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Effect of 5E learning cycle assisted with concept maps on conceptual understanding

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ABSTRACT

This study aims to examine the effect of conceptual understandings related to anion-cation, acid-base, ionic-covalent, metal-nonmetal, and number of protons-number of electrons concept pairs taught in the periodic table to 8th grade students with the 5E learning model supported by concept maps. The study was conducted among 100 (50 in the experimental group and 50 in the control group) 8th grade students in North Cyprus in the second term of the 2018-2019 academic year. Data was collected using the chemistry concept diagnostic test, open-ended questions, and semi-structured interviews related to the concept pairs designed by the researchers. As a result of the study, it has been determined that the 5E learning model supported by concept maps improves the students' conceptual understanding, and the opinions of students from the experimental group on the learning environment have been analyzed.

Keywords: concept map, conceptual understandings, 5E learning model

INTRODUCTION

In light of studies on education, the approaches related to the nature of learning have shifted towards cognitivism from behaviorism to a constructivist learning perspective in which the learner is currently active (Cooper, 1993). In the constructivist learning approach, learning is defined as the process in which the individual constructs new information in their mind and interprets the new situation based on their previous experiences and the information that they already have. It is stated that the previous knowledge, personal characteristics, and learning environment of the individual are very important for learning (Fung, 2000; Yildirim et al., 2017). Constructivist research has shown that students construct their information, actively participate in the learning process, and learn better in learning environments (Shymansky, 1992). The constructivist approach is based on the premise that students interpret new situations using their pre-knowledge and experiences in science. In this context, studies on different learning applications for science education and student-centered teaching methods stand out. The results of these studies have shown that students combine new information with their existing knowledge and participate actively in classes; they construct their information and learn better in constructivist learning environments that avoid memorization (Jones & Brader-Araje, 2002).

Sequeira et al. (1993) state that scientists and educators must encourage students' conceptual development with a constructivist approach and prevent them from developing alternative concepts. Learning models like 3E, 4E, 5E, and 7E emerged with the transfer of the constructivist learning approach to learning environments. Cooper and Stowe (2018) utilized constructivism as an efficient idea for chemistry education research.

Constructivist learning models help students completely understand course concepts by focusing on students' constructing information (Jobrack, 2013). The common ground of these learning models is revealing the pre-knowledge of students, providing that they have rich experiences related to the concept and the opportunity to apply the things they learned to different areas (Putra et al., 2018).

The teaching model used in this study is the 5E learning model. The learning cycle model, one of the constructivist approach's learning applications, is the most used and efficient in science education and also forms the basis of studies by Atkin and Karplus (1962) in the 1960s. The 5E learning cycle model, which Rodger Bybee has proposed, is the model that includes

(1) engage (attention-getting and revealing pre-knowledge),

This study is generated from doctoral dissertation of the first author that supervised by the second author and co-supervised by the third author.

(2) explore (investigation),

(3) explain (explanation),

(4) elaborate (transfer), and

(5) evaluate (assessment), especially in constructivist education in science (Bybee, 1993, 1997; Bybee et al., 2006).

Literature Review

The 5E learning model is one of the learning models that provides the possibility to use different methods and techniques in a class environment, is identified with the constructivist learning approach and can be used efficiently in science education (Hun, 2017). There are studies in the literature that have shown that the 5E learning model improves students' attitudes, success, motivation, meaningful learning, and conceptual understanding (Aktas, 2013; Bilgin et al., 2013; Campbell, 2006; Ceylan & Geban, 2009; Putra et al., 2018; Qarareh, 2012; Yalcin & Bayrakceken, 2010).

Studies have been conducted about learning cycles ranging from 3E to 7E revealed that students' understanding of various science fields improved (Balta & Sarac, 2016; Ceylan, 2008; Hadinugrahaningsih et al., 2021). In the meta-analysis study conducted by Yaman and Karasah (2018) on learning models (4E, 5E, and 7E), it was reported that the most commenly used and effective model was 5E. Besides, Sarac (2017) states that the 5E learning model has positive effect on students learning outcomes. In the light of these studies, it was thought that the most appropriate learning model is 5E for this study that aim to evaluate the conceptual understanding of secondary school students with concept maps considering the lesson durations and learning environment.

