Active learning applications in the history of chemistry: Pre-service chemistry teachers' level of knowledge and views

Gülten ŞENDUR[1], Merve POLAT[2], Abdullah TOKU[3], and Coşkun KAZANCI[4]

[1]Dokuz Eylül University, Department of Secondary Science and Mathematics Education, Izmir/ TURKEY

E-mail: gulten.sendur@deu.edu.tr

[2]Celal Bayar University, Faculty of Education, Department of Science Education, Demirci-Manisa, TURKEY

E-mail: merve.polat@bayar.edu.tr

[3]Celal Bayar University, Faculty of Education, Department of Science Education, Demirci-Manisa, TURKEY

E-mail: tokuabdullah@gmail.com

[4]Dokuz Eylul University, Educational Sciences Institute, Department of Chemistry Education, Izmir, TURKEY

E-mail: coskun.kazanci.deu@gmail.com

Received 11 Sept., 2014
Revised 16 Dec., 2014

Contents

- Abstract
- Introduction
- The research
    - Purpose of study

- Method
- Participants
- Data collection
- Procedure
- Data analysis
- Results
  - Results from the open-ended questionnaire
  - Results of the semi-structured interview
- Conclusion and discussion
- References

Abstract

This study aims to investigate the effects of a History and Philosophy of Chemistry-I course based on active learning applications on the level of knowledge of pre-service chemistry teachers about the history of chemistry. The views of pre-service chemistry teachers about these activities were also investigated. The study was carried out with 38 pre-service chemistry teachers from a university in Turkey in the academic year 2012-2013. In the History and Philosophy of Chemistry-I course; instruction was carried out based on five steps that included pre-service teachers' oral presentations, poster presentations, the assessment of the pre-service teachers' posters presentations with a rubric, preparing a timeline, and an assessment of the pre-service teachers' timelines. The data of this study was collected with an open-ended questionnaire. The questionnaire was administered to all the pre-service teachers before and after the instruction. The results of the study indicated that the pre-service teachers' level of knowledge about the history of chemistry had increased after the instruction. Also, interviews revealed that the pre-service teachers had positive views about the active learning activities.

Keywords: active learning, history of chemistry, pre-service chemistry teachers

Introduction

Using the history of science in science education has been discussed for many years. Many researchers have expressed the contributions of the use of historic elements in teaching and learning in the following way:

- Students can learn about the nature of science.
- Students' critical thinking can be developed.
- Parallels can be drawn between students' knowledge about subject matter and knowledge about the historical development of the subject matter.
- Teachers can address practical problems of instruction such as the organization of course content
- Rich and varied learning opportunities can be presented based on daily-life experience, historical and scientific problems.
- Relating historical stories can increase students' motivation.
- Students' pre-conceptions can be affected as a result of dealing with historical controversies.
- Students can identify themselves with historical researchers (Herron, 1975; Janes, 2004; Jansen, 1995; Justi & Gilbert, 1999; Kubli, 2005; Matuschek & Jansen, 1985; McKinney & Michalovic, 2004; Scheffel et al., 2009).

In this context, using historic elements in chemistry education have made important contributions to both chemistry teachers and students. One of the important contributions of the history of chemistry is that it provides explanatory clues about the processes involving the evolution of chemical concepts and helps learners to understand general problems and their solutions (Quilez, 2004). Thus, Sanchez and Martin (2003) have stated that teachers may benefit from the history of chemistry to make a meta-disciplinary analysis of didactic topics.

