Journal of Education and Learning; Vol. 6, No. 1; 2017
ISSN 1927-5250 E-ISSN 1927-5269
Published by Canadian Center of Science and Education

The Effects of 5E Inquiry Learning Activities on Achievement and Attitude toward Chemistry

Senol Sen[1] & Ozge Ozyalcin Oskay[1]

[1] Faculty of Education, Hacettepe University, Ankara, Turkey

Correspondence: Senol Sen, Faculty of Education, Hacettepe University, Beytepe, 06800, Ankara, Turkey. Tel: 90-312-297 8601. E-mail: schenolschen@hacettepe.edu.tr

Received: August 8, 2016 Accepted: August 31, 2016 Online Published: September 25, 2016

doi:10.5539/jel.v6n1p1 URL: http://dx.doi.org/10.5539/jel.v6n1p1

Abstract

The purpose of this study was to investigate the effects of 5E inquiry learning activities on students' achievement, attitude toward chemistry. A non-equivalent control group design was used to the quasi-experimental research in this study. A total of 34 (8 males and 26 females) undergraduates in Turkey voluntarily participated in the study. The 5E Inquiry Learning Activities were applied to the experimental group and lecture-based traditional activities were applied to the control group. The both two groups were taught by the same instructor and used same books. The Chemical Equilibrium Concept Test (CECT) and the Attitude toward the Subject of Chemistry Inventory (ASCI) were applied to both groups as pre-test and post-test. The results of the study revealed that 5E inquiry learning activities were more effective in improving the achievement in chemical equilibrium compared to lecture-based traditional activities. In addition, the results showed that there was no statistically significant mean difference between experimental and control groups with respect to attitude toward chemistry.

Keywords: 5E Inquiry Learning Activities, achievement, attitude, chemical equilibrium, lecture-based traditional activities

1. Introduction

The student-centred paradigm emerged with constructivist approach with the reforms made in education. With this paradigm, students take on more active roles in learning, they design their own research, and they learn from each other by interacting with each other in group work. Teachers, on the other hand, play the roles of an arranger, a guide and a leader rather than a source of correct answers in the classroom (Anderson, 1997). One of the best methods usable in creating student-centred learning environments is inquiry-based learning (Marshall, Smart, & Horton, 2010). While inquiry-based learning provides students with opportunities to structure the new knowledge and to try their thoughts, it also assures that students form evidence-based thoughts and to inquire the thoughts critically. Due to this property, inquiry learning is regarded as an approach which is student-centred and which supports the configuration of knowledge (Koseoglu & Tumay, 2015).

Inquiry-based learning helps learners to develop inquiry skills, which are among the basic skills of the 21st century (Kong & Song, 2014). Inquiry-based learning is defined as learning by asking questions, and by researching, and as the process of learning by analysing the knowledge and transforming the data into useful knowledge (Perry & Richardson, 2001). Inquiry-based learning is a method of learning which is based on constructivist theory and which is effective in students' learning and in developing upper-order thinking skills. In this method, students go through such processes as making observations, collecting evidence, making guesses, doing experiments, testing the probable explanations and interpreting the findings by using the techniques scientists use in scientific research (Colburn, 2000; NRC, 2000; Keselman, 2003; Pedaste, Mäeots, Leijen, & Sarapuu, 2012).

Students work like scientists in the process of inquiry-based learning and find answers to the questions and problems about which they are curious through research that they themselves configure. Therefore, the use of the method especially in science classes will raise students' motivation, their solving creative problems, their reaching real information and permanent learning (Lord & Orkwiszewski, 2006; Wilke & Straits, 2005). Besides, scientific inquiry-based learning environments are also influential in increase in students' beliefs in their capabilities in learning a subject and in becoming aware of having responsibilities for their own learning (Wilke & Straits, 2005). In a similar way, Alvarado and Herr (2003) point out that students' interest in and motivation for the course increases, their conceptual understanding deepens, and thus they can set up associations between their present knowledge with their participation in inquiry-based learning environments.