It is thought that students are the most efficient in the exploration phase of the 5E learning model because it is the phase in which they produce thoughts together. At this phase, it will be appropriate to support the concept maps they can prepare together in small groups to encourage opinion exchange (Koseoglu & Tumay, 2015; Mertoglu, 2020). On the other hand, the supporting explanation phase, defined as the phase in which the learning is most efficient with concept maps, will allow students to see the relationship between concepts better and understand new information easily (Koseoglu & Tumay, 2015; Ozturk, 2017). The conducted studies support that using concept maps in the evaluation phase to assess the students' conceptual understanding will help teachers determine the students' understanding level and spot concept misunderstandings (Hasturk, 2017; Ruiz-Primo, & Shavelson, 1996). Concept maps can be applied in all phases of education to determine deficiencies and for assessment at the end of the process, namely, in determining students' level of preparation at the beginning of the education process and for supervision of the education process (Korkmaz, 2004).

In the 1980s, Novak and Gowin (1984) emphasized using concept maps to develop meaningful learning and teaching. Based on Ausubel's research on how children learn (Novak & Musonda, 1991), concept maps were made in Novak's (1990) program to help understand and track how children's knowledge grows.

Some studies use concept maps as a useful tool in science education (Novak, 1990), as a teaching tool (Horton et al., 1993; Trowbridge & Wandersee, 1994), and as an assessment tool (Ruiz-Primo & Shavelson, 1996; McClure et al., 1999; Van Zele et al., 2004).

Novak (1990) stated that concept maps are used to improve science education in four different areas: learning strategy; education strategy; teaching program planning strategy; and assessment of students' understanding of science concepts. Students' pre-knowledge is activated by revealing, determining concept misunderstandings, and reviewing and repeating the subject or assessment (Kinchin, 2000). Hein and Price (1994) say that concept maps are useful tools that can be used at all stages of the learning process.

Studies examined found that concept maps are an effective teaching tool in chemistry education (Gilewski et al., 2019; Kilic & Cakmak, 2013; Markow & Lonning, 1998; Zendler & Greiner, 2020). In addition, the 5E learning model was used to support different methods and techniques in chemistry education (Majid & Rohaeti, 2018).

Significance of the Study

This study ensured that the students could notice the relationships between anion-cation, acid-base, ionic-covalent, metal-nonmetal, and proton number-electron number concept pairs and understand new information more easily by using the 5E learning model supported by concept maps in the exploration and explanation phases. Furthermore, in the evaluation phase, it was provided that the level of understanding of the concept pairs of the students was revealed. The results obtained from the study are supposed to contribute to the literature.

In this context, the study's research problems aim to examine the conceptual meanings related to anion-cation, acid-base, ionic-covalent, metal-non-metal, and number of protons-number of electrons that are taught in the periodic table to 8th grade students with the 5E learning model supported by concept maps.

Research Questions

1. Is there any significant difference between the experimental and control group's conceptual understanding related to anion-cation, acid-base, ionic-covalent, metal-non-metal, and number of protons-number of electrons concept pairs depending on the applied teaching method?
2. How is the level of understanding of control and experimental group students related to anion-cation, acid-base, ionic-covalent, metal-non-metal, and number of protons -number of electrons concept pairs?
3. How are the students' opinions in the experimental group on the learning environment prepared with the 5E learning model supported by concept maps?

METHODS

Experimental Design of the Study

In this study, the subject was taught using the 5E learning model supported by concept maps to the experimental group and the existing teaching method to the control group. This study aimed to analyze the effect of the teaching method, an independent variable, on the conceptual understanding and understanding levels of students, which are dependent variables. We used qualitative and quantitative data collection tools in the study.

The Participants

Participants are 8th grade students from a secondary school in Northern Cyprus who were selected using a purposeful sampling method. Purposeful sampling models allow for detailed research by selecting situations thought to be rich in information and also allow for generalization to the universe (Patton, 1987, as cited in Yildirim & Simsek, 2016).The reason for the study being conducted in this secondary school is that the students here are suitable for the study because of their quality. Students who participated in the study were selected through an exam conducted by the TRNC National Education and Culture Ministry in 5th grade, and they had education according to the syllabus until grade 8.

The study was carried out with 100 students who were selected randomly for two experimental (female: 22, male: 28) and two control (female: 21, male: 29) groups. The ethical committee approved the study. The study was also approved by the TRNC National Education and Culture Ministry to be applied.

