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FACILITATING CONCEPTUAL CHANGE IN UNDERSTANDING STATE OF MATTER AND SOLUBILITY CONCEPTS BY USING 5E LEARNING CYCLE MODEL

MADDENİN YOĞUN FAZLARI VE ÇÖZÜNÜRLÜK KAVRAMLARINI ANLAMADA 5E ÖĞRENME MODELİNİN KULLANIMI İLE KAVRAMSAL DEĞİŞİMİN KOLAYLAŞTIRILMASI

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ABSTRACT: The main purpose of the study was to compare the effectiveness of 5E learning cycle model based instruction and traditionally designed chemistry instruction on 10th grade students' understanding of state of matter and solubility concepts. In this study, 119 tenth grade students from chemistry courses instructed by same teacher from an Anatolian High School in Ankara, Turkey took part. This study included two groups which were randomly assigned as experimental and control groups. During teaching the topic state of matter and solubility concepts, students were taught with instruction based on 5E learning cycle model in experimental group while students in control group were taught with the traditional instruction. The results revealed that 5E learning cycle model caused significantly better acquisition of the scientific conceptions related to state of matter and solubility concepts than traditional instruction.
Keywords: 5E learning cycle model, sate of matter and solubility, chemistry education.

OZET: Bu çalışmanın başlıca amacı, 5E öğrenme modeline dayalı öğretim yönteminin 10. sınıf öğrencilerinin maddenin yoğun fazları ve çözünürlük konularındaki kavramları anlamalarına etkisini geleneksel kimya öğretim yöntemi ile karşılaştırarak incelemektir. Bu çalışma, Ankara ilinde Atatürk Anadolu Lisesinde, aynı öğretmenin kimya derslerinde bulunan 119 onuncu sınıf öğrencilerinin katılımı ile gerçekleşmiştir. Bu çalışmada, deney grubu ve kontrol grubu olarak rastgele seçilen iki grup bulunmaktadır.Maddenin yoğun fazları ve çözünürlük kavramlarının öğrenimi sırasında, deney grubundaki öğrencilere 5E öğrenme modeline dayalı öğretim yapılırken, kontrol grubunda geleneksel öğretim kullanılmıştır. Sonuçlar göstermiştir ki, 5E öğrenme modeli geleneksel öğretim yöntemine kıyasla öğrencilerin maddenin yoğun fazları ve çözünürlük konusunu daha iyi kavramalarına neden olmuştur.
Anahtar Sözcükler: 5E öğrenme modeli, maddenin yoğun fazları ve çözünürlük, kimya eğitimi.

1. INTRODUCTION

Research on science education have consistently showed that students come to classrooms with well-established understandings about how and why everything behaves as they do (Posner, Strike, Hewson, & Gertzog, 1982; Resnik, 1983; Strike, 1983; Savinainen, Scott, & Viiri, 2004). However, students' existing knowledge which appears them logical, sensible, and valuable, may be differing from the definitions accepted by experts and scientific definitions (Osborne, 1982; Schoon & Boone, 1998). Students conceptions or ideas that are differ from the definitions accepted by experts or scientific community are generally called misconceptions (Hewson & Hewson, 1984; Schmidt, 1997; Sungur, Tekkaya & Geban, 2001), alternative conceptions (Driver & Easley, 1978; Taber, 2001), preconceptions (Novak, 1977), alternative frameworks (Kuiper, 1994; Gonzalez, 1997; Taber, 2001), naive conceptions (Champagne, Klopfer, & Gunstone, 1982), children's science (Osborne & Cosgrove,1983), alternative conceptual framework (Taber, 1998), intuitive conceptions (Lee & Law, 2001).

Students' pre-existing beliefs have important role in gaining new scientific knowledge and play an essential role in subsequent learning (Tsai, 1996). Since the knowledge is actively constructed by learner on the basis of the knowledge that individual already held (Duit & Tregaust, 1998), misconceptions should be taken into consideration and eliminated to prevent new ones developing (Olgun, 2008).

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It was accepted that misconceptions are persuasive, stable, and resistant to change via traditional instructional strategies and these beliefs may be found in individuals' cognitive structure even after completion of years of formal science instruction (Guzzetti, 2000; Osborne & Cosgrove, 1983; Stavy, 1991; Tsai, 1996; Wandersee, Mintzes, & Novak, 1994). Several contemporary instructional approaches based on constructivism were developed to overcome and remediate students' alternative conceptions. Instruction based on learning cycle model, also based on constructivist epistemology, is an instructional model in which conceptual change is facilitated (Boylan, 1988).