It is pointed out that there are three types of inquiry-based learning as structured, guided, and open inquiry (Colburn, 2000). This study uses the method of guided inquiry. Guided inquiry is a method in which teachers act as guides with their questions, students plan their own questions and processes, and they form new concepts by associating with previous knowledge (Colburn, 2000); because on examining constructivist approach, a comparison of the types of inquiry learning shows that guided inquiry learning is more compatible with constructivist learning and that it produces more effective learning outputs than the other types of inquiry learning (Brown & Campione, 1994; cited in Koseoglu & Tumay, 2015; Minner, Levy, & Century, 2010; cited in Koseoglu & Tumay, 2015).

One of the models used in implementing inquiry-based learning in science classes is the 5E Model. The 5E learning model assures that students are active in classes, they have the opportunity to research and analyse, and that they reach knowledge by creating discussion environments and by continuously inquiring (Gunduz Bahadir, 2012). 5E learning cycles model is composed of five inquiry stages. The sages are: engagement, exploration, explanation, elaboration and evaluation. The first stage of the 5E learning model—the stage of engagement—is the most important stage of the model. At the stage of checking prior knowledge and arousing curiosity the knowledge that students acquired in the previous years is brought to light. At the stage of exploration students are active and they find probable answers to the questions they are curious about by researching and inquiring. At the stage of explanation teachers have a big job. They ask students questions to teach the concepts formed at the previous two stages, they associate the subjects of chemistry with real life, and they try to eliminate students' misconceptions by detecting them and by making explanations. At the stage of elaboration students have the opportunity to adapt their knowledge into new situations and to use it in real life. The final stage is the stage of evaluation. At this stage, whether or not the gains targeted at the beginning of the course have been obtained or to what extent the gains have been obtained is found by using different complementary measurement and evaluation techniques. This stage is important in two ways. It assures that students exhibit their learning status and development and receive feedback. And it also assures that teachers see the extent to which students have developed and they have attained the goals of teaching. Evaluation is made not only at the end of the course but in the whole process (Bybee et al., 2006; Ozturk, 2013; Wilder & Shuttleworth, 2005).

Students do a mental activity to solve a number of problems in the process where the 5E learning cycles model—which is based on inquiry—is used. Working in pairs or in groups of three, students ask questions, and they share their opinions in response to explanations offered as answers to the questions. Students' answers to open-ended questions help to uncover their misconceptions. Recording the data gathered for the whole class by using all facilities of technology with experiments and observations assures that students make a comparison of their data with others' by going through a mental process and that they inquire the aspects that their data agree and disagree with others' data. Thus, students' scientific process skills begin to develop. Besides, it also becomes possible for students to use the materials they are familiar with—that is to say, to associate their new experiences with their previous experiences and to structure the knowledge (Colburn, 2007).

Students acquire not only science subjects but also such skills as logical thinking, asking questions, researching the answers and solving daily problems in science classes taught through inquiry-based learning (Germann, 1994). This study also uses the guided inquiry learning method to enable students to learn the factors affecting the chemical equilibrium because, by using students' process of knowledge acquisition and their problem solving skills, inquiry-based learning aims to make students research knowledge within life and to develop skills and attitudes enabling them to generalise the knowledge (Wilder & Shuttleworth, 2005). Students should also be given opportunities to design research, form hypotheses, interpret the results, and to create their own knowledge and comprehension (Roth & Roychoudhury, 1994). A number of studies have shown that inquiry-based learning facilitates students' understanding of the concept of the nature of science, contributes to the development of scientific process skills and to an increase in their attitudes towards and achievement in science courses; and those studies point out that it is the best method in science education (Backus, 2005; Coll, Dalgety, & Salter, 2002; Deters, 2005; Ertepinar & Geban, 1996; Gibson & Chase, 2002; Holloway, 2015; Khan, Hussain, Ali, Majoka, & Ramzan, 2011; Khishfe & Abd-El-Khalick, 2002; Lord & Orkwiszewski, 2006; Ryder, Leach, & Driver, 1999; Sandoval, 2003; Saunders & Shepardson, 1987). Therefore, it was aimed to investigate the effects of 5E inquiry learning activities on students' achievement and attitudes toward chemistry in this study.