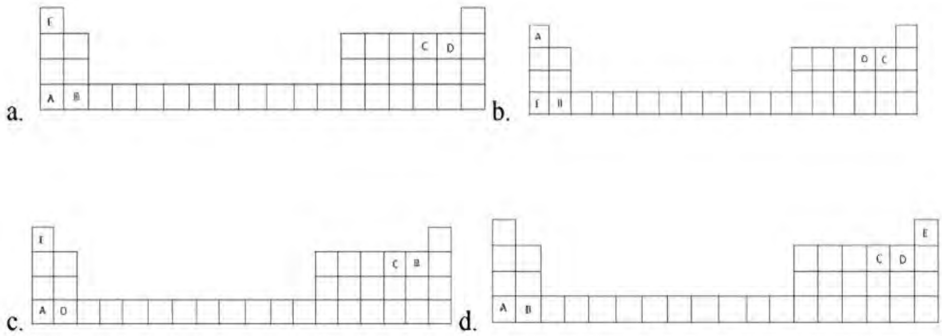
Data Collection Tools

In order to assess the conceptual understanding of students related to concept pairs, the chemistry concept diagnostic test (CCDT) that researchers developed was used (Varoglu et al., 2020). Expert opinion was taken from two expert chemistry teachers and two instructors who study chemistry education for the content validity of CCDT. The reliability coefficient was calculated as.857 for the first tier and.908 for both tiers (Varoglu et al., 2020). The students were asked to give an answer to a related concept pair at the first tier and explain the reason for the answer at the second tier (Treagust, 1986). The second tier of two-tier concept diagnostic tests provides the possibility to underline students' answers (Kaltakci Gurel et al., 2015; Tsui & Treagust, 2010).

There are 17 two-tiered questions in CCDT. The first tier of each question in CCDT consists of answers with four choices, similar to multiple-choice tests, and the second tier consists of four choices that underline why they chose that answer (Varoglu et al., 2020). When assessing CCDT, students who answer both tiers of the test correctly get 1 point, and students who answer either only one tier or both incorrectly get 0 points. In this context, the lowest grade in CCDT is 0, and the highest grade is 17. Each question in CCDT focuses on concept pairs jointly. A question-related ionic-covalent concept pair is given below as an example:

Through the following, which one of the given tables represents the true location for A, B, C, D, and E?

(i) A & D form ionic bond (ii) E & C form covalent bond (iii) E & D form covalent bond (iv) B & C form ionic bond



- Which of the following statement can best explain your answer?
  - (a) Covalent bonding is not formed between non-metals.
  - (b) Ionic bonding forms between non-metals by sharing electrons.
  - (c) Non-metals (except hydrogen) are not on the right side of the periodic table.
  - (d) Covalent bonding is formed with non-metals by sharing electrons, and ionic bonding forms between metals and non-metals by transferring electrons.

In order to assess the conceptual understanding of the students in experimental and control groups, the students were asked open-ended questions on the definition of each concept pair, and their answers were assessed according to their understanding level (Abraham et al., 1994). With the open-ended question, students could explain the reason for their answers, so they were constructing their answers, and therefore, they were freer to express their opinions on the subject (Gronlund, 1998). An example of an open-ended question on the ionic-covalent concept pair is given below.

Please explain the concepts given below:

Table 1. Example grading on ionic-covalent concept pair (Abraham et al., 1994)

NS	Grading criteria	Example student answers
0	Empty answers, meaningless, unrelated answers, answers which repeat the question	"Covalent" "Ionic"
1	Scientifically incorrect answers	"Covalent connection is formed with electron exchange." "Covalent connection is formed with electron exchange."
2	Partially correct answers given because of concept mistakes, incorrect examples	"Covalent connection is formed by mutual utilization of electrons, like NaCl." "Ionic connection is formed between metals and non-metals, in HCl example, hydrogen gives one electron and chlorine takes one electron."
3	Correct answers are given with examples and without a definition, and deficient, partially correct explanations	"Covalent connection is formed between non-metals." "Ionic connection is formed between metals and non-metals."
4	Scientifically correct explanations given on ionic & covalent connections	"Covalent connection is a chemical connection type which is formed as a result of electrons coming together between atoms, and it is formed between non-metals." The type of connection in HCl can be an example." "Ionic connection is a chemical connection between metal and non-metal atoms formed as a result of gravitational force deriving from antipole electricity load."

Ionic: ………

Covalent:……

Semi-constructed interviews were conducted, and feedback forms were used to gather the opinions of students in the experimental group on the learning environment. The researchers developed the interview form and the feedback form and obtained expert opinion to provide validity.

Data Analysis

The quantitative data collected in the study was analyzed using the SPSS package program, and statistical analyses were performed as needed., standard deviation, minimum, maximum, skewness, and kurtosis values, which are descriptive statistics, were analyzed. Inferential statistics were conducted after conducting and analyzing assumptions for the parametric tests. An independent sample t-test was used in order to analyze the difference between CCDT post-test and pre-test scores of students. On the other hand, open-ended questions focused on concept pairs in the study were graded following Abraham et al. (1994). **Table 1** shows an example of how students' answers to a question on the ionic-covalent concept pair are assessed.