Instructional models based on learning cycle considered to be important and became popular as it use of coordinated and coherent sequencing lessons. 5E learning cycle model has a potential to be applied several levels in the design of curriculum materials and instructional sequences. Each phase in the 5E instructional model contributes learners to better understand scientific and technological knowledge and each phase has a different function (Bybee, 1997). These phases are engagement, exploration, explanation, elaboration, and evaluation. In the engagement phase (1), students are exposed to an object, problem, situation or events which were prepared to activate students' misconceptions that were identified before the instruction. And, these activities serve to create cognitive conflict and motivate students to learning activity. In exploration phase (2), the required time to investigate objects, materials, and situations is provided. Students have a chance to establish relationships, observe patterns, identify variables, and question events as a result of mental and physical involvement in the activity. Students try to find out the rationale behind their ideas to overcome and remedy their misconceptions. In explanation phase (3), concepts, process, and skills are presented simply, clearly, and directly by attracting students' attention to specific aspects of engagement and exploration experiences. The reason of the misconceptions and the correct scientific explanation of the misconception are also presented in this phase. In the elaboration phase (4), students are involved further experiences to extent or elaborate their concepts, skills, and processes. In other words, extension of the concepts is provided in this phase. So, students who have still misconceptions find a chance to remedy these misconceptions and comprehend their understanding. In the last phase, evaluation (5), students' misconceptions and educational outcomes that are identified at the beginning of the lesson are evaluated through formative evaluation to give students feedback about their misconceptions that they already had and their understandings (Bybee et al., 2006).

It was indicated that understanding of chemistry is a hard thing for most of the students (Nieswandt, 2001; Chittleborough, Treagust & Mocerino, 2002). Facilitating conceptual change and remediation of misconceptions about chemistry subjects should be the main aims to promote meaningful learning. Since state of matter and solubility constitute fundamentals of complex topics in chemistry, it is very important to find an instructional method that prevent students from the misconceptions and eliminate the misconceptions about this subject. For instance, the properties of gases and the fundamentals of gases concepts can be understood more meaningfully when the phase changes concepts are learned appropriately. Although many researchers investigated students' misconceptions about chemistry topics such as electrochemistry (Garnett & Treagust, 1992), acid-base (Cakır, Uzuntiryaki & Geban, 2002), atom and molecules (Griffiths & Preston, 1992), chemical equilibrium (Chiu, Chou & Liu, 2002), chemical change (Hesse & Anderson, 1992), researches about state of matter and solubility topic are limited. As it was indicated above, 5E learning cycle model can be effective on removing students misconceptions related to chemistry concepts especially in state of matter and solubility concepts.

2. METHOD

2.1. Purpose

The main purpose of this study was to investigate the effectiveness of instruction based on 5E learning cycle model over traditionally designed chemistry instruction on 10^{th} grade students' understanding of state of matter and solubility concepts.

2.2. Subjects

An Anatolian High School was chosen from the schools in Çankaya district in Ankara. Four classes of chemistry course were selected randomly from the 12 possible classes of this Anatolian High School. Since the classes were formed at the beginning of the semester by school administration, it was not possible to assign students randomly to both experimental and control group. However, the classes were randomly assigned as control and experimental group. 119 tenth grade students that involve 69 male and 50 female students participated this study. The experimental groups in which instruction based on 5E learning cycle model was implemented consisted of 59 tenth grade students while the control groups in which instruction based on traditional methods was implemented consisted of 60 tenth grade students.

2.3 Instruments

State of Matter and Solubility Concept Test (SMSCT): This test consisted of 20 multiple choice and 2 open-ended questions, five of them taken from literature (Mulford & Robinson, 2002; Ebbing & Gommon, 2005), and the rest of the questions were developed by researcher by examining related literature (Ahmad, 2000), textbooks (Ebbing & Gommon, 2005; Sarıkaya & Erdik, 2005). The test includes State of Matter concepts which include solid and liquids, phase transitions, boiling point and melting point, heat of phase transition subtopics; Solubility concepts which include solubility and the solution process, colligative properties of solutions, boiling point elevation and freezing point depression subtopics. The multiple choice items in the test included one correct answer and three or four distracters that reflected students' probable alternative conceptions identified in the related literature (Kind, 2004; Stavy, 1990; Osborne & Cosgrove, 1983; Bodner, 1991; Mulford & Robinson, 2002; Ure & Colinvaux, 1989; Krnel, Watson & Glazar, 1998; Hatzinikita & Koulaidis; 1995) and interviews with chemistry teachers (see Table 1). Before using of the test in its actual aim, a pilot test was conducted to evaluate its reliability and validity aspects. Cronbach-alpha reliability of the pilot scores was found 0.673.

