misconceptions encountered in chemistry: A research on acid and base. *Educational Sciences: Theory & Practice*, *4*(1), 73-80.
Demirel, H. S. (2013). *Biochemistry*. TUSEM Medical Publications.
Dori, Y. J., Avargil, S., Kohen, Z., & Saar, L. (2018). Context-based learning and metacognitive prompts for enhancing scientific text comprehension. *International Journal of Science Education*, *40*(10), 1198-1220.
Drechsler, M., & Schmidt, H. J. (2005). Textbooks' and teachers' understanding of acid-base models used in chemistry teaching. *Chemistry Education Research and Practice*, *6*(1), 19-35.
Fakokunde, J. B. (2021). Effects of gender and cognitive style on students' learning retention in social studies using computer-based instructional puzzle. *Mediterranean Journal of Education*, *1*(1), 91-101.
Febiana, H., Partana, C. F., Wiyarsi, A., & Sulistyo, B. (2019). Automotive engineering Chemistry module: Exploring acid-base and electrochemistry topic in-vehicle context. *Journal of Physics Conference Series*, 1156. doi:10.1088/1742-6596/1156/1/012023
Field, A. (2009). *Discovering Statistics Using SPSS* (3rd Edition). London: Sage Publications, London.
Green, S. B., & Salkind, N. J. (2003). *Using SPSS for Windows and Macintosh: analyzing and understanding data* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.
Gunduz, T. (2008). *Qualitative analysis textbook*. Ankara: Gazi Publications.
Guyton, A. C., & Hall, J. E. (1996). *Textbook of Medical Physiology* (9th ed.). Nobel Medical Publications.
Harman, G., & Yenikalaycı, N. (2020). ABSQR Code Game: reinforcing the names, formulas, types and reactions of acids, bases and salts. *Journal of Materials Education*, *42*(1–2), 1–14.
Ivanoska, K., & Stojanovska, M. (2021). Addressing and eliminating the misconceptions about acid and bases concepts in primary school chemistry teaching. *Macedonian Journal of Chemistry and Chemical Engineering*, *40*(2), 325-339.
Jabessa, C. A. (2019). *The effect of context-based approach on teaching the concept of acid base indicators on college students' achievement and attitudes* (Master Degree Thesis). Haramaya University, Haramaya.
Joag, S. D. (2014). An effective method of introducing the periodic table as a crossword puzzle at the high school level. *Journal of Chemical Education*, *91*(6), 864-867.
Johnstone, A. H. (2010). You can't get there from here. *Journal of Chemical Education*, *87*(1), 22-29.
Kara, F. (2019). An activity examples concerning learning of elements and periodic table. *Journal of Inquiry Based Activities*, *9*(2), 67-83.
Karsli, F., & Yigit, M. (2017). Effectiveness of the REACT strategy on 12th grade students' understanding of the alkenes concept. *Research in Science & Technological Education*, *35*(3), 274-291.
Kim, S., Song, K., Lockee, B., Burton, J., Kim, S., Song, K., ... & Burton, J. (2018). *What is gamification in learning and education?* (pp. 25-38). Springer International Publishing.
Kousathana, M., Demerouti, M., & Tsaparlis, G. (2005). Instructional misconceptions in acid-baseequilibria. *Science and Education*, *14*(2), 173-193.
Lin Lai, E., & Lee, T. T. (2022). Let the acid and base flash out!. *Central Asia & the Caucasus*, *23*(1), 1855- 1875.
Majid, A. N., & Rohaeti, E. (2018). The Effect of Context-Based Chemistry Learning on Student Achievement and Attitude. *American Journal of Educational Research*, *6*(6), 836-839.
Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Sage Publications, Inc.

Mshayisa, V. V. (2020). Students' perceptions of Plickers and crossword puzzles in undergraduate studies. *Journal of Food Science Education*, *19*(2), 49-58.

Mubarokah, F. D., Mulyani, S., & Indriyanti, N. Y. (2018). Identifying students' misconceptions of acid-base concepts using a three-tier diagnostic test: A case of Indonesia and Thailand. *Journal of Turkish Science Education*, *15*, 51-58.

Nahum, T. L., Mamlok-Naaman, R., Hofstein, A., & Taber, K. S. (2010). Teaching and learning the concept of chemical bonding. *Studies in Science Education*, *46*(2), 179-207.

Nakiboglu, N., & Nakiboglu, C. (2016). University students' understanding of density and concentration: a cross-level investigation. *The Eurasia Proceedings of Educational & Social Sciences (EPESS)*, *4*, 550-553.