2. Method

2.1 Research Design

This study employs non-equivalent control group design. Participants are not assigned into groups randomly in this design. One of the groups present is set as the experimental group, and the other as the control group (Gay, Mills, & Airasian, 2012).

2.2 Study Group

A total of 34 undergraduate students in total participated in the research. The study was conducted in 2015-2016 academic year with students attending a state university in Turkey. 6 of the participants were male whereas 28 of them were female. Two classes were included in the research, and one of them was set as the experimental group (n = 18), and the other as the control group (n = 16) randomly. Convenience sampling—one of the non-random sampling methods—was used in this research.

2.3 Data Collection Tools

2.3.1 Chemical Equilibrium Concept Test (CECT)

Chemical Equilibrium Concept Test (CECT) developed by the researchers was used in order to determine students' conceptual achievement in chemical equilibrium as pre-test prior to the application and as post-test after the application. 16 multiple choice questions containing two stages were prepared about the factors influencing chemical equilibrium in the process of test development. Expert opinion was obtained from two chemistry lecturers so as to attain content validity. The required modifications were made in accordance with expert' recommendations and after reliability analyses, item discrimination and item difficulty indices. In consequence, Cronbach Alpha internal coefficient was calculated as .73 for 16-question CECT test. For each stage of the questions, the correct answers given by students were coded as "1", and incorrect answers as "0". If students answered one of the stages correctly and the other incorrectly, again they received "0" for their incorrect answer.

2.3.2 Attitude toward the Subject of Chemistry Inventory (ASCI)

Attitudes toward the Subject of Chemistry Inventory (ASCI) was developed by Bauer (2008) so as to evaluate attitudes toward Chemistry course, and was adapted into Turkish by Sen, Yilmaz and Temel (2016). ASCI containing 8 items is composed of two sub-parts labelled as cognitive (items 1, 2, 3 and 6), and as affective (items 4, 5, 7 and 8).

2.4 Treatment

The study continued for 5 weeks in total. The classes were taught in 3 hours a week in both the experimental and the control groups. The pre-tests were administered to both groups in the first week and the post-tests were administered to both groups in the final week. What had been learnt in the previous class was revised in the first five minutes at the beginning of each lesson, and thus, students' prior knowledge was brought to light. At the end of the lessons, evaluation was made on what students had learnt.

2.4.1 Experimental Group: 5E Inquiry Based Learning

Although different methods of teaching were developed to implement inquiry-based learning, science educators usually prefer the 5E instructional model (Bybee, 1997). Therefore, the 5E instructional model—a modification of learning cycle—was used for inquiry-based science teaching in this study (Bybee, 1997; Bybee et al., 2006). Students worked in pairs or in groups of three in this process. At the first stage—the stage of engagement—of the 5E inquiry learning, students generated questions for scientific researches and problems in accordance with the goals of the course. In this process, the instructor led students by helping them to generate questions. Then, at the stage of exploration, students did research in relation to the answers to the questions they had generated at the previous (engagement) stage. While the students worked in cooperation with hands on, minds on activities, the instructor participated in the process as the facilitator. Thus, it was made sure that the students observed the factors affecting chemical equilibrium by doing experiments and that they collected data. In this process, the instructor led them by asking questions. The students were encouraged to collect data from different sources. In consequence, the students collected various data and created a model for themselves. At the explanation stage of the 5E model, the students associated their explanations for the concepts based on the individual and group activities with scientific knowledge. They were asked to explain the concepts in their own words in this process. In corrections and explanations made by the instructor, students' experiences were taken into consideration, and it was assured that the students structured the concepts. In addition to that, efforts were made to eliminate the students' misconceptions. At the stage of elaboration, the students were given opportunities to apply the learnt knowledge and concepts to different situations, and they were asked to explain the new experiences they had. Here especially, the students analysed the factors affecting chemical equilibrium with different reactions. Besides, the students observed the differentiation with the same reaction by changing the factors affecting a reaction in the experiments they did. They associated the data they obtained through these observations with the questions they asked at the stage of engagement, and thus they formed a general framework for the newly learnt knowledge. The 5E evaluation stage is the stage where students evaluate what they have learnt in accordance with the goals of the course. Yet, the evaluation was not made at the end of the process only. It was made at every stage of the 5E model. In this process, it was observed by the instructor that the students applied the new knowledge, concepts and skills to the subject of solubility equilibrium. Moreover, the students also made evaluations about themselves and about the process in the report they prepared at the end of the experiments (Goldston, Dantzler, Day, & Webb, 2013; Wilder & Shuttleworth, 2005).