Table 1: List of Students' Misconceptions about State of Matter and Solubility

The weight or mass of a substance changes as it melts or evaporates. Mass not conserved.
Water (or alcohol) disappears as it evaporates.
Bubbles from boiling water made of air, or air and oxygen gas, or hydrogen gas, or heat, or oxygen and hydrogen gas.
The temperature at which water (or any substance) boils is the maximum temperature to which it can be raised
Molecules are breaking up on boiling and reforming on condensing during the state change of matter.
Freezing always occurs at cold temperatures and boiling occurs at hot temperatures.
Water condensing on the outside surface of a sealed glass jar containing ice comes through the glass, or due to the coldness that comes through the glass, or due to the cold surface and dry air (oxygen and hydrogen) react to form water, or due to the water in the air sticks to the glass.
The ice or the cold water from the ice prevented the water's temperature from rising during the process of melting.
The reason for constant temperature is due to the thermometer being in the ice cube in the process of melting.
Water molecules are largest and heaviest when in the solid phase.
The meaning of "dissolving" has been referred to outside action such as stirring, mixing, and in some cases heating or to dissolve means to mix
Mass of sugar and water solution is less than mass of the sugar and water.
The process of melting and dissolving are used interchangeably.
Sugar breaks down into its ions or elements during the process of dissolving in water.
Salt becomes liquid salt when it dissolves.
Concentration of a saturated solution increases or decreases as water evaporates
A strong solution of a salt contains more of that salt than a weak solution, without regard to the quantity of solution.

Science Process Skills Test (SPST): The test was developed by Okey, Wise and Burns (1982). This test consisted of 36 four-alternative multiple choice questions. The reliability of the test was found to be 0.85. This test includes five subsets designed to measure the different aspects of science process skills. These are identifying variables, identifying and stating hypothesis, defining operationally, designing investigations, graphing and interpreting data.

2.4. Treatment

This study was conducted over six-week period. 119 tenth grade students from four chemistry classes of same teacher were participated in the study. Two of these classes were assigned as the experimental group in which the instruction was designed with respect to instruction based on 5E learning cycle model, the other classes were assigned as the control group in which the instruction was designed with respect to traditional instruction. During the treatment, the state of matter and solubility concepts was covered as part of the regular curriculum in the chemistry course. The classroom instruction was two 40-minute sessions per week.

In the control groups, the teacher used lecture/discussion method to teach state of matter and solubility concepts. The students were instructed with respect to teaching strategies that are relied on teacher explanation and textbooks without considerations of students' alternative conceptions. Before the lessons, reading the related topics in the textbooks on their own was offered to the students. The definitions of the concepts and chemical reactions were written to the chalkboard and worksheets were passed out for students to complete. The main underlying principle was that the whole knowledge about the subject was known only by teacher and it is the teacher's responsibility to transfer that knowledge as fact to students. After teacher's explanations of concepts, discussion environment was directed by teacher's questions to discuss some concepts that were not understood completely by students. The worksheets involved some practice activities, open-ended questions to reinforce the concepts presented in the classroom sessions.

In the experimental groups, the alternative conceptions were taken into account and the plausibility of scientific conceptions was provided. In addition, instruction was designed to maximize student active involvement in the learning process. Before the treatment, the teacher was trained about three hours. In this training, the teacher was informed about constructivist learning strategies, how to implement lesson that was design based on 5E learning cycle model, and in which stage the activities will be performed. In engagement phase (1), the teacher started the lecture with inquiry questions with respect to the list of alternative conceptions to activate students' prior knowledge and misconceptions and promote the interaction in class. Teacher attempted to create a discussion environment and tried to explore students' inappropriate conceptions about the related concepts with these questions. Teacher acted as a guide in this discussion and directed students to understand their conceptions were not sufficient to explain some phenomena. In other words, students were puzzled and actively motivated by these discussions. In the exploration phase (2), activities were designed for students to acquire concrete experiences upon which concepts, processes, and skills formulated. Demonstrations, hands-on activities, and laboratory activities were used in this phase. Some of these activities were about phase changes, melting point and boiling point, colorimeter, vapour pressure, dissolving of NaCl in water, unsaturated solutions, saturated solutions, supersaturated solutions, and boiling point elevation and freezing point depression. Teacher behaved as a facilitator and coach in this phase and supplied sufficient time and opportunity to students for investigating objects and materials. In the exploration (3) phase, students attention was directed to specific aspects of the engagement and exploration experiences. First, teacher gave opportunities to students to explain their opinions and ideas. Second, scientific and technological explanations were introduced in a direct, explicit, and formal manner. Video animations such as changes of state, solution formation by dilution, dissolution of NaCl in water, solution formation from a solid were used to present concepts and skills briefly, simply, clearly, and directly. In the elaboration phase (4), students were involved further experiences to extent or elaborate the concepts, processes, or skills. The activities that were used in this phases were closely related to activities that were presented in exploration phase, but they were completely based on new situation. Teacher gave students time to deal with these activities and also created discussion environment based on these activities. As in the exploration phase, these activities were some laboratory activities, hands-on activities, demonstrations, or discussion of an event. Students defended and presented their ideas and approaches on new situation. Students found opportunities to gain information from each other, the teacher, and activities they conducted during the discussion sessions. In the evaluation phase (5), teacher gave students opportunities to evaluate their understanding and skills that they acquired during previous phases. In addition, students received feedback about their understanding and skills.

3. RESULTS

Prior to treatment, t-test were performed to investigate whether there was a significant mean difference between the control group (CG) and experimental group (EG) with respect to students' pretest scores on SMSCT. The results revealed that there was no significant difference between CG and EG in terms of students understanding of state of matter and solubility concepts, $t(117) = -0.519$, $p > 0.05$. While the experimental group students' pre-test mean (X_{EG}) score was 10.06, the control group students' pre-test mean score (X_{CG}) was 9.92.