Implementation phase

The study's 5E learning model supported by concept map activities was prepared about anion-cation, acid-base, ionic-covalent, metal-non-metal, and number of protons-number of electrons concept pairs in the periodic table topic. Students were informed about the 5E learning model and concept maps before the implementation. After that, the students participating in the study were asked to prepare a concept map, considering they had information about the water concept. It is found that students easily prepared the concept map and were able to form cross-links. In the model used in the study, concept maps were systematically placed in the exploration, explanation, and evaluation phases of the 5E model. Therefore, it was used in the exploration phase of the 5E learning model, in which the students are the most eager to explore new information or concepts, and in the explanation phase, in which the learning is more active, and students will find answers to questions in their minds and in the evaluation phase. It is stressed in many studies that concept maps can be used for assessment purposes (Aubrecht et al., 2019; Hasturk, 2017; Hung et al., 2012).

In the presented study, the exploration, explanation, and evaluation phases of the 5E learning model were used with the support of concept maps. An example class that is prepared to use the 5E learning model together with concept maps systematically in phases is given below.

Engagement phase

Students' attention is gathered with the question on electron exchange given below:

> "Merlin went to the stationery to buy a book. His friend Arthur was waiting for Merlin to buy a book. Merlin had 10, and Arthur had 20 dollars. With the current increase in prices, each book costs 15 dollars. Merlin lent five dollars to Arthur to buy a book. Can atoms do a similar exchange between themselves with electrons as the money exchange we mentioned? If so, why?"

Exploration phase

A concept map supported this phase. In this context, students are separated into two groups. Atomic numbers and symbols of 1^{st}, 2^{nd}, and 3^{rd} period elements are written on cards, and the cards are put into a box. Teams draw cards from the box, and they start telling with how many electrons the element is written on the card will reach octet. If it is an ion, what is its charge? This makes the other group guess the name of the element. After all the cards are drawn, the students will discuss how, and which atoms of these elements can form a connection. The students are asked to create a concept map using atom, ion, number of protons, number of electrons, anion, cation, and octet concepts. In this phase, students form groups of two, discussing and creating concept maps in direction of concepts given. **Figure 1** reflects a representation of a concept map drawn by the students.

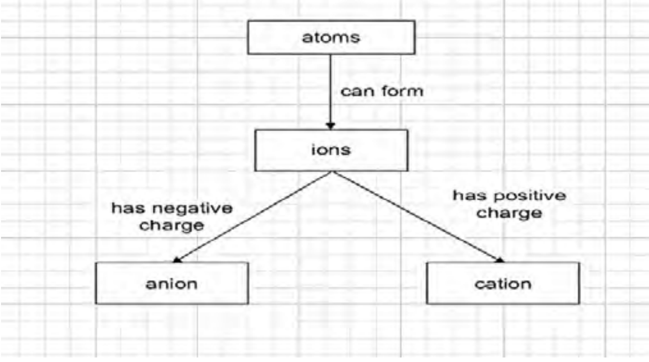


Figure 1. A representation of an example concept map prepared by student groups in the exploration phase (Varoglu, 2021)

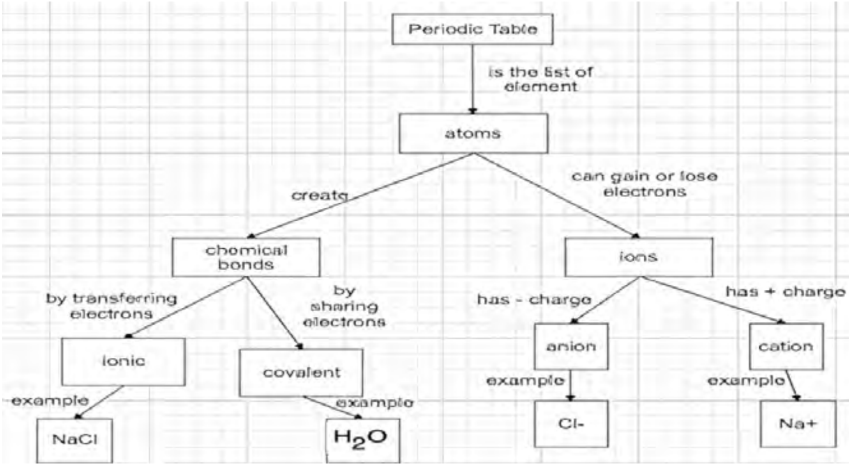


Figure 2. A representation of a concept map used in the explanation phase (Varoglu, 2021)

Figure 3. Element cards are prepared for the elaboration phase (Varoglu, 2021)

Explanation phase

The concept map prepared and presented by the teacher in this phase is presented in **Figure 2**. The teacher transfers information to the students using the concept map.