2.4.2 Control Group: Traditional Teaching Method

The same instructor taught the lessons to the experimental and the control groups. The same course book was used in both groups. The factors affecting chemical equilibrium was taught through lecture-based traditional activities. Lecture and questioning methods were used in classes. Prior to each lesson, the students studied the subject. The whole of the classroom environment and the learning process were configured by the instructor. The instructor made the students take notes, explained the necessary concepts by writing on the board, and the questions on the factors affecting the chemical equilibrium were answered in writing.

3. Results

Independent t-test was used in finding whether or not there were any significant differences between students' pre-test scores for CECT and ASCI administered prior to teaching with 5E Inquiry Learning Activities. Yet, the assumptions such as the independence of observations and normality assumptions were examined prior to the t-test. The skewness and kurtosis values were calculated for normal distribution. Following the analyses, it was found that the skewness and kurtosis values remained in the +2 and -2 interval, and it was regarded that the data had normal distribution (George & Mallery, 2003). Having found that the t-test assumptions were satisfied, the independent samples t-test results were checked and it was found that equal variances assumption was met $p > .05$. On examining the differences between the groups, it was found that there were no significant differences between the experimental group and the control group in terms of their achievement ($M_{Exp.} = 5.5$, $SD = 2.94$; $M_{Cont.} = 5.06$, $SD = 2.79$; $t\,(32) = .44$, $p = .66$, two-tailed) and affective attitudes scores ($M_{Exp.} = 18.67$, $SD = 3.55$; $M_{Cont.} = 17.63$, $SD = 3.20$; $t\,(32) = .894$, $p = .378$, two-tailed), but it was found that there were significant differences between students' cognitive scores ($M_{Exp.} = 14.33$, $SD = 3.66$; $M_{Cont.} = 17.38$, $SD = 4.57$; $t\,(32) = -2.15$, $p = .039$, two-tailed) . For this reason, gain scores (posttest-pretest) were used in order to determine the effects of 5E inquiry learning activities on students' cognitive attitudes.

Whether or not there were any significant differences between the experimental group and the control group students' posttest, affective attitudes posttest and cognitive attitudes gain scores were analysed with independent samples t-test. Consequently, it was found that equal variances assumption was satisfied. It was found in consequence that there were significant differences between the experimental group and the control group achievement ($M_{Exp.} = 10.72$, $SD = 2.78$; $M_{Cont.} = 7.31$, $SD = 2.68$; $t\,(32) = 3.63$, $p = .001$, two-tailed). The magnitude of the differences in the means (mean difference = 3.41, 95% *CI*: 1.50 to 5.32) was very large (etasquared = .29). However, it was found that there were no significant differences between the students' cognitive gain scores ($M_{Exp.} = 1.11$, $SD = 2.81$; $M_{Cont.} = 2.19$, $SD = 4.28$; $t\,(32) = -.877$, $p = .387$, two-tailed) and their affective attitude ($M_{Exp.} = 17.56$, $SD = 4.19$; $M_{Cont.} = 17.19$, $SD = 4.05$; $t\,(32) = .260$, $p = .797$, two-tailed) scores (see Table 1).