After the treatment, univariate Analysis of covariance (ANCOVA) was used to determine the effectiveness instruction based on 5E learning cycle model on understanding of sate of matter and solubility concepts when students' science process skills was controlled as covariate. The analysis results showed that there was a significant difference between the post-test mean scores of the students taught by instruction based on 5E learning cycle model and those taught by traditional method with respect to the understanding of state of matter and solubility concepts when science process skill was controlled as a covariate ($F = 236.32$; $p<0.05$). The experimental group scored significantly higher than control group ($X_{EG} = 17.28$; $X_{CG} = 11,96$). On the other hand, science process skills was a statistically significant predictor for understanding of state of matter and solubility concepts ($F = 49.09$; $p<0.05$).

Items in the SMSCT were developed with respect to students' misconceptions in state of matter and solubility concepts and the objectives in the curriculum. The items were also written in terms of levels in Bloom's taxonomy. The proportions of correct responses and alternative conceptions were examined by using item analysis for experimental and control group. The results revealed that whereas the percentages of correct responses are nearly the same in the questions requiring simple recall, define, and label for both experimental and control group students, the percentages of correct responses was higher in the questions requiring interpret, organize, and integrate the knowledge for experimental group students. For instance, one of the items related to temperature changes during the phase changes. In this item, students were asked to simply to recall whether the temperature changes during phase changes. After the treatment, 60 % of the students in control group and 72.9% of the experimental group students answered this question correctly. On the other hand, another item was related to the relationship between temperature changes and molar concentrations of saturated solutions. Students were required integrating their knowledge about saturated solutions with the effect of temperature on concentration changes of the solutions, and interpreting a graph to answer this item. The percentage of students who answered this item correctly was 38.3% in control group. In experimental group, 71.2% of the students answered this item correctly. It was realized that students in control group had some difficulties to integrate and infer their knowledge to answer related questions. This striking difference can be seen in another item related to molecular appearance of the water in different phases. Students in experimental group were better in understanding phase change concepts in molecular level. After the treatment, while 38.3% of the students in control group selected the desired answer, 59.3% of the students in experimental group answer this item correctly. In addition, the results indicate that treatment has an effect on remediation of misconceptions. For example, an item was related to students' misconceptions about defining the bubbles that form during the boiling process. Whereas 40% of the students in control group defined these bubbles properly, the percentage of students who defined the bubbles that form during the boiling process was 72.9% in the experimental group. Moreover, 58.3% of the students in control group held the alternative conception about the 'condensing water on the outside surface of a sealed class jar containing ice', whereas 40.7% of the students in experimental group held this misconception after the treatment. What is more, students in the experimental group used better the relevant information in adressing the problems, interpret the information, and use the priciples to solve the problems in anwering the essay type items. For instance, students required to know some of the principles about the colorimetry to answer one of the essay type question. The results revealed that while 56.7% of the students in control group responded this item correctly, 67,8% of the students in experimental group answered this item correctly.

Moreover, in an item, students were required to simply recall the conservation of mass during phase changes. The misconception which was stated as "the weight or mass of a substance changes as it melts or evaporates, mass not conserved" was identified from literature and structured interviews at the beginning of the study. After the treatment, 26.7 % of the students in control group held this misconception; on the other hand only 6.8 % of the students in experimental group had this misconception. In other words, whereas 61.7% of the students in control group answered this question correctly, the proportion of students in experimental group who answered this item was 86.4%. In addition, 11.7% of the students in control group selected only the correct response, the reason of the correct response were not written. And, 6.4% of the students in experimental group did not write the reason of the correct response. Therefore, the percentages of correct responses for this item in both groups indicated as evidence to say that instruction based on 5E learning cycle model improve students' performance skills better when compared with the instruction based on traditional method. In another items, it was required thinking critically to answer these items correctly. Whereas 25% of the students in control group answered one of these items correctly, the percentage of correct response for this item was 66.1% in experimental group. In addition, while 23.3% of the students in control group answered the other item correctly, 59.3% of the students in experimental group answered this item correctly

4. DISCUSSION AND IMPLEMENTATION

It was found that the instruction based on 5E learning cycle model caused a significantly better acquisition of scientific conceptions and elimination of alternative conceptions related to state of matter and solubility concepts than the traditionally designed chemistry instruction. There is a consistency between the findings in our study and the previous studies in that instruction based on 5E learning cycle can facilitate learning of scientific concepts (Akar, 2005; Coulson, 2002; Boddy, Watson, & Aubusson 2003; Garcia, 2005; Campell, 2000; Balcı, Çakıroğlu & Tekkaya, 2006; Lord, 1997; Mecit, 2006; Bevenino, Dengel & Adams, 1999). In these studies, activities in the phases of 5E learning cycle model were used to remedy students' alternative conceptions and better acquisition of scientific conceptions. In addition, 5E learning cycle model use a sequence and emphasis the phases in this sequences and use the work of Jean Piaget (Piaget & Inhelder, 1969; Piaget, 1975). Moreover, 5E learning cyle model view learning as dynamic and interactive process and this model believes that changing and improving conceptions often require to challenge students' current conceptions and to show students the inadequacies of these concepts.