Elaboration phase

In order to depend on what the students have learned, they are asked to write down the ions of the atoms of the given element, classify them as anion or cation, and define the compound formed between same-shaped ions as ionic or covalent (**Figure 3**). In this phase, students will explore how many electrons the element will have when considering their number of protons and group numbers on the periodic table. Also, they will learn that the elements in the same group will reach octet if they take or give the same number of electrons. Students will become aware that the number of exchanged electrons will be the same when chemical compounds are formed by discussing their chemical formula in case elements with the same geometrical shape form a compound. A photo of the materials prepared for the activity of this phase is given above (**Figure 3**).

For example, one of the students drew the card of the element Mg, which is round-shaped. The student stated the element's place on the periodic table, its atom number, and that it can reach octet if it gives two electrons, and its charge will be +2 if it creates an ion. Another student drew the round-shaped element Cl card and stated that it is in group 7A and will reach octet if it takes one electron with a -1 charge. After that, students who drew the same geometrical-shaped cars will exchange their cards and discuss among themselves to reach the conclusion that these two elements will form an ionic compound, and their formula will be ($MgCl_2$).

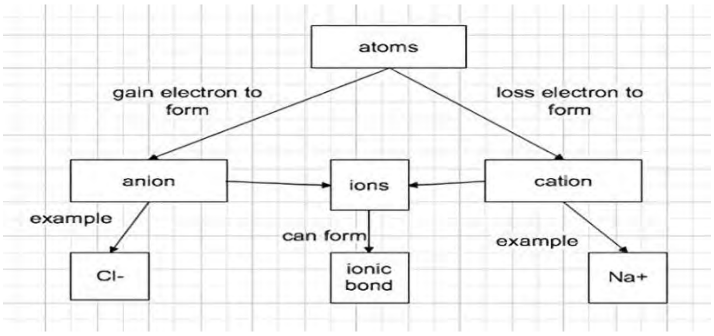


Figure 4. A representation of an example concept map prepared by student groups in the evaluation phase (Varoglu, 2021)

Table 2. Results of independent samples t-test

Group	n	X	S	SD	t	p-value
Experimental	50	15.06	5.29	98	6.108	0.000
Control	50	8.68	4.81			

Evaluation phase

A concept map supports this phase, and the students were asked to prepare a concept map from scratch. **Figure 4** shows an example of a concept map made by the students during the evaluation phase.

During this process, students in the control group will be taught the same subjects using the lesson book and teacher-centered current teaching method. The teacher used direct instruction and question-and-answer techniques.

RESULTS

The effect of the learning method utilized in the study on the understanding of students in control and experimental groups on concept pairs related to periodic table topics was assessed following their CCDT test grades and answers they gave to open-ended questions. Also, the opinions of experimental group students on the learning environment were assessed.

Findings Related to the 1st Research Question

We used an independent samples t-test to see if there was a significant difference in pre-test grades between experimental and control group students. The analysis has determined that there is no meaningful difference between the experimental groups' grades ($X_{experimental}$=4.52, ss=3.04) and the control groups' grades ($X_{control}$=4.08, ss=2.78).

The experimental and control group students' post-test results ($X_{experimental}$=10.20, ss=3.80, and $X_{control}$=7.68, ss=3.61) were analyzed using an independent samples t-test, and it was determined that there is a meaningful difference (t[98]=0.40, p<.05).

Findings Related to the 2nd Research Question

The results consisting of sum of the scores for each concept pair obtained from the evaluation according to the Abraham et al. (1994) reflected in **Table 2**. As a result of the independent samples t-test, a significant difference was determined in terms of the students' understanding of these concepts between the experimental and control groups (t[98]=6.11, p<.01).

Concerning the second research question, the level of understanding of students in the experimental group and the control group for each concept pair was looked at (**Figure 5**).

The findings on each concept pair shown in **Figure 5** show that students in the experimental group have a higher level of understanding than students in the control group. It can be seen that the maximum understanding level of students in the experimental group for anion, cation, ionic-covalent, metal-non-metal, and number of protons and electrons is at the level of four. Students in the experimental group scored very high in understanding levels of four compared to students in the control group. On the other hand, it has been determined that the maximum understanding level of students in the experimental group for the acid-base concept pair is three, and the maximum understanding level of students in the control group for the same concept pair is zero. It can be seen that the answers given by students in the experimental and control groups for the acid-base concept pair are at the lowest level (understanding level zero).