At the same time, many researchers have stated that the history of chemistry can help chemistry teachers to develop strategies that promote students' understanding in chemistry and that it can also help students link newly learned concepts to their prior knowledge and historical knowledge (Wandersee, 1992; Wandersee & Griffard, 2002). Wandersee and Griffard, (2002) expressed their view that the main aim of chemistry education is to assist learners to construct a meaningful and mindful understanding of matter and changes in matter, learn how the basic ideas in chemistry emerged and were constructed over time in an effort to help learners understand chemistry. In another study, Jensen (2011) explained the history of chemistry to allow chemistry teachers to explain the nature of the scientific method through a recounting of a significant event or past revolution in chemical thought. According to Matuschek and Jansen (1985), the history of chemistry can help students learn about chemistry as a part of intellectual history and its position in culture. In another study conducted by Niaz and Rodríguez (2001), the researchers stated that various topics in the general chemistry program, at both the high school and freshman university level, can be presented within a history and philosophy of science perspective, and that this perspective can help to facilitate students' conceptual understanding. Also, Niaz and Rodríguez (2000) reported that most of authors emphasized the importance of history in chemistry beginning in the 1930s, and that these authors also recognized the lack of adequate teaching materials and strategies in this context. Similarly, Wang and Cox-Petersen (2002) explained that most teachers believe that history in science is important, but they often have limited instructional materials and inappropriate training.

In the light of the above-mentioned research, it was seen that the importance of the history of chemistry has been emphasized in many studies, but studies about teaching the history of chemistry are very rare. There have been studies, however, on teaching the history of science (Höttecke, et al., 2012; Özgelen & Öktem, 2013; Şimşek, 2011; Tural, 2012). For this reason, developing new and effective teaching activities related to the history of chemistry is necessary. Thus, Coştu, Ünal and Ayas (2007) stated that it is necessary to develop ways of effective teaching as well as tools and strategies that can be presented to teachers for their use in science classes.

At the same time, learners' perspectives on and interest in chemistry and its history. Thus, Höttecke, Henke and Riess, (2012) asserted that learners would probably have little interest in activities such as reading texts and listening to lectures. Lin, Hung and Hung (2002) also reported that when learners took part in discussions, presentations, debates, role-play and in hands-on activities related to the activities of earlier scientists' activities in addition to listening to historical description; they would be more likely to construct their own manner of understanding.

Consequently, this study has focused on the development of active learning applications on the history of chemistry that would be more likely to increase learners' interest, develop creativity, and promote their understanding.

Active learning is a student-centered learning process that allows students to participate effectively in class (Mulongo, 2013; Prosser & Trigwell, 1999;

Şeşen-Acar & Tarhan, 2011). In this process, the roles of students are not passively listening to an instructor's lecture or taking notes (Fayombo, 2012; Karamustafaoğlu, et al., 2006). Active learning encourages students to take actions in various ways that concern how to learn, use mental abilities, think, and interpret the knowledge by cooperating with other students (Kalem & Fer, 2003). To activate students, a variety of techniques that include simulation, small group discussions, student presentations, games, role-playing, hands-on projects can be used in the learning process (Sivan, et al., 2000). It is in this way that students' high-order thinking skills, such as analyzing, synthesizing and evaluation, can develop (Allen, 1995; Bonwell & Eison, 1991). Thus, many studies indicate the effectiveness of active learning in students' learning process (Aydede & Matyar, 2009; Fies, 2005; Kalem & Fer, 2003; Sivan, et al., 1991; Şeşen-Acar & Tarhan, 2011).

In this study, active learning applications in which pre-service chemistry teachers participate effectively were used to teach the history of chemistry. Toward this aim, teaching activities included the oral and poster presentations of the pre-service teachers, assessments, preparing the time line, and the discussions that were developed by researchers.

Although all pre-service science/ chemistry teacher training programs do not include the "History of Chemistry" as a major subject, most of the programs do include the subject of "The Nature of Science and the History of Science." These two subjects are intimately related, and hence it is thought that this study will help to redesign and renew the teaching of the subjects of "The History of Chemistry"/ "The Nature of Science and the History of Science." In this context, the current study is important, since it should make a contribution to the pre-service professional development of the science/chemistry teacher.

Additionally, this study may be seen as an example study since it will provide useful information for chemistry teachers and chemistry educators. The study will inform chemistry teachers about the importance of the history of chemistry, and help chemistry teachers to see how active learning activities can be used effectively in teaching "The History of Chemistry" in chemistry classes.