The superiority of instruction based on 5E learning cycle model caused from its instructional sequence and the activities that used in the phases of 5E learning cycle. In the engagement phase (1), activities were developed to create interest and generate curiosity which involved a problem, situation, or an event. The activities that were employed in this phase exposed students' prior knowledge and made connections to present and future topics. In the exploration phase (2), students were exposed to activities to explore the ideas. The activities which were common for all students in class were designed for students to identify the current concepts, include misconceptions, processes and skills and facilitate conceptual change. In the explanation phase (3), the concepts, processes, or skills became plain, comprehensible, and clear. Although teacher preferred to use verbal explanations, variety of techniques and strategies such as videos, films, and educational courseware were employed. In addition, students found opportunities to explain their ideas and concepts related to state of matter and solubility concepts. In elaboration phase (4), the extension of concepts that had experienced through the previous three stages was achieved. Students who had still misconceptions found additional time to understand a concept in terms of the exploratory experience and to remedy misconceptions. In the evaluation phase (5), students found opportunity to evaluate their understanding, which were gained in previous phases. In addition, feedback on the adequacy of students explanation were provided by teacher.

On the other hand, the traditional instruction in this study comprised lectures given by teacher, use of textbooks, and clear explanation of important concepts. The major responsibility of the teacher in this group was transferring the knowledge to the students. The difference between the two strategies was that while the traditional approach did not take account students' alternative conceptions, the conceptual change approach explicitly dealt with students alternative conceptions. The results found in this study support the view that traditional instruction methods have not enough quality to eliminate students' alternative conceptions.

Coulson (2002) conducted a study to investigate how varying levels of fidelity to the 5E learning cycle model affected student learning. It was found that teachers who taught their students with medium of high levels of fidelity to the 5E learning cycle model contributed students leaning gains nearly double that of teachers did not used the model or used with levels of fidelity. In other words, when teachers implemented the 5E learning cycle model with a medium or high level of fidelity, the learning gains experienced by their students were significantly greater than the learning gains of teachers who did not adhere closely to the 5E learning cycle model. In this study, the lessons that implemented in both experimental and control group were observed by researcher and observation checklist that was prepared by the researcher was completed. The evidences gathered from the results of observations indicated that teacher implemented the 5E learning cycle model with a high level of fidelity for the current study.

Also, a significant portion of variation in students' understanding of state of matter and solubility concepts was accounted by the degree of students' science process skills in this study. It is useful to bring out analysis ability of students in solving complex problems that requires students' conceptual understanding, because it measures the intellectual abilities of students including the items related to identifying variables, identifying and stating the hypotheses, operationally defining, designing investigations and graphing and interpreting data. To understand complex concepts and problems in science, students should be able to apply fundamental facts and principles, use appropriate conceptual and theoretical frameworks, and perform calculations.

In instruction based on 5E learning cycle model, students' prior knowledge were taken into account and integrated with the new knowledge. As it was indicated, it is very difficult to understand concepts in meaningful way when the prior conceptions are inconsistent and students can not link the new knowledge with existing knowledge. Students' misconceptions were examined by teachers at the beginning of the instruction based on 5E learning cycle model to avoid students to create more misconceptions in their mind. Well designed instruction based on 5E learning cycle model can lead better acquisition of scientific concepts. Therefore, the principles and the fundamentals of 5E learning cycle model should be explained to science and chemistry teachers in in-service teacher training programs.

5. RECOMMENDATIONS

Similar studies can be conducted in different school types or different grade levels with a larger sample size to increase generalizability of the study. Studies can be conducted to investigate the effect of instruction based on 5E learning cycle model on students' understanding of concepts, attitudes and motivations other than state of matter and solubility concepts. In addition, similar studies can be conducted to investigate the effect of instruction based on 5E learning cycle model on students' understandings of concepts, students' motivation and learning strategies in other subject areas such as biology and physics.

REFERENCES

Ahmad, J. (2000). Crystallization from a Supersaturated Solution of Sodium Acetate. *Journal of Chemical Education*, *77*(11), 1446.

Akar, E. (2005). *Effectiveness of 5e learning cycle model on students' understanding of acid-base concepts*. Unpublished master thesis, Middle East Technical University, Turkey.

Balci, S., Cakiroglu, J., & Tekkaya, C. (2006). Engagement exploration, explanation, extension, and, evaluation (5E) learning cycle and conceptual change text as learning tools. *Biochemistry and Molecular Biology Education*, *34*(3), 199-203.

Bevenino, M., Dengel, M. J., & Adams, K. (1999). *Constructivist Theory in the Classroom*. The Clearing House.

Boddy, N., Watson, K. & Aubusson, P. (2003). A trial of five Es: A referent model for constructivist teaching and learning. *Research in Science Education. 33*(1), 27-42.