On the other hand, it is determined that the highest level of understanding, which is four, of students in the experimental group is for the anion-cation concept pair, and the students in the control group have reached the same level in the metal-non-metal concept. In summary, it has been found that students in the experimental group have given answers that are increasing in level, starting from the lowest level to the highest level for all concept pairs. As a result, it can be seen that the understanding level of students in the experimental group is higher than that of students in the control group.

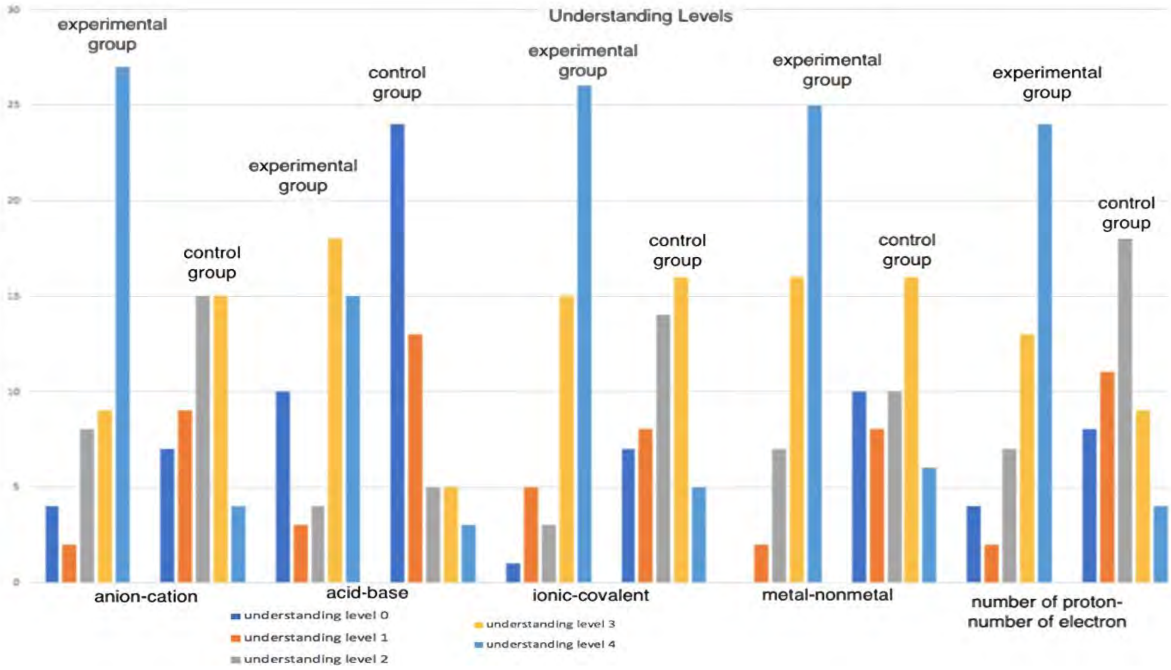


Figure 5. Understanding the level of students through the concept pairs (Source: Authors' own elaboration)