Table 1. The results of independent samples t-test

		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
								Upper	Lower
CECT Post-test	Equal variances assumed	.14	.71	3.63	32.00	.00	3.41	1.50	5.32
Cognitive Gain Scores	Equal variances assumed	1.13	.30	-.88	32	.39	-1.08	-3.58	1.42
Affective Post-test	Equal variances assumed	.63	.43	.26	32	.80	0.37	-2.52	3.26

4. Discussion

This study analysed the effects of 5E Inquiry Learning Activities on undergraduate students' achievement and on their attitudes towards Chemistry course by using non-equivalent control group design. 34 university students in total were included in the research. In this research the lessons were taught through 5E inquiry learning activities in the experimental group whereas they were taught through leacture-based traditional activities in the control group. The data were then analysed through independent samples t-test. According to the results obtained, it was found that the achievement of undergraduate students in the experimental group was higher than that of undergraduate students in the control group in terms of factors affecting chemical equilibrium. This finding obtained through experimental procedures is parallel to the ones obtained in previously conducted studies (Aho, Huopio, & Huttunen, 1993; Basaga, Geban, & Tekkaya, 1994; Chang & Mao, 1998; Çelik & Çavaş, 2012; Nwagbo, 2006). It was found in Hwang, Wu, Zhuang and Huang (2013) that the experimental group students learning through inquiry-based mobile learning were more successful and had less cognitive load than the control group students learning in traditional teaching methods. Koksal and Berberoğlu (2014) found that guided-inquiry learning increased students' understanding of science concepts and their inquiry skills when compared to traditional teaching method. Additionally, at the end of the application, the researchers also found that the experimental group students' attitudes towards science were higher than those of control group students. It was found in Sen (2015) that process-oriented guided inquiry learning method increased high school students' achievement in electrochemistry course in contrast to traditional teaching method. The researcher's interviews with the students demonstrated that the majority of the students liked the method and that the method motivated them in positive ways.

Another finding obtained from this research was about students' attitudes towards chemistry course. As different from the findings obtained in many studies in the literature, this study found that there were no significant differences between the experimental group and the control group students' cognitive and affective attitudes. Similar results were obtained in studies concerning the effects of learning cycles model on students' attitudes (Gonen, Kocakaya, & Inan, 2006; Koseoglu & Tumay, 2010; Nuhoglu & Yalcin, 2006). One of the reasons for this result could be the fact that the application was done in a very short time—in five weeks. Apart from that, the restricting the study to only the factors affecting chemical equilibrium did not cause a change in students' attitudes towards chemistry course. Another reason for the result could be the negative views held by some students' in relation to 5E inquiry learning activities. In this way, students can resist against the new experiences with which they are not pleased (Felder, 1997). Yet, in many studies in the literature, it was found that inquiry-based learning developed students' attitudes in positive ways (Chin & Kayalvizhi, 2005; Çelik & Çavaş, 2012; Gibson & Chase, 2002; Koksal & Berberoglu, 2014; Tatar & Kuru, 2009). It was also found in Tatar and Kuru (2009) that students' attitudes in inquiry-based science classes were significantly higher than the ones in teacher-centered science classes. In Gibson and Chase (2002), on the other hand, the students participating in inquiry-based science camp stated that they liked the activities in the summer camp, that the science concepts which they learnt by researching increased their interest in science and created a positive atmosphere for learning. Cheng, Yang, Chang and Kuo (2016) pointed out that the 5E mobile inquiry learning approach increased the learning motivation of the university students in the experimental group. Çelik and Çavaş (2012) researched the effects of inquiry-based learning on primary school students' academic achievement, on their scientific process skills and on their attitudes towards science course in terms of the subjects of reproduction, growth and living organics. At the end of the study, it was found that inquiry-based learning method employed in the experimental group increased students' academic achievement, their scientific process skills and their attitudes towards science and technology.

In conclusion, it was found that the guided inquiry-based learning used in this study increased students' achievement, but that it did not influence their attitudes. Consequently, it may be said that the students in the experimental group understood the subject of factors affecting chemical equilibrium better than the students in the control group, and that they had fewer misconceptions in this matter.