Bodner, G. M. (1991). I have found you an argument. *Journal of Chemical Education***,** *68*(5), 385-388.

Boylan, C. (1988). Enhancing learning in science. *Research in Science & Technological Education, 6*(2), 205-217.

Bybee, R. W. (1997). *Improving Instruction. In Achieving Scientific Literacy: From Purposes to Practice*. Portsmouth, N.H: Heinemann.

Bybee, R.W., Taylor, A.J., Gardner, A., Van Scotteer P., Powell, J.C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications*. Full report. Colorado Springs.

Cakir, O. S., Uzuntiryaki, E., & Geban, O, (2002). *Contribution of conceptual change texts and concept mapping to students' understanding of acid and bases.* Paper presented at the annual meeting of the national association for research in science teaching, New Orleans, LA.

Campbell, M.A. (2000). *The effects of the 5E learning cycle model on students' understanding of force and motion concepts*. Unpublished master thesis, Millersville University, Florida.

Champagne, A. B., Klopfer, L. E., & Gunstone, R. F. (1982). Cognitive research and the design of science instruction. *Educational Psychologist*, *17*(1), 31-53.

Chittleborough, G.D., Treagust, D. F., & Mocerino, M. (2002). *Constraints to the development of first year university chemistry students' mental models of chemical phenomena.* Teaching and Learning Forum: Focus on the Student. 1-7.

Chiu, M.-H., Chou, C.-C., & Liu, C.-J. (2002). Dynamic processes of conceptual change: Analysis of constructing mental models of chemical equilibrium. *Journal of Research in Science Teaching***,** *39*(8), 688-712.

Coulson, D. (2002). *BSCS Science: An Inquiry Approach: 2002 Evaluation Findings*. Arnold, MD: PS International.

Driver, R., & Easley, J. A. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education, 5*, 61-84.

Duit, R., & Treagust, D. F. (1998). *Learning in science - From behaviourism towards social contructivism and beyond.* International handbook of Science Education, Part 1. B. J. Fraser, Tobin, K. G. Dordrecht, Netherlands, Kluwer Academic Press**:** 3-25.

Ebbing, D. D., & Gammon, S. D., (2005). General Chemistry. New York, Boston: Houghton Mifflin Company.

Garcia, C. M. (2005). *Comparing the 5Es and traditional approach to teaching evolution in a hispanic middle school science classroom*. Unpublished master thesis, California State University, USA.

Garnett, P. J., & Treagust, D. F. (1992). Conceptual difficulties experienced by senior high school students of electrochemistry: Electric circuits and oxidation-reduction equations. *Journal of Research in Science Teaching***,** *29*(2), 121-142.

Gonzalez, F. (1997). Diagnosis of Spanish primary school students' common alternative science conceptions. *School Science and Mathematics, 97*(2), 68-74.

Griffiths, A. K., & Preston, K. R. (1992). Grade-12 students' misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Science Teaching*, *29*(6), 611-628.

Guzetti, B, J. (2000). Learning counter intuitive science concepts: what have we learned from over a decade of research? *Reading, Writing, Quarterly*, *16*, 89-95.

Hatzinikita, V & Koulaidis, V (1995). *Children's and undergraduate students' conceptions of the changes in satte of water.* In Proceedings, 2nd European Conference on Research in Chemical Education. University of Pisa, Italy.

Hesse, J. J., & Anderson, C. W. (1992). Students' conceptions of chemical change. *Journal of Research in Science Teaching*, *29*(3), 277-299.

Hewson, P. W., & Hewson, M. G. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science*, *13*, 1-13.

Kind, V. (2004). *Beyond Appearances: Students' misconceptions about basic chemical ideas.* Durham: Durham University.

Krnel, D., Watson, R. , Glazar, S. (1998). Survey of research related to the development of the concept of 'matter'. *International Journal of Science Education, 20*(3), 257-289.

Kuiper, J. (1994). Student ideas of science concepts: Alternative frameworks? *International Journal of Science Education*, *16*(3), 279-292.

Lee, Y., & Law, N. (2001). Exploration in promoting conceptual change in electrical concepts via ontological category shift. *International Journal of Science Education*, *23*(2), 111-150.

Lord, T. R. (1997). A comparison between traditional and constructivist teaching in college biology. *Innovative Higher Education, 21*(3), 197-216.

Mecit, Ö. (2006). *The effect of 7E learning cycle model on the improvement of fifth grade students' critical thinking skills*. Unpublished doctoral dissertation, Middle East Technical University, Turkey.

Mulford, D. R. & Robinson, W. R. (2002). An inventory for alternate conceptions among first-semester general chemistry students. *Journal of Chemical Education*, *79*(6), 739-744.

Nieswandt, M. (2001). Problems and possibilities for learning in an introductory chemistry course from a conceptual change perspective. *Science Education*, *85*(2), 158-179.

Novak, J. D. (1977). *A theory of education*. Ithaca, N. Y.: Cornell University Press.