The research

Purpose of study

In the light of the above-mentioned rationale, the main aim of this study was to investigate the effect of the History and Philosophy of Chemistry-I course based on active learning applications on the levels of knowledge of pre-service chemistry teachers about the history of chemistry. The study also sought to reveal pre-service chemistry teachers' views about active learning applications, and whether these applications help to develop pre-service chemistry teachers' abilities in the context of peer assessment, creativity, inter-group relationships and preparing posters or not.

Based on these aims, the research questions were addressed as follows:

- What was the level of the pre-service chemistry teachers' knowledge about he History of Chemistry at the beginning of the study?
- What was the level of the pre-service chemistry teachers' knowledge about the History of Chemistry at the end of the study?
- What are the views of the pre-service chemistry teachers about active learning applications?
- Do active learning applications help pre-service chemistry teachers develop abilities such as peer assessment, creativity, inter-group relationships and preparing posters?

Method

The study was designed as a case study since it was conducted in a small group before implementing results in a larger group. Kalof, Dan and Dietz (2008) have stated that case studies can be useful when researchers want to examine how a particular program or intervention will unfold in use; the intervention can be introduced in one setting before applying it broadly. In this context, active learning applications related to the History of Chemistry were developed by the researchers and applied it a small group. Firstly in the study, an open-ended questionnaire about the history of chemistry was administered to the group before the instruction. Thereafter, the group was instructed via active learning applications for seven weeks. After the instruction, the same questionnaire was administered to the same group. At the same time, semi-structured interviews were conducted individually with all of the pre-service teachers after the instruction.

Participants

The participants of the study consisted of 38 pre-service chemistry teachers enrolled in a History and Philosophy of Chemistry-I course in a public university in Turkey. All of the pre-service chemistry teachers volunteered to participate in the study. The pre-service chemistry teachers had quite similar backgrounds since they had been admitted to the chemistry education department only after they had successfully passed a university entrance examination. Also, the socioeconomic status of the pre-service chemistry teachers was similar, with the majority of them coming from low- to middle-class families. The ages of the pre-service chemistry teachers ranged from 20 to 23 years. The study was conducted during the 2012–2013 spring semester.

Data collection

The data of this study was collected through an open-ended questionnaire and semi-structured interviews. The open-ended questionnaire consisted of five questions and was developed by the researchers in the light of various studies (Bayrakçeken, et al., 2011; Şimşek, 2011). The questionnaire was administered to identify the pre-service chemistry teachers' prior knowledge four weeks before the instruction. The same questionnaire was employed one week after the instruction.

Fifteen-minute semi-structured interviews were conducted individually with all of the pre-service teachers to determine their opinions about the active learning applications and whether these applications helped them to develop abilities such as peer assessment, creativity, inter-group relationships and preparing posters after the instruction. An audio recorder was used in the interviews and the entire interview was recorded. The fourth researcher conducted each interview session. In the interview, each pre-service teacher was asked two questions that had been developed by the researchers. The opinions of two specialists in chemistry education were enlisted in developing the questions for the interviews. The interview questions took their final form after revisions and additions were made in line with the recommendations of the specialists. These questions and their targets are presented in Table 1.

Table 1. Content of questions in the interview

Question	Target
1st Question	Revealing effects of the active learning activities on the pre-service teachers
2nd Question	Comparison of active learning activities in the History and Philosophy of Chemistry-I Course with other courses.

Procedure

History and Philosophy of Chemistry-I is an elective course that is studied in the spring semester of the fourth year of the chemistry education program. The content of the course encompasses ancient Chemistry, the antique and Hellenistic eras, origins of alchemy and Islamic alchemy, European alchemy, alchemy in the Italian Renaissance, Chemistry in the 16th and 17th centuries, and Introduction to modern Chemistry. The course was comprised of five steps, as follows:

1. The pre-service chemistry teachers' oral presentations
2. The pre-service chemistry teachers' poster presentations
3. The assessment of the pre-service chemistry teachers' poster presentations with a rubric
4. Preparing a timeline
5. Assessment of the pre-service chemistry teachers' timelines.

