Preservice science teachers' attitudes towards chemistry and misconceptions about chemical kinetics*

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Abstract

The present study investigates preservice science teachers' attitudes towards chemistry; their misconceptions about chemical kinetics; and relationships between pre-service science teachers' attitudes toward chemistry and misconceptions about chemical kinetics were examined. The sample of this study consisted of 81 freshman pre-service science teachers (female 42, male 39) at a public university in the southwest part of Turkey. The result of the study demonstrated that preservice science teachers' attitudes towards chemistry were at medium level and preservice science teachers had some misconceptions about chemical kinetics. There is not a statistically significant relationship between pre-service science teachers' attitudes towards chemistry and their misconceptions about chemical kinetics. Also, the result of this study revealed that there is not a statistically significant difference in understanding of the chemical kinetics concepts between pre-service science teachers having high and low attitudes.

Keywords: Attitudes towards chemistry, chemical kinetics, misconceptions, preservice science teachers

Introduction

The major goal of the science education is to make students scientifically literate. Lederman & Nies (1998) defined scientific literacy as the understanding of the science content, science processes (such as observation, data organization, hypotheses generation, hypothesis testing, data interpretation, and conclusions inferences from data) and using science content and processes for solving personal and societal problems. Bybee (1997) proposed multidimensionality of the scientific literacy and stated that scientific literacy has four dimensions: nominal, functional, conceptual and procedural, and multidimensional. Words and questions were classified as scientific by nominal scientific literates; but they minimally understand science topics so they have misconceptions and naïve explanations (Bybee, 1997). Functional scientific literates use scientific vocabulary, define terms and concepts, memorize scientific facts, vocabulary and information and understand scientific contents (Bybee, 1997). Conceptual and procedural scientific literates comprehend scientific conceptual schemes, procedural knowledge, skills and processes (as cited in Boujaoude (2002), p.143). Multidimensional scientific literates comprehend the nature and history of science, links to other disciplines and science and society (Bybee 1995 & 1997). There is no teaching sequence for scientific literacy dimensions, it develops both horizontal and vertically. For example, in order to develop functional literacy of students, students' vocabulary could be improved. Thus, students could understand the relations between concepts and underlying main ideas and conceptual literacy of students could be enhanced.

One of the dimensions of the scientific literacy is to understand the concepts and principles of science. Ausubel (1968) stated that the most important indication of learning is what the learner already knows because an image or an example directs the learner to relevant prior experience or learning and also points forward to new material. Like Ausubel (1968), Shapiro (2004) and Dochy, Segers, and Buehl (1999) stressed the importance of prior knowledge in learning and they stated that students shape their own meaning according to their prior knowledge. Errors are characteristics of initial phases of learning because students' existence knowledge is insufficient and supports only partial understanding. However, many researchers revealed that students' views about an image or an example are not matched with scientific views. Even after formal instruction, students learn concepts different from scientific consensus, and these wrong ideas are called "misconceptions". Misconceptions mean the difference between learners' understanding and scientifically accepted understanding of the concept. However, they do not mean the lack of knowledge, factual errors or incorrect definitions; they are the demonstration of the constructed explanations of students in response to their prior knowledge and experience. Misconceptions hinder students' learning, and as Ausubel (1968) stated they interrupts the formation of relations between ideas, concepts and information and also linkage between concepts. Thus, students could not establish meaningful learning.