Okey, J. R., Wise, K. C., & Burns, J.C. (1982). Integrated process Skill Test-2 (Avaliable from Dr. James R. Okey, Department of Science Education, University of Georgia, Athens, GA 30602).

Olgun, O. S. C. (2008). Examining the fifth graders' understanding of heat and temperature concepts via concept mapping. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 34*, 54-62.

Osborne, R. (1982). Conceptual change - For pupils and teachers. *Research in Science Education, 12*, 25-31.

Osborne, R., & Cosgrove, M. (1983). Children's conceptions of the changes of state of water. *Journal of Research in Science Teaching*, *20*(9), 825-838.

Piaget, J. & Inhelder, B. (1969). *The Psychology of the Child*. NY: Basic Books.

Piaget, J. (1975). *Equilibration of Cognitive Structures*. Chicago: University of Chicago Press.

Posner, G. J., Strike, K. A. , Hewson, P. W. , & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211-227.

Resnik, L. (1983). Mathematics and science learning: A new conception. *Science, 220*, 477-478.

Sarıkaya, Y. & Erdik, E. (2005). *Temel Universite Kimyası*. Ankara: Hacettepe Taş.

Savinainen, A., Scott, P., & Viiri, J. (2004). Using a bridging representation and social interactions to foster conceptual change: Designing and evaluating an instructional sequence for Newton's third law. *Journal of research Science Teaching,* 175-185.

Schmidt, H. (1997). Students' misconceptions - Looking for a pattern. *Science Education, 81*(2), 123-135.

Schoon, K., & Boone, W. (1998). Self-efficacy and alternative conceptions of science of preservice elementary teachers. *Science Education*, *82*(5), 553-568.

Stavy, R. (1990). Children's conceptions of changes in the state of matter: From liquid (or solid) to gas. *Journal of Research in Science Teaching*, *27*(3), 247-266.

Stavy, R. (1991). Using analogy to overcome misconceptions about conservation of matter. *Journal of Research in Science Teaching*, *28*(4), 305-313.

Strike, K. A. (1983). *Misconceptions and conceptual change: Philosophical reflections on the research program.* Proceedings of the International Seminar Misconceptions in Science and Mathematics, Cornell University**:** 67-78.

Sungur. S., Tekkaya, C. & Geban, Ö. (2001). The conribution of conceptual change texts accompanied by concept mapping to students' understanding of the human circulatory system. *School Science and Mathematics, 101*(2), 91-101.

Taber, K. (1998). An alternative conceptual framework from chemistry education. *International Journal of Science Education*, *20*(5), 597-608.

Taber, K. S. (2001). Shifting sands: A case study of conceptual development as competition between alternative conceptions. *International Journal of Science Education*, *23*(7), 731-754.

Tsai, C. C. (1996). *The interrelations between junior high school students' scientific epistemological beliefs, learning environment preferences and cognitive structure outcomes.* Unpublished doctoral dissertation, Teachers College, Columbia University, USA.

Ure, M. C., Colinvaux, D. (1989). Developing adults' views on the phenomenon of change of physical state in water. *International Journal of Science Education***,** *11*(2), 153-160.

Wandersee, J. H., Mintzes, J. J. , & Novak, J. D. (1994). *Research on alternative conceptions in science.* Handbook of research on science teaching and learning. D. Gabel. New York, Macmillan**:** 177-210.

GENİŞLETİLMİŞ ÖZET

Araştırmalar, öğrencilerin derslere, öğrenecekleri konularla ilgili, günlük yaşamlarındaki deneyimlerinden ve birbirleri ile olan iletişimlerinden elde ettikleri birtakım bilgilerle geldiklerini ortaya koymaktadır. Öğrencilerin derslere gelmeden, öğrenecekleri konu hakkında edinmiş oldukları bilgiler çok önemlidir. Öğrencilerin bir konu hakkında derse gelmeden sahip oldukları bu bilgiler, her ne kadar kendilerine mantıklı ve değerli gelse de, bu bilgiler kabul edilmiş bilimsel anlamlarından farklılık gösterebilir. Bilim adamlarının kabul ettiği bilimsel kavramlardan farklılık gösteren bu kavramlara kavram yanılgıları denmektedir. Yapılandırmacı yaklaşımın da savunduğu gibi bilgi birey tarafından aktif bir şekilde bireyin sahip olduğu bilgiler üzerine yapılandırıldığı için yeni bilgilerin anlamlı bir şekilde öğrenilmesi, bireyde varolan bilgilere bağlıdır. Bu nedenle öğrencilerin yeni kavramları doğru öğrenebilmesi için sahip olduğu kavram yanılgılarının giderilmesi gerekmektedir. Kalıcı, değişmesi zor olan bu kavram yanılgılarını gidermek geleneksel öğretim yöntemi ile pek mümkün olmamaktadır. Çağdaş, yapılandırıcı yaklaşıma dayalı öğretim yöntemleri öğrencilerin varolan bilgilerini dikkate aldığından öğrencilerin kavram yanılgılarını gidermekte etkilidirler.