Before the instruction, the pre-service chemistry teachers were informed about the instruction. Their responsibilities and the responsibilities of the instructors, the utilization of resources, the preparation of posters were also explained. The 38 pre-service chemistry teachers then formed groups of five or six among themselves and their research topics were determined randomly. The groups carried out their research over the three weeks. In this process, the instructor (the first researcher), evaluated the work of each group, made recommendations, and provided feedback with guiding questions. In the following weeks, the groups started to present their research topics to the class.

All lessons started with each group's oral presentation. In the oral presentation, the pre-service chemistry teachers focused on important periods in the history of chemistry, the general characteristics of these periods, the important scientists of those periods, and these scientists' contributions to chemistry. Thereafter, the groups presented their posters. While they prepared their posters, it was requested of them to prepare the poster in accordance with scientific format. In other words, they were asked to make sure that the poster included an abstract, keywords, an introduction, method, conclusion and reference section. The groups then summarized their research topics with their posters. After the groups' poster presentations, the pre-service chemistry teachers in the other groups evaluated their peers' posters according to the rubric. The pre-service chemistry teachers also made evaluations about the posters. At the end of this stage, the instructor explained her assessments about the posters, emphasizing their strengths and weaknesses. Following the groups' presentations and the pre-service chemistry teachers' assessments, the other groups began to prepare their timelines based on the contents of the presentations. In this stage, all of the pre-service chemistry teachers shared their opinions with the group and the group discussion about the contents and structure of the timelines began. The students then came to a consensus about the content and structure of the timelines, and shared their timelines with the class. In the last stage, all of the groups' timelines were evaluated by the instructor and the pre-service chemistry teachers who presented oral and poster presentations. During the assessment, some incorrect knowledge about scientists, their contributions to chemistry, and the general characteristics of the periods in the history of chemistry were discussed with all the groups and explained. This procedure was conducted over a 7-week period (two 45-minute sessions per week). One week after the procedure, an open-ended questionnaire was employed as a post-measurement.

Data analysis

Data from the open-ended questionnaire and the records of the interviews were assessed by content analysis. In this process, the two researchers (the first and second researchers) separately coded the dates and the percentage of agreement between the two series of codes was calculated to be 0.94 (for the open-ended questionnaire), and 0.89 (for the interviews) (Miles & Huberman, 1994).

Results

This section describes the results obtained from the open-ended questionnaire and the semi-structured interviews.

Results from the open-ended questionnaire

The students' responses to the first questions in the open-ended questionnaire are shown in Table 2.

Question 1. Could you give examples of scientists who contributed to chemistry and their contributions?

Table 2. Pre-service chemistry teachers' responses related to question 1

Scientists and their contributions to chemistry	Pre-test f	Post-test f
Dalton (Atomic Model)	18	22
Bohr (Atomic Model)	14	4
Balmer (Visible Spectral Lines)	10	1
Lewis (Definition of Lewis Acids-Bases)	9	2
Thomson (Atomic Model)	8	1
Faraday (Electrolysis)	6	2
Markovnikov (Addition Reactions)	5	1
Newton (Gravitation)	4	0
Rutherford (Atomic Model)	4	1
Mendeleev (Table of Elements)	4	26
Arrhenius (Definition of Acids-Bases)	3	0
Lavoisier (Conservation of Mass)	2	24
Avogadro (Avogadro Hypothesis)	2	19
Gay-Lussac (the Relationship P-T)	2	23
Millikan (Millikan Oil Drop Experiment)	2	0
Lyman (Ultraviolet Spectrum)	2	0
Gibbs (Gibbs Free Energy)	2	0
Archimedes (Buoyant Force)	1	0
Tesla (Electric Power)	1	0
Paschen (Infrared Spectrum)	1	0
Graham (Graham's Law of Effusion)	1	1
Charles (Relationshipbetween T-V)	1	1
Rault (Raoult's Law)	1	0
R.Boyle (Relationship between P- V)	1	5
Ibn Sina (Avicenna) (Minerals, the Formation of Rocks)	0	15
Maria the Jewess (Water-Bath)	0	11
Thales (Theories of Matter)	0	10
Democritus- Leucippus (Definition of Atom)	0	9
Van Helmont (Carbon Dioxide)	0	7
Jabir Ibn Hayyan (Geber) (Synthesis of Nitric Acid, Distillation)	0	7
Cleopatra (Metals)	0	6
Paracelsus (Iatrochemistry)	0	4
Zakariya al-Razi (Classification of Substances, Synthesis of Formic Acid)	0	4
Priestley (Discovery of Oxygen)	0	3
Cavendish (Densities of the Gases, Hydrogen)	0	3