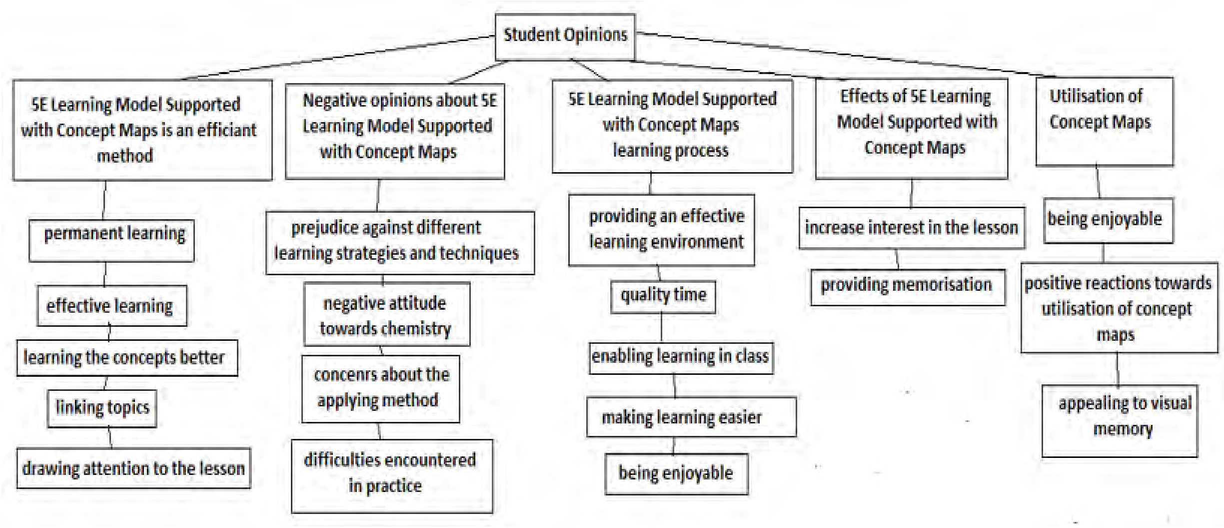


Figure 6. Student opinions (Varoglu, 2021)

Findings Related to the 3rd Research Question

This study was conducted to assess students' conceptual understanding related to the 5E learning model supported by concept maps. In this context, we have used feedback forms that include opinions of students and semi-constructed interviews with nine students who have scored comparatively high, low, and medium-level success in the final test results of CCDT.

We have used the content analysis method for qualitative data analysis. The interviews conducted in the study were recorded, and the recordings were transcribed with the consent of the students. Data acquired from open-ended questions, interviews, and feedback forms was coded to create sub-categories, and then categories were created from these sub-categories. After the coding process concluded, participants were shown results related to the data, and they certified these results. In the coding made as 1M-I or 2F-FF for the students, "1" and "2" represent the order of the student, "F" and "M" represent the gender, "I" represents the data from interviews, and "FF" represents the data acquired from the feedback form. The categories and sub-categories formed as a result of the data analysis are given in **Figure 6**.

Then, five categories from these 20 sub-categories were determined after the answers students gave to open-ended questions and interviews were analyzed. We have used summary content analysis, which reduces data sets to acquire important content in the study (Mayring, 2004). The purpose was to acquire a general overview that reflects the data set as a result of the analysis. Four of the five categories acquired as a result of the analysis were related to the 5E learning model supported with concept maps, and the last of them was related to the opinions of the students on the utilization of concept maps in the classes.

The opinions related to the 5E learning model supported with concept maps as an efficient method include the following: providing more sustainable and efficient learning with the 5E learning model supported with concept maps, it helps to learn concepts better and supports the creation of links between concepts, and it draws the students' attention to the class. Some of the students stated that they were used to having classes with the traditional methods and, therefore, they are not used to this new model. They do not like chemistry classes, and they always find chemistry classes boring in the negative opinions on the 5E learning model supported by concept maps category. Students stated that they found the classes more enjoyable with the 5E learning model supported with concept maps; they learned the subject in the class; they did not have to memorize; and they found the time spent in the class as quality time in the opinions on the 5E learning model supported with concept maps learning process category. In the category of opinions on the effects of the 5E learning model supported by concept maps, students have stated that their interest in the classes has increased, and they think it will be easier for them to memorize the things they have learned. The category of opinions on utilizing concept maps reflects students' opinions on concept maps. Students stated that using concept maps makes them use their visual memory, which is fun and useful when learning new things.

Some of the answers of students in each sub-category are given below.

Permanent learning

> 4F-FF: "The class was efficient because it helped us keep the things we learned in our minds more."

> 9M-I: "I think it was better. I am not very good at chemistry. I understood better this way. I understood the periodic table better and can memorize it better now."

Learning the concepts better

> 14F-FF: "The classes we had with this method were very efficient. I especially understood the concepts better and learned to create links between them."

Prejudice against different learning strategies and techniques

> 7F-FF: "As I am used to having classes the way we always do them, I was initially a bit hesitant. Nevertheless, I understood that it was beneficial afterward."

Quality time

> 22F-FF: "I think the administration provided us with the opportunity to have quality time with my friends and review the things we learned."

Making learning easier

> 46F-FF: "This method made me, and my friends learn the classes we had easily and kept the periodic table subject in our minds better."

Being enjoyable

> 16M-FF: "I want this method to be used in classes." The classes go faster as it is enjoyable and sincere."

> 18M-FF: "I do not remember any other chemistry or science class I have learned in this much fun."

Providing memorization

> 33F-FF: "I think I will remember the periodic table topic better in the exam. The information is like an image in my mind."

Appealing to visual memory

> 33F-FF: "I think I will better memorize the periodic table topic we learned with concept maps." It is as if the things I learned are before my eyes when I close them."