5. Implications

- Science teachers usually have difficulties in organising inquiry-based teaching activities in their classes and in forming the stages of the 5E teaching model (Glasson & Lalik, 1993; Gunckel, 2011). Teachers may be offered in-service training in this respect.

- Teachers themselves firstly should have positive attitudes towards and high levels of self-efficicacy in 5E and Inquiry learning activities so that they can use them in their classes. The curricula in Educational Faculties should be re-designed in a manner that prospective teachers can frequently implement the examples of such activities.

- With the spread of the use of 5E Inquiry Activities, students' perception that science courses such as chemistry are learned by memorisation can be hindered.

- The formation of misconceptions can be hindered by giving examples for the applications of 5E Inquiry activities in real life and by working in small groups.

References

Aho, L., Huopio, J., & Huttunen, S. (1993). Learning science by practical work in Finnish primary schools using materials familiar from the environment: A pilot study. *International Journal of Science Education*, *15*(5), 497-507. http://dx.doi.org/10.1080/0950069930150504

Alvarado, A. E., & Herr, P. R. (2003). *Inquiry-based learning using everyday objects: Hands-on instructional strategies that promote active learning in grades 3-8*. Thousand Oaks, CA: Corwin Press, INC.

Anderson, R. D. (1997). The science methods course in the context of the total teacher education experience. *Journal of Science Teacher Education*, *8*(4), 269-282. http://dx.doi.org/10.1023/A:1009494817356

Backus, L. (2005). A year without procedures. *The Science Teacher*, *72*(7), 54-58.

Basaga, H., Geban, O., & Tekkaya, C. (1994). The effect of the inquiry teaching method on biochemistry and science process skills achievements. *Biochemical Education*, *22*, 29-32. http://dx.doi.org/10.1016/0307-4412(94)90163-5

Bauer, C. F. (2008). Attitude toward chemistry: A semantic differential instrument for assessing curriculum impacts. *Journal of Chemical Education*, *85*, 1440-1445. http://dx.doi.org/10.1021/ed085p1440

Bybee, R. (1997). *Achieving scientific literacy: From purposes to practices*. Portsmouth, NH: Heinemann.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carlson, J., Westbrook, A., & Landes, N. (2006). *The BSCE 5e instructional model: Origins and effectiveness*. A report for Office of Science Education National Institutes of Health. Retrieved from http://www.bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_ModelExecutive_Summary_0.pdf

Chang, C. Y., & Mao, S. L. (1998, April). *The effects of an inquiry-based instructional method on earth science students' achievement*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Diego, CA.

Cheng, P. H., Yang, Y. T. C., Chang, S. H. G., & Kuo, F. R. R. (2016). 5E Mobile inquiry learning approach for enhancing learning motivation and scientific inquiry ability of university students. *IEEE Transactions on Education*, *59*(2), 147-153. http://dx.doi.org/10.1109/TE.2015.2467352

Chin, C., & Kayalvizhi, G. (2005). What do pupils think of open science investigations? A study of Singaporean primary 6 pupils. *Educational Research*, *47*(1), 107-126. http://dx.doi.org/10.1080/0013188042000337596

Colburn, A. (2000). An inquiry primer. *Science Scope*, *23*(6), 42-44.

Colburn, A. (2007). Constructivism and conceptual change, part II. *The Science Teacher*, *74*(8), 14.

Coll, R., Dalgety, J., & Salter, D. (2002). The development of the chemistry attitude and experience questionnaire (CAEQ). *Chemistry Education and Practice in Europe*, *3*(1), 19-32. http://dx.doi.org/10.1039/B1RP90038B

Deters, K. M. (2005). Student opinions regarding inquiry-based labs. *Journal of Chemical Education*, *82*, 1178-1180. http://dx.doi.org/10.1021/ed082p1178

Ertepinar, H., & Geban, O. (1996). Effect of instruction supplied with the investigative oriented laboratory approach on achievement in a science course. *Educational Research*, *38*, 333-344. http://dx.doi.org/10.1080/0013188960380306

Felder, R. M. (1997). Cooperative learning in sequence of engineering courses: A success story. *Cooperative Learning and College Teaching Newsletter*, *5*(2), 10-13.