Many researchers explored students' misconceptions about some scientific concepts and tried to overcome misconceptions by suggesting alternative teaching methods. In Chemistry, one of the concepts studied was reaction rate. While a group of researchers investigated students' misconceptions on reaction rate , another group of researchers investigated teaching methods for overcoming misconceptions (e.g., Balci, 2006; Cakmakci, Donnely & Leach, 2005; Cakmakci, Leach & Donnely, 2006; Tastan, Kirik & Boz, 2010; Tastan, Kirik, Yalcinkaya & Boz, 2010). However, Kahveci (2009) stated that most of the studies on the Chemistry misconceptions were conducted with primary and secondary education students and there is not much research on higher grades such as preservice teachers, or undergraduate students or faculty members. Meanwhile, as Kolomuc and Tekin (2011) stated, one of the concepts that were not studied much with pre-service elementary teachers was reaction rate. Thus, in order to make both elementary students and pre-service elementary teachers scientifically literate, the first step is to evaluate pre-service teachers' subject matter knowledge (Kahveci, 2009). Therefore, in this study, pre-service science teachers' conceptual understanding of the reaction rate were investigated and we could get some idea related to these pre-service teachers' misconceptions about chemical kinetics. Chemical kinetics could be considered as a central topic for general chemistry curricula, since it is composed of more than one topic; such as, the rate of reaction, activation energy, factors affecting reaction rate and collision theory. Thus, chemical kinetics could be prerequisite for understanding of the *relation between chemical change and energy, the types of chemical reactions and the chemical change processes* (Kolomuc & Tekin, 2011, p. 85). Therefore, in the present study, pre-service science teachers' misconceptions about chemical kinetics will be examined.

The American Association for the Advancement of Science (AAAS, 1989) stated that rather than scientific knowledge, the other components of the scientific literacy are *understanding of the scientific process and the orientation of attitudes during the learning process* (As cited in Wu, Shein, Tsai, Chou, Wu, Liu, Chiu, Hung, Chao & Huang, 2012). The AAAS (1989) also mentioned that people perceive science as an attitude. Ministry of Turkish Education (MEB, 2004) also focused on scientific literacy dimensions and MEB mentioned that attitudes toward science is the one of the most important dimensions of the scientific literacy. Both AAAS (1989) and MEB (2004)'s description of scientific literacy suggests the importance of the students' attitudes toward science.

In order to develop students' scientific literacy, they should have positive attitudes towards science. Attitudes toward science can be defined as *the feelings, beliefs and values held about an object which may the enterprise of science, school science, the impact of science on society or scientists themselves* (Osborne, Simon, & Collins, 2003, p.1053). Pre-service teachers are going to be teachers and when they are going to be a scientifically literate; their students are going to be scientifically literate because they could influence their students. Thus, in this study, pre-service teachers' attitudes towards chemistry is examined.

Students' science achievement and their misconceptions are affected by their attitudes towards science. There are some research studies showing the relation between students' attitudes towards science and their science achievement (Freedman, 1997; Ingram & Nelson, 2006; Osborne & Collins, 2001; Simpson & Oliver, 1990). The result of most of these studies demonstrated that there is a positive relationship between students' attitudes towards chemistry and their science achievement (e.g., Osborne & Collins, 2001; Simpson & Oliver, 1990). However, some research studies revealed that high school students' attitudes was negatively correlated with science achievement (Freedman, 1997). In addition to these studies, Ingram and Nelson (2006) stated that science achievement could not be predicted by attitude, and attitude explains only moderate amount of variation in achievement. Thus, it could be stated that there is no consensus on the extent of the relationship between attitudes towards science and science achievement. The reason of these different research results concerning this relationship could stem from the domain specific nature of attitudes.

Osborne & Collins (2001) stated that for each different domain of science, such as chemistry, biology and physics, students had different attitudes towards different domains of the science. For example, students' attitudes towards chemistry could be different from their attitudes towards physics. Salta and Tzougraki (2004) mentioned that there is much research related to attitudes towards science in general, however; there is not much research related to attitudes towards specific domains of the science. For example, there are few studies that investigated attitudes towards chemistry (Kaya & Geban, 2011; Menis, 1983, 1989; Salta & Tzougraki, 2004). Salta & Tzougraki (2004) investigated the relation between 11th grade students' attitudes towards chemistry and their chemistry achievement and reported that there is a moderate correlation between these variables.

Rationale of the Present Study:

This study is important for several reasons: First, the ultimate aim of science education is to make students scientifically literate. In order to make students scientifically literate, one of the requirements is that students should have adequate understanding about science concepts. However, the literature reported that students have many misconceptions and these misconceptions could hinder learning of science concepts, thus, students could not achieve meaningful science learning. It is important for pre-service teachers to establish meaningful learning during their teacher education because they are going to be science teacher in future and their misconceptions could influence their students' misconceptions. One of the most important sources of students' misconceptions were teachers so it is essential to reveal and remedy pre-service teachers' misconceptions on chemistry topics.