Valentinus (Antimony)	0	2
Becher (Spirit of Fire)	0	2
Agricola(metallurgy)	0	2
Raimundus Lullus (Synthesis of Alcohol)	0	2
Roger Bacon (Modern Scientific Method)	0	1
Stahl (Phlogiston)	0	1

This question was designed to determine the pre-service teachers' knowledge about scientists and their contributions to chemistry. When Table 2 is analyzed, it can be seen that the pre-service chemistry teachers mostly gave examples of scientists related to atomic structure at the beginning of the study. One of the reasons for this may be that scientists related to atomic structure had been emphasized countless times both throughout secondary school and at the university. Similar results have been reported in various other studies in the literature (Metz et al; 2007; Şimşek; 2011; Özgelen & Öktem, 2013). For example, Dalton (f=18), Bohr (f=14), Thomson (f=8), Rutherford (f=4) and their atomic models were revealed at high frequency at the beginning of the study. Similarly, Millikan-Millikan's Oil Drop Experiment (f=2), Balmer-visible spectral lines (f=10), Lyman-ultraviolet spectrum (f=2), Paschen-infrared spectrum (f=1), which are related to atomic structure, were identified at pre-test. At post-test, while some of these examples such as Millikan, Lyman, and Paschen were not given, while others such as Dalton, Bohr, Thomson, Rutherford, and Balmer were identified. However, their frequency decreased after the instruction except for Dalton. This result is not surprising since only Dalton and his contribution to chemistry, as mentioned above, scientist had been treated in the introduction to modern Chemistry. From Table 2, it can be understood that frequencies of responses about the definition of Acids-Bases were striking at the beginning of the study. This result was also not surprising because the definition of acids-bases (Lewis, Arrhenius, etc.) was the content of general and analytic chemistry courses. At the same time, these scientists and their definition of acid-bases was discussed in secondary school chemistry. At post-test, only the definition of Lewis Acids- Bases was identified. Table 2 shows that the pre-service teachers' responses about gas and basic laws in chemistry (such as Lavoisier-conservation of mass (f=2); Avogadro-Avogadro Hypothesis (f=2); Gay-Lussac-the relationship between P-T (f=2); Robert Boyle-relationship P-V (f=1); Graham-Graham's Law of Effusion (f=1); Charles-Relationship between T-V (f=1) had low frequencies before the instruction. After the instruction, while the frequencies of most had increased (Lavoisier, Avogadro, Gay-Lussac, and Robert Boyle), the frequencies of Graham and Charles did not change. One of the reasons was revealed in the response about Mendeleev. While at pre-test, only two pre-service teachers' responses were Mendeleev and the table of elements whereas after the instruction, the frequency of this response actually increased (f=26). The major reason for the increasing responses about Lavoisier, Avogadro, Gay-Lussac, Robert Boyle, and Mendeleev may be that these scientists and their contributions were discussed in detail in the introduction of modern chemistry.

Also, at the beginning of the study, some responses were received about scientists (Faraday-electrolysis (f=6); Markovnikov-Addition reactions (f=5); Gibbs-Gibbs Free Energy (f= 2); and Raoult-Raoult's Law (f= 1) that were also the subject of many chemistry lessons. After the instruction, the frequencies of these responses decreased, and some such as Gibbs and Raoult were not even identified.