Gay, L. R., Mills, G. E., & Airasian, P. (2012). *Educational research: Competencies for analysis and applications*. Upper Saddle River, NJ: Pearson.

George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference 11.0 update* (4th ed.). Boston: Pearson Education, Inc.

Germann, P. J. (1994). Testing a model of science process skills acquisition: An interaction with parents' education, preferred language, gender, science attitude, cognitive development, academic ability, and biology knowledge. *Journal of Research in Science Teaching*, *31*(7), 749-783. http://dx.doi.org/10.1002/tea.3660310707

Gibson, H. L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education*, *86*(5), 693-705. http://dx.doi.org/10.1002/sce.10039

Glasson, G. E., & Lalik, R. V. (1993). Reinterpreting the learning cycle from a social constructivist perspective: A qualitative study of teachers' beliefs and practices. *Journal of Research in Science Teaching*, *30*(2), 187-208. http://dx.doi.org/10.1002/tea.3660300206

Goldston, M. J., Dantzler, J., Day, J., & Webb, B. (2013). A psychometric approach to the development of a 5E lesson plan scoring instrument for inquiry-based teaching. *Journal of Science Teacher Education*, *24*(3), 527-551. http://dx.doi.org/10.1007/s10972-012-9327-7

Gonen, S., Kocakaya, S., & Inan, C. (2006). The effect of the computer assisted teaching and 7E model of the constructivist learning methods on the achievements and attitudes of high school students. *The Turkish Online Journal of Educational Technology—TOJET*, *5*(4), 82-88.

Gunckel, K. (2011). Mediators of a preservice teacher's use of the ınquiry-application ınstructional model. *Journal of Science Teacher Education*, *22*, 79-100. http://dx.doi.org/10.1007/s10972-010-9223-y

Gunduz Bahadir, E. B. (2012). *Researching the Effect of the Animation Technique and 5E Learning Model on Academic Achievement, Attitude and Critical Thinking Skills While Processing the Unit of "Electricty in Our Life" for the 8th Grades* (Master Thesis). Atatürk University, Erzurum, Turkey.

Holloway, C. E. (2015). *Teacher's level of ınquıry-based chemıstry and student's attıtude about hıgh school chemıstry* (Dissertation). University of Alabama, USA.

Hwang, G. J., Wu, P. H., Zhuang, Y. Y., & Huang, Y. M. (2013). Effects of the inquiry-based mobile learning model on the cognitive load and learning achievement of students. *Interactive Learning Environments*, *21*(4), 338-354. http://dx.doi.org/10.1080/10494820.2011.575789

Keselman, A. (2003). Supporting inquiry learning by promoting normative understanding of multivariable causality. *Journal of Research in Science Teaching*, *40*(9), 898-921. http://dx.doi.org/10.1002/tea.10115

Khan, M., Shaukat, H., Riasat, A., Majoka, M. I., & Ramzan, M. (2011). Effect of inquiry method on achievement of students in chemistry at secondary level. *International Journal of Academic Research*, *3*(1), 955-959.

Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of research in science teaching*, *39*(7), 551-578. http://dx.doi.org/10.1002/tea.10036

Koksal, E. A., & Berberoglu, G. (2014). The Effect of guided-inquiry instruction on 6th grade Turkish students' achievement, science process skills, and attitudes toward science. *International Journal of Science Education*, *36*(1), 66-78. http://dx.doi.org/10.1080/09500693.2012.721942

Kong, S. C., & Song, Y. (2014). The impact of a principle-based pedagogical design on inquiry-based learning in a seamless learning environment in Hong Kong. *Educational Technology & Society*, *17*(2), 127-141.

Koseoglu, F., & Tumay, H. (2010). The effects of learning cycle method in general chemistry laboratory on students' conceptual change, attitude and perception. *Journal of Kirsehir Education Faculty*, *11*(1), 279-295.