Nicol, A. A. M. (2020). A highly interactive application of self-generated crosswords in the classroom. *College Teaching*, *68*(1), 3-4.

Nieto-Escamez, F. A., & Roldan-Tapia, M. D. (2021). Gamification as online teaching strategy during Covid-19: A mini-review. *Frontiers in Psychology*, *12*(648552), 1-9.

Orgill, M. K., & Sutherland, A. (2008). Undergraduate chemistry students' perceptions of and misconceptions about buffers and buffer problems. *Chemistry Education Research and Practice*, *9*(2), 131-143.

Ozmen, H., & Yıldırım, N. (2005). Effect of work sheets on student's success: Acids and bases sample. *Journal of Turkish Science Education*, *2*(2), 10-13.

Pearson, R. J. (2020). Online chemistry crossword puzzled prior to and during COVID-19: Light-hearted revisions aids that work. *Journal of Chemical Education*, *97*(9), 3194-3200.

Prins, G. T., Bulte, A. M. W., & Pilot, A. (2018). Designing context-based teaching materials by transforming authentic scientific modelling practices in chemistry. *International Journal of Science Education*, *40*(10), 1108-1135.

Robson, C. (2015). *Scientific Research Methods: Real World Research*. (Şakir Çınkır & Nihan Demirkasımoğlu Eds.). Anı Publishing.

Romero, M. (2017). Competitive, collaborative, and cooperative play. In K. Peppler (Ed.), *The SAGE Encyclopedia of Out-of-School Learning*. New York NY: SAGE Publications, pp. 115–116, doi: 10.4135/9781483385198.n51

Salame, I. I., Montero, A., & Eschweiler, D. (2022). Examining some of the students' challenges and alternative conceptions in learning about acid-base titrations. *International Journal of Chemistry Education Research*, *6*(1), 1-10.

Schmidt, H. J., & Chemie, F. (1995). Applying the concept of conjugation to the Brønsted theory of acid-base reactions by senior high school students from Germany. *International Journal of Science Education*, *17*(6), 733-741.

Secer, I. (2015). *Practical data analysis with SPSS and LISREL: analysis and reporting* (2nd ed.). Ankara: Anı Publications.

Sheppard, K. (2006). High school students' understanding of titrations and related acid-base phenomena. *Chemistry Education Research and Practice*, *7*(1), 32-45.

Simsek, N. (2007). *Öğrenmeyi Öğrenmede Alternatif Yaklaşımlar* (2nd ed.) [Alternative Approaches to Learning to Learn (2nd ed.)]. Ankara: Asil Publishing.

Skoog, D. A., Holler, F. J., & West, D. M. (1996). *Fundamentals of analytical chemistry* (7th edition). Orlanda, Florida, USA: Saunders College Publications.

Stojanovska, M. (2020). Celebrating the international year of the periodic table with chemistry educational games and puzzles. *Chemistry Teacher International*, *3*(1), 1-9.

Supatmi, S., Setiawan, A., & Rahmawati, Y. (2019). Students' misconceptions of acid-base titration assessments using a two-tier multiple-choice diagnostic test. *African Journal of Chemical Education*, *9*(1), 18-37.

Thompson, R. A., & Zamboanga, B. L. (2004). Academic aptitude and prior knowledge as predictors of student achievement in introduction to psychology. *Journal of Educational Psychology*, *96*(4), 778-784.

Treagust, D. F., Harrison A. G., & Vennile, G. J. (1996). Using an analogical teaching approach to engender conceptual change. *International Journal of Science Education*, *18*(2), 213-229.

Ultay, N., & Calik, M. (2016). A comparison of different teaching designs of 'Acids and Bases' Subject. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(1), 57-86.

Ural, E., & Gencoglan, D. M. (2020). The Effect of Argumentation-Based Science Teaching Approach on 8th Graders' Learning in the Subject of Acids-Bases, their Attitudes towards Science Class and Scientific Process Skills. *Interdisciplinary Journal of Environmental and Science Education*, *16*(1), 1-15.

Widarti, H., Permanasari, A., & Mulyani, S. (2017). Undergraduate students' misconception on acid-base and argentometric titrations: a challenge to implement multiple representation learning model with cognitive dissonance strategy. *International Journal of Education*, *9*(2), 105-112.

Yesari, B. (2018). *The effect of consept puzzle in social sciences lesson unit "adventure of democracy" to student's success* (Master Degree Thesis). Nigde Omer Halisdemir University, Nigde.

Yuriev, E., Capuano, B., & Short, J. L. (2016). Crossword puzzles for chemistry education: learning goals beyond vocabulary. *Chemistry Education Research and Practice*, *17*(3), 532-554.