Moreover, the pre-service teachers gave examples of scientists in the field of physics at the beginning of the study. Similarly, some studies in the literature have reported that pre-service teachers have a limited knowledge about scientists, and mostly, that their knowledge were about the most famous scientists (Şimşek, 2011; Özgelen & Öktem, 2013). For example, while the responses of Newton-gravitation (f=4), Archimedes-buoyant force (f=1), Tesla-electric power (f=1) were identified at the beginning of the study, these responses did not appear after the instruction. From this change, it was understood that the pre-service teachers were able to provide responses based on the history of chemistry after the instruction.

One of the important results of the study was that after the instruction, the pre-service teachers were able to provide responses that were not identified at the beginning of the study. Particularly, the responses of Ibn Sina (Avicenna)-minerals, the formation of rocks (f=15), Maria the Jewess–water- bath (f=11), Thales-theories of matter (f=10), Democritus and Leucippus-definition of atom (f=9), Van Helmont-carbon dioxide (f=7), Jabir Ibn Hayyan (Geber)-synthesis of nitric acid, distillation (f=)7, Cleopatra-metals (f=6) showed that the pre-service teachers had more knowledge about scientists in chemistry and their contributions after the instruction as compared to before. Similarly, scientists that had important roles in the development of chemistry, such as Paracelsus- iatrochemistry (f=4), Zakariya Al-Razi-classification of substances, synthesis of formic acid (f=4), Priestley-discovery of oxygen (f=3), Cavendish-densities of the gases, works on hydrogen(f=3), Valentinus-Antimony (f=2), Becher-spirit of fire (f=2), Agricola-metallurgy (f=2), Raimundus Lullus-synthesis of alcohol (f=2), Roger

Bacon-modern scientific method (f=1), Stahl-phlogiston (f=1) were revealed after the instruction.

Question 2 Who has the biggest role as a scientist in the scientific development of chemistry? Explain.

Table 3. Pre-service chemistry teachers' responses related to question 2

Scientist who has the biggest role in the scientific development of chemistry	Pre-test f	Post-test f
Dalton- Atomic Model	6	4
Mendeleev- Periodic Table	4	5
Maria Curie- Radioactivity	2	0
Bohr- Atomic Model	1	1
Einstein-Atom Bomb	1	0
Einstein-Theory of Relativity	1	0
Lavoisier-Conservation of Mass, Combustion	1	12
Robert Boyle –Experimental Chemistry	0	4
Jabir Ibn Hayyan (Geber)-Distillation and Alembic	0	4
Ibn Sina-Scientific Method	0	3
Democritus- Leucippus- Definition of Atom	0	2
Avogadro –The difference between Atoms and Molecules	0	1
Paracelsus- Iatrochemistry	0	1
Van Helmont-Quantitative Methods in Chemical Experiments.	0	1

In question 1, the pre-service teachers were asked to give examples of scientists and their contributions to chemistry. Question 2 was prepared to make Question 1 specific. When Table 3 is examined, it is seen that the pre-service teachers gave limited responses at the beginning of the study. Within these responses, Dalton, Mendeleev and Maria Curie had higher frequencies than the other responses. Similar to Question 1, in this question, the pre-service teachers mostly gave examples of scientists who had been treated in the content of many previous chemistry courses at pre-test. Some of the pre-service teachers' responses are presented below:

- "Mendeleev, since he developed the periodic table. The periodic table is very important for chemistry and chemists." PT-30 "Dalton. Dalton was the first scientist who stated a model about the atom. For this reason, his model of the atom is very important since it affected the other scientists." PT-9
- "In my opinion, Marie Curie had the biggest role in the development of chemistry since she discovered a radioactive element, and she also defined radioactivity. Today, we know the benefits and damages of radioactivity because of her studies on radioactivity." PT-2

Furthermore, at the beginning of the study, some of the pre-service teachers stated that Bohr, Einstein, and Faraday had important roles in the scientific development of chemistry. Some examples of these responses are the following:

- "Bohr's contributions in chemistry are very important since he developed the atomic model and his atomic model caused the development of modern atomic theory." PT- 17
- "Nowadays, countries that have the atom bomb are very powerful counties. Einstein made the suggestion to develop the atom bomb." PT-20
- "The theory of relativity developed by Einstein is important in chemistry since this theory is related to atoms." PT-4