Lord, T., & Orkwiszewski, T. (2006). Moving from didactic to inquiry-based instruction in a science laboratory. *American Biology Teacher*, *68*(6), 342-345. http://dx.doi.org/10.1662/0002-7685(2006)68[342:DTIIIA]2.0.CO;2

Marshall, J., Smart, J., & Horton, R. (2010). The design and validation of EQUIP: An instrument to assess inquiry-based instruction. *International Journal of Science and Mathematics Education*, *8*(2), 299-321. http://dx.doi.org/10.1007/s10763-009-9174-y

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.

Nuhoglu, H., & Yalcin, N. (2006). The effectiveness of the learning cycle model to increase students' achievement in the physics laboratory. *Journal of Turkish Science Education*, *3*(2), 49-65.

Nwagbo, C. (2006). Effects of two teaching methods on the achievement in and attitude to biology of students of different levels of scientific literacy. *International Journal of Educational Research*, *45*, 216-229. http://dx.doi.org/10.1016/j.ijer.2006.11.004

Ozturk, N. (2013). *The effect of activities based on 5e learnıng model ın the unit titled light and sound at the sixth grade science and technology lesson on learnıng outcomes* (Unpublished Dissertation). Gazi University, Ankara, Turkey.

Pedaste, M., Maeots, M., Leijen, A., & Sarapuu, S. (2012). Improving students' inquiry skills through reflection and self-regulation scaffolds. *Technology, Instruction, Cognition and Learning*, *9*, 81-95.

Perry, V. R., & Richardson, C. P. (2001). The New Mexico tech master of science teaching program: An exemplary model of inquiry-based learning. In *Frontiers in Education Conference* (Vol. 1). IEEE. http://dx.doi.org/10.1109/fie.2001.963917

Roth W. M., & Roychoudhury, A. (1994). Physics students' epistemologies and views of knowing and learning. *Journal of Research on Science Teaching*, *31*(1), 5-30. http://dx.doi.org/10.1002/tea.3660310104

Ryder, J., Leach, J., & Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching*, *36*(2), 201-219. http://dx.doi.org/10.1002/(SICI)1098-2736(199902)36:2%3C201::AID-TEA6%3E3.0.CO;2-H

Sandoval, W. A. (2003). The inquiry paradox: why doing science doesn't necessarily change ideas about science. In C. P. Constantinou, & Z. C. Zacharia (Eds.), *Sixth Intl. Computer-Based Learning in Science Conference* (pp. 825-834). Nicosia, Cyprus.

Saunders, W. L., & Shepardson, D. (1987). A comparison of concrete and formal science instruction upon science achievement and reasoning ability of sixth grade students. *Journal of Research in Science Teaching*, *24*, 39-51. http://dx.doi.org/10.1002/tea.3660240105

Sen, S. (2015). *Investigation of students' conceptual understanding of electrochemistry and self-regulated learning skills in process oriented guided inquiry learning environment* (Unpublished Dissertation). Hacettepe University, Ankara, Turkey.

Sen, S., Yilmaz, A., & Temel, S. (2016). Adaptation of the Attitude toward the Subject of Chemistry Inventory (ASCI) into Turkish. *Journal of Education and Training Studies*, *4*(8), 27-33. http://dx.doi.org/10.11114/jets.v4i8.1485

Tatar, N., & Kuru, M. (2009). Inquiry-based learning approach versus descriptive methods: Effects on elementary students' attitudes towards science. *Pamukkale University Journal of Education*, *25*, 142-152.

Wilder, M., & Shuttleworth, P. (2005). Cell inquiry: A 5E learning cycle lesson. *Science Activities*, *41*(4), 37-43. http://dx.doi.org/10.3200/sats.41.4.37-43

Wilke, R. R., & Straits, J. W. (2005). Practical Advice for teaching inqiry based science process skills in the biological sciences. *The Amerıcan Biology Teacher*, *67*(98), 534-540. http://dx.doi.org/10.1662/0002-7685(2005)067[0534:PAFTIS]2.0.CO;2