As a second reason of conducting the present study, we observed that chemistry misconceptions particularly reaction rate concepts were mostly studied with primary and secondary-level school students and there is not much study on pre-service teachers (Kahveci, 2009; Kolumuc & Tekin, 2011). Therefore, we need research studies focusing on pre-service teachers. Third, chemical kinetics is one of the central topics of general chemistry curricula and it is prerequisite for understanding of some chemistry concepts and processes: relations between chemical change and energy, types of chemical reactions, and chemical change processes (Kolomuc & Tekin, 2011). Thus, we need studies particularly focusing on chemical kinetics. As a last reason of conducting the present study, we can claim that we need to have much more study investigating relationships between attitudes towards chemistry and misconceptions about chemistry. The current literature showed that there is an inconsistency about relationships between attitudes towards chemistry and misconceptions about chemistry, so we need further research studies exploring these relationships.

The purpose of the present study is to investigate relationships between preservice science teachers' chemistry achievement and their attitudes towards chemistry. The research questions of the study are:

1. What are the preservice science teachers' attitudes towards chemistry?
2. What are the preservice science teachers' misconceptions about chemical kinetics?
3. Is there any relationship between preservice science teachers' attitudes towards chemistry and their misconceptions about chemical kinetics?

Method

Sample

The sample of this study consisted of 81 freshman pre-service science teachers (female 42, male 39) at a public university in the southwest part of Turkey. Fraenkel and Wallen (2006) suggest that number of participants for a correlation study should be fifty and over. In the present study, the mean age of preservice science teachers was twenty. Their age ranges from nineteen to twenty-three years old. These preservice teachers were involved in the study voluntarily. After these preservice science teachers complete the program, they will have certificate to teach science to 6th through 8th grade students. Preservice science teachers took science content (Physics, Chemistry, and Biology) and pedagogical courses (science methods and field education) in order to graduate from their science teacher education program.

Instrumentation

Chemistry Attitude Scale

In order to measure students' attitudes towards chemistry, Chemistry Attitude Scale (CAS) which was developed by Geban, Ertepinar, Yilmaz, Altin, and Sahbaz (1994) were used. The instrument has one dimension. It has 15 items with five-point Likert type (fully agree, agree, undecided, disagree, fully disagree). The internal consistency reliability of the instrument was found 0.83. The minimum score for CAS is 15 and the maximum score is 75. The higher scores in CAS lead the more positive attitudes towards chemistry. The whole items could be obtained from the study of Geban, Ertepinar, Yilmaz, Altin, and Sahbaz (1994).

Some items from this instrument are as follow:

I like reading books related to science.
Science is not important in our daily life.
I get bored when I study science.
I like solving chemistry problems.
I would like to learn more thing about chemistry subjects.

Chemical Kinetics Concept Test

This test was developed by Balci (2006) for measuring students' understanding on chemical kinetics. Distractors in the concept test include misconceptions about chemical kinetics topic (Balci, 2006). This test covers the concepts of rate of reaction and its measurement, collision theory, activation energy, the factors affecting rate of reaction (concentration effect, temperature effect, catalyst effect, surface area effect), reaction mechanism, rate law, and order of reactions. The instrument includes 20 multiple-choice items and each item rated as five-point. Students' test scores could range from 0 to 100. The reliability of the instrument was found 0.75. One item from this instrument, which represents whole questions in terms of the format and content is given below:

Which one of them is correct related to the rate of reaction?

a) *Reaction rate is the change in amount per unit time*
b) *Reaction rate is the time from the beginning of the reaction to the end of the reaction*
c) *All reactions occur at the same rate*
d) *The step determining the reaction rate is the fastest step in reaction mechanism*
e) *The reaction rate describes only by reactants*

Data Collection and Analysis

Two instruments were implemented to preservice science teachers by the research assistant who does not included in the present study in order to eliminate the experimenter bias for internal validity. Response rate of the questionnaires was around 90%. Volunteer preservice teachers completed the questionnaires in class while research assistant was also in the class in order to answer any questions of preservice teachers. All of the questionnaires were implemented by the research assistant and they were returned to the authors of this paper. All of these were conducted to control the experimenter bias for threats to internal validity.