Positive reactions towards the utilization of concept maps

> 3F-I: "I liked the utilization of concept maps. Because I memorized the subject better."

Being enjoyable

> 6F-FF: "Concept maps were like a game to me; it was exciting to learn new things when playing a game."

DISCUSSION

The study examined the conceptual understandings related to anion-cation, acid-base, ionic-covalent, metal-non-metal, and number of protons-number of electrons concept pairs taught in the periodic table to 8th grade students with the 5E learning model supported with concept maps.

According to the analysis and assessment results of the study, the 5E learning model supported by concept maps is an efficient method that supports the conceptual understanding the students have of concept pairs in the periodic table topic. According to the literature, some studies show that using the 5E learning model by systematically supporting it with concept maps improves the students' conceptual understanding. In the literature on studies on chemistry education, there are studies on assessing students' success and conceptual understanding with the 5E learning model supported by different methods, techniques, and strategies. In the study that Gokalp and Adem (2020) conducted on 5E learning model phases with the REACT strategy and computer-assisted learning environments, they stated that they acquired efficient results with both methods. Derman and Badeli (2017) supported the context-based teaching method with the 5E learning model in teaching pure matter and compound topics for primary education 4th grade students. They reported that this method increased the students' conceptual understanding and positive attitude towards science class. As a result, it can be stressed that studies on the 5E learning model supported with different methods and techniques contribute to students' academic success (Bagci & Yalin, 2018), conceptual understanding (Supasorn & Promarak, 2015), improvement of scientific process skills (Izgi & Kalayci, 2020), problem-solving skills (Fadiawati et al., 2019), and critical thinking (Cahyarini et al., 2016).

The findings of this study follow the findings of studies on the 5E learning model (Demircioglu et al., 2016; Derman & Badeli, 2017; Sahin & Cepni, 2012; Putra et al., 2018) and teaching applications which were conducted with concept maps (Aydin et al., 2009; Kharatmal, 2009; Novak, 2005; Turan & Boyraz, 2004) that provide proof that it improves the conceptual understanding of the students.

In order to determine the opinions of the students in the experimental group on the learning environment prepared with the 5E learning model supported by concept maps, the answers of students to open-ended questions in the feedback form and their expressions in the semi-constructed interviews were analyzed. As a result, overall, students expressed positive opinions despite some negative opinions. According to the literature, generally, students have expressed positive opinions on the learning environment prepared with the 5E learning model (Bilgin et al., 2013; Demirbas & Pektas, 2015; Metin et al., 2011). Evans (2004) stated that the 5E learning model supports the students actively participating in the class, taking responsibility, and enjoying it.

As a result, we have determined that the conceptual understanding of students in the experimental group has improved more than that of students in the control group. The study assessed the conceptual understanding of students in experimental and control groups on related concept maps with CCDT and open-ended questions. According to the comparison between CCDT pre-test and final test results of the students in the experiment and control groups, it is found that the conceptual understanding of students in the experimental group is higher than the students in the control group. Similarly, it has been determined that the students in the experimental group have higher levels of understanding for all concept pairs compared to students in the control group, according to the answers they gave to open-ended questions. Also, students in the experimental group mostly stated positive opinions about the learning environment. In light of these findings, the 5E learning model supported by concept maps is considered an efficient method for improving students' conceptual understanding.

Suggestions for Further Research

It is suggested that teachers should constantly prepare new activities and consider conceptual misunderstandings in the dynamic education process to prevent them. The study assessed students' conceptual understanding with qualitative and quantitative approaches in the study, and it has been determined that the 5E learning model supported by concept maps improves the students' conceptual understanding of the related concept pairs. In this situation, it is suggested that teachers use the 5E learning model supported with concept maps for other chemistry classes and subjects.

Implications

According to the literature, the constructivist approach has positive effects on students learning (Jobrack, 2013; Shymansky, 1992). The 5E learning cycle that has various phases, helps students to construct their own knowledge with diversities on phases. This study improves 5E learning models phases with concept maps, and thus have several implications. First, our results shows that 5E learning cycle assisted with concept maps improved students conceptual understandings, so we highlight the importance of using this model in chemistry teaching. Many researchers used 5E learning model with various strategies, methods and techniques (Bagci & Yalin, 2018; Derman & Badeli, 2017; Gokalp & Adem, 2020).

In the literature, many lack of knowledge about science concepts reported (Kaltakci Gurel et. al, 2015; Treagust, 1986). Second, our study focus on some concept pairs that are essential for understanding chemistry. Further studies exploring students understandings about foundational concept pairs required.

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