Maddenin yoğun fazları ve çözünürlük konusu kimyadaki birçok konunun öğrenimine temel oluşturduğundan çok önemli bir yere sahiptir. Örneğin, gazlar konusunun daha iyi anlaşılması için, kimyasal değişim ve fiziksel değişim arasındaki farkların daha iyi anlaşılması için maddenin yoğun fazları konusunun iyi anlaşılması gerekmektedir. Bununla beraber, maddelerin faz değişimleri sırasındaki sıcaklık değişimi termodinamik konusunun alt yapısı için önemlidir. Çözünürlük konusu, çözünürlük dengesi ve elektrokimya konuları için bir temel oluşturmaktadır.

Bu çalışmanın amacı, maddenin yoğun fazları ve çözünürlük konusunda onuncu sınıf öğrencilerinin sahip oldukları kavram yanılgılarının giderilmesi ve maddenin yoğun fazları ve çözünürlük konusunu daha iyi anlamaları için 5E öğrenme modeline dayalı öğretim yöntemi geliştirmektir. 5E öğretim yöntemi içerisinde izlenen basamaklar şöyledir: Meşguliyet (engagement) basamağı (1); bu basamakta öğrenciler, dersden önce öğretmen tarafından belirlenmiş olan kavram yanılgılarını aktif hale getirecek bir nesneye, bir duruma veya bir olaya maruz bırakılırlar. Bu etkinlikler öğrencileri bir kavram çelişkisine sürükler ve içinde bulundukları kavram yanılgıları ile belli durumları açıklayamadıklarını onlara gösterir. İkinci basamak keşfetme (exploration) basamağıdır (2); bu basamakta öğrecilerin olayları, durumları ve sunulan materyalleri keşfetmesi sağlanır. Sunulan etkinliklere aktif olarak katılan öğrenciler, olayları gözlemleme, ilgili değişkenleri tanımlama ve olayları sorgulama fırsatı bulurlar. Öğrenciler içinde bulundukları kavram yanılgılarının arkasındaki fikirlerin mantığını bulmaya çalışarak gidermeye çalışırlar. Üçüncü basamak açıklama (explanation) basamağıdır (3). Bu basamakta kavramlar, bilimsel süreç ve beceriler, daha önceki iki basamakta edinilen deneyimler ışığında, öğrencilere basit, net ve doğrudan sunulur. İlk olarak öğrencilerin kavramları açıklamarı sağlanır ve daha sonra öğretmen kavramları net ve açık bir yolla izah eder. Dördüncü basamak, ayrıntılara girerek işleme (elaboration) basamağıdır (4). Bu basamakta öğrenciler kavramlarını, becerilerini genişletmek ve ayrıntıları daha iyi anlamak için aynı konularda faklı deneyimlere maruz bırakılırlar. Hala kavram yanılgılarına sahip olan öğrenciler bu basamakta bu kavram yanılgılarını giderme ve konuları daha iyi kavrama fırsatı bulurlar. Son basamak, değerlendirme (evaluation) basamağıdır (5). Öğrencilerin kavram yanılgıları ve konuyu kavramaları çeşitli testler veya etkinliklerle değerlendirilerek, öğrencilere dönütler verilir.

Bu çalışma, Ankara'daki bir Anadolu Lisesinde, aynı öğretmenin kimya derslerinde bulunan 119 onuncu sınıf öğrencisinin katılımı ile gerçekleşmiştir. Kontrol grubundaki öğrencilere geleneksel kimya öğretim yöntemi uygulanırken, deney grubundaki öğrencilere 5E öğrenme modeline dayalı öğretim yöntemi uygulanmıştır. Deney grubunda öğrencilere 5E öğrenme modelinin içerdiği basamaklar gösteriler, video animasyonları, laboratuvar aktiviteleri ve tartışma yoluyla uygulanmıştır. Kontrol grubunda dersler öğretmen açıklamaları ve ders kitaplarına dayalı olarak işlenmiştir. Maddenin yoğun fazları ve çözünürlük testi (SMSCT), öğrencilere ilk-test ve son-test olarak dağıtılarak öğrencilerin maddenin yoğun fazları ve çözünürlük konularını anlamaları değerlendirilmiştir. Öğrencilerin bilimsel işlem becerilerini belirlemek üzere bilimsel işlem beceri testi (SPST) çalışmanın başında öğrencilere uygulanmıştır.

Uygulanan tek değişkenli kovaryans (ANCOVA) analizi sonucunda, 5E öğrenme modeli kullanılan öğrencilerin, maddenin yoğun fazları ve çözünürlük kavramlarını, geleneksel kimya anlatımı kullanılan gruba göre daha iyi anladıkları tespit edilmiştir. Son olarak, öğrencilerin bilimsel işlem becerileri, öğrencilerin maddenin yoğun fazları ve çözünürlürlük kavramlarını anlamasında belirleyici bir unsur olarak karşımıza çıkmaktadır.