In the first part of the data analysis, we tried to validate the CAS and Chemical Kinetics Concept Test. These tests were applied after teaching the chemical kinetics concepts,in the context of Chemistry class but the aim was not to test the effects of Chemistry class on pre-service science teachers' attitudes towards science and misconceptions on science. Instead of this, the aim was to explore the current condition of freshman pre-service science teachers' attitudes towards chemistry and their misconceptions about the subject of chemical kinetics. The.CAS had one dimension and had positive and negative items. Negative items were reversed and then a total score for each preservice science teacher was calculated. Preservice science teachers having higher scores on CAS reflected more positive attitudes towards chemistry. The reliability and validity of the CAS have been provided in several studies (e.g., Gurses, Acikyildiz, Dogar & Sozbilir, 2007; Pınarbasi, Canpolat, Bayrakceken & Geban, 2006; Tastan, Yalcinkaya & Boz, 2008).

Chemical Kinetics Concept Test was validated by researchers. All of the items were evaluated by two experts in order to determine the content validity of the instrument. In order to figure out whether the difficulty level of the test is appropriate to the sample, the test was administered to the other section of the class. Then, preservice teachers were interviewed about the questions whether they correctly understood the items of the test. According to the interview and the other section application of the test, some questions were altered and removed. After that the concept test administered to the sample.

In the second part of the data analysis, Pearson Product Correlation was conducted in order to determine how attitudes toward chemistry might be associated with Chemical Kinetics Concept Test.

Results

Pre-service Science Teachers' Attitudes towards Chemistry

In the present study, "attitudes towards chemistry" is a uni-dimensional construct. Pre-service science teachers' mean score of the attitudes towards chemistry was 42.34 with standard deviation of 5.034. Since the minimum score for this instrument is 15.0 and the maximum score for this instrument is 75.0, the mean score of the participants' attitudes towards chemistry could suggest that pre-service science teachers had medium level of attitudes towards chemistry.

Pre-service Science Teachers' Misconceptions about Chemical Kinetics

Pre-service science teachers' mean score of the chemical kinetics concept test was 37.35 (out of 100.0) with standard deviation of 13.3. This shows that pre-service science teachers had lower performance for the concept test. It suggests that pre-service teachers had misconceptions on some items. The misconceptions reflected by the distracters of the chemical kinetics concepts test items were the common misconceptions in a certain chemical kinetics topic.

When pre-service teachers' responses about Chemical Kinetics Concept Test were closely examined, most of the pre-service teachers had misconceptions
Table 1 shows the objectives of the questions and pre-service teachers' misconceptions and their percentages.

Table 1. Objectives of the questions and percentage of pre-service teachers' misconceptions on that question

Question Number	Context	Correct Response (%)	Misconceptions and their rate*
1	identification of the catalyst in reaction	54.3	Mixed the catalyst with the reaction intermediate in a reaction mechanism/ 37.0%
2	Factors affecting reaction rate	67.9	The concentration of reactants/13.6%
3	rate equation	29.6	Reaction rate equals to the multiplication of reactants' concentration/ 28.4%
7	the graph of the reaction rate versus time	14.8	The reaction rate is the time that reactants turn into products, reaction rate in a chemical reaction means the process of reactants to form products, reaction rate is an amount of substance that turns into product in a certain temperature and concentration/ 49.4%
8	the properties of endothermic and exothermic reactions.	35.8	In exothermic reaction, increasing the temperature decreases the rate of reactions/ 30.9%
8	the properties of endothermic and exothermic reactions.	35.8	In only endothermic reaction, increasing the temperature increases the rate of reactions/ 17.3%
10	the effect of catalyst on activation energy.	12.3	When catalyst is added to a reaction, only pathway with lower activation energy is available. Also, they confused with catalyst and negative catalysts/ 30.9%
15	reaction mechanism	35.8	When concentration increases, then the time of reaction process increases/ 27.2%
15	reaction mechanism	35.8	Activation energy does not affect the reaction rate/ 7.4 %
15	reaction mechanism	35.8	The fast step determines the reaction rate/ 17%
20	reaction mechanism	19.8	The difficulties related to what is the reaction intermediate and catalyst in a reaction mechanism/ 16%
20	reaction mechanism	19.8	Confused with the slow step determine the reaction rate/ 24.7%

* Misconceptions lower than 10 percent did not be mentioned in the table.

Descriptive measures of the Chemical Kinetics Concept Test and Attitudes toward Chemistry scores are presented in Table 2.

Table 2. Descriptive measures of the Chemical Kinetics Concept Test and Attitudes towards Chemistry scores

		Chemical Kinetics Concept Test		Attitudes toward Chemistry	
	n	Mean	Std. Dev.	Mean	Std. Dev.
Total	81	37,35	13,3	42,34	5,034

Correlation between Preservice Science Teachers' Attitudes towards Chemistry and their Misconceptions about Chemical Kinetics

In order to determine the relationship between preservice science teachers' attitudes towards chemistry and their understanding of chemical kinetics, first attitudes towards chemistry and understanding of chemical kinetics concept were plotted. The assumptions of the Pearson's Product-Moment Correlation were checked. Both attitudes toward chemistry and the concept test scores were normally distributed. There are two outliers, but when these were extracted from the analysis, the result of the Pearson correlation did not change.

The graph showed that there is no linear relationship between attitudes toward chemistry and understanding of chemical kinetics. Figure 1 shows this relationship.

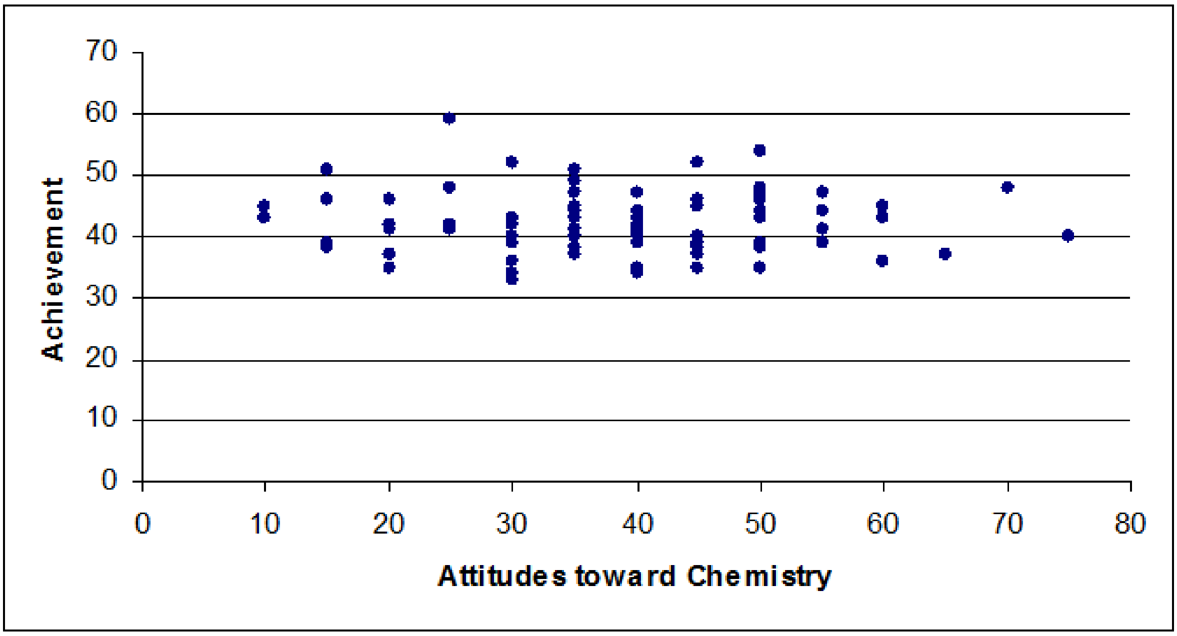

Figure 1. The relationship between attitudes towards chemistry and achievement.

Since there is no linear relationship between variables, Pearson's Product-Moment Correlation was not implemented. The result demonstrated that there was not a significant correlation ($r = 0.010$) between pre-service teachers' understanding of chemical kinetics and their attitudes towards chemistry.

Discussions and Implications

The result of the study demonstrated that preservice science teachers' attitudes towards chemistry were at medium level and they had some misconceptions about chemical kinetics. There is not a statistically significant relationship between preservice science teachers' attitudes towards chemistry and their misconceptions related to chemical kinetics.

This study revealed that preservice science teachers had medium attitudes towards chemistry and the reason of this could be the characteristics of the sample. The sample of the study was preservice science teachers and they are engaged in more science education courses and they do laboratory experiments about science (physics, chemistry, and biology). If they took much more chemistry courses and laboratory experiments about chemistry we could observe much more positively developed attitudes towards chemistry. We may suggest much more chemistry-related courses in science teacher education programs. Pre-service teachers' medium attitudes toward chemistry could suggest that they could have medium scientific literacy since the development of scientific literacy requires positive attitudes toward science. Thus, in order to develop pre-service teachers' scientific literacy, the activities promoting their attitudes toward science could be developed. Another result of this study is that there is not a statistically significant relationship between preservice science teachers' attitudes towards chemistry and their misconceptions about chemical kinetics. The result of the study demonstrated that there is not a significant relationship between preservice science teachers' attitudes towards chemistry and students' understanding of the chemical kinetics. For high school students, Salta & Tzougraki (2004) found a significant relationship between attitudes towards chemistry and science achievement. This shows that the relationship patterns between students' attitudes towards chemistry and understanding of chemistry topics may depend on sample characteristics. Therefore, this relationship pattern should be studied considering sample characteristics. According to the result of the present study, it could be stated that pre-service teachers could have misconceptions although they have higher attitudes toward chemistry. In the same way, pre-service teachers could not have misconceptions although they lower attitudes toward chemistry. Thus, activities that are promoting pre-service teachers' attitudes toward chemistry could not have influence on their misconceptions.

Investigation of preservice science teachers' understanding about chemical kinetics is essential since one of the sources of students' misconceptions is teachers (Bar & Travis, 1991,references). By revealing the misconceptions of the preservice science teachers' about chemical kinetics, teaching methods could be developed in order to overcome preservice science teachers' misconceptions and so their students' misconceptions could be remediated. Pre-service teachers' misconceptions could be remediated by using hands on activities and laboratory practices since chemical kinetics concepts are abstract (how developed instruction to remediate misconceptions please discuss). The present study revealed some misconceptions about the chemical kinetics topic. Since pre-service teachers have misconceptions about chemical kinetics topic then it could be stated that pre-service teachers could not develop scientific literacy. In order to develop scientific literacy, pre-service teachers should have coherent understanding of the chemical kinetics topics.

Preservice science teachers generally had difficulties in understanding of the reaction rate that equals to the multiplication of reactants' concentration, and also they confused with the meaning of the reaction intermediate and catalyst in a reaction mechanism.

Also, in this study students had difficulty in understanding of the idea in that in exothermic reactions increasing the temperature decreases the rate of reactions. Also students hold the misconception in which in only endothermic reactions, increasing the temperature increases the rate of reactions. These results are in line with the findings of the studies of Balcı (2006) and Kolomuc and Tekin (2011). This result suggests that students could confuse with the concept of enthalpy and reaction rate.

Also, students had difficulty in understanding of the reaction rate vs time graph. Students had difficulty in understanding of some chemical processes: reaction rate is the time that reactants turn into products; reaction rate in a chemical reaction means the process of reactants to form products; and reaction rate is an amount of substance that turns into product in a certain temperature and concentration. Cakmakci, Donnelly and Leach (2005) also found the same misconceptions for preservice chemistry teachers.

According to the results of the Chemical Kinetics Concept test, students had misconceptions about key concepts of reaction rate. Thus, preservice science teachers' courses should be designed in order to overcome their misconceptions on these essential chemistry concepts. Also, teaching methods for promoting conceptual change could be designed in order to remediate the misconceptions. Misconceptions are resistant to change so preservice science teachers could be aware of their misconceptions on these chemistry concepts and processes during their science teacher education and so they could eliminate them.

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