At post-test, it was understood, as seen in Table 3, that the pre-service teachers could give more of a variety of responses and also responses related to the content of the course. The increasing frequencies of responses about Lavoisier were particularly striking. Some of the responses are the following:

- "Lavoisier is the most important scientist who had an important role in developing chemistry. He explained combustion, and as a result of this, he opposed the theory of phlogiston." PT-35
- "Lavoisier, father of modern chemistry. His contributions are considered very important in chemistry. For example, he developed the law of conservation of mass." PT-25

At the same time, the responses about Robert Boyle, Jabir Ibn Hayyan and Ibn Sina were identified after the instruction. Some of these responses are below:

- "I think Robert Boyle is very important in chemistry. He attacked the Aristotelian theory of the elements and the tria prima theory, and he doubted these theories. He stated the importance of experimentation." PT- 30
- "Jabir Ibn Hayyan, since he used some scientific techniques such as evaporation, crystallization and distillation and also developed some instruments. For example, alembic is very important for the process of distillation." PT-16
- "Ibn Sina lived in early years. Although alchemists had an important effect in that time, he refuted the alchemists and stated that the process of transmutation was not possible. He led the scientific method in chemistry." PT-5

In addition to these responses, the pre-service teachers stated that some scientists such as Democritus-Leucippus, Avogadro, Paracelsus and Van Helmont had important roles in the scientific development of chemistry. Some of the pre-service teachers' responses are presented below:

- "In my opinion, Democritus-Leucippus, since they were the first to state the concept of the atom and tried to explain the structure of matter. As a result, these explanation affected the other scientists." PT-15
- "I think Avogadro had a very important role in developing chemistry. Avogadro stated that atoms and molecules were different from each other, and he explained that molecules could be made of two or more atoms." PT-23
- "Van Helmont, since he used balance in his studies, and as a result, quantitative methods in chemical experiments gained importance." PT-12
- "Paracelsus as he developed iatrochemistry. Also he used experiments in that time." PT-4

Question 3 Could you give examples of periods contributing to chemistry and the contributions to chemistry in these periods?

Table 4. Pre-service chemistry teachers' responses related to question 3

Periods -Their Contributions to Chemistry	Pre-test f	Post-test f
Prehistoric Period - Mummification	12	14
Prehistoric Period - Cosmetics	11	12
Renaissance Period- Elements	2	2

Prehistoric Period- Discovery of Fire	1	8
Islamic Alchemy Period- Converting Base Metals into Gold	1	13
Middle Ages in Europe-Symbolism	0	14
Alexandrian Period-Converting Base Metals into Gold	0	11
Phlogiston Period-Combustion	0	8
Islamic Alchemy Period-Immortality	0	6
Antique Period- Atom	0	6
Modern Chemistry Period- The law of conservation of mass	0	5
Iatro Period - Drugs	0	4
Modern Chemistry Period- Periodic Table	0	3
Antique Period-Theories of Matter	0	3
Modern Chemistry Period-Gas laws	0	2

This question is aimed at revealing the knowledge of the pre-service teachers' about the important periods in the history of chemistry and what kind of contributions to chemistry were seen in these periods. From Table 4, it is seen that only three kinds of periods were identified at the beginning of the study and that mostly, the prehistoric period were given in the responses. These results indicate that most of the pre-service teachers accepted that the "discovery of fire," "cosmetics," "mummification" were important contributions to the area of chemistry in the prehistoric period. Also, responses regarding the Renaissance and the periods of Islamic alchemy were recorded at pre-test. When the responses identified at post-test were examined, it was seen that eight new responses were revealed in addition to the other responses. Particularly, the response of converting base metals into gold in the Alexandrian and Islamic alchemy periods has a high frequency. At the same time, immortality was connected to the Islamic alchemy period. These results showed that many prospective teachers thought that the alchemy period was an important part of chemistry and that progress had been made in this period. The other high frequency response is the Middle Ages in Europe. One of the distinctive characteristics of this period is the representation of chemical substances and compounds with symbols. Thus, the pre-service teachers could associate the Middle Ages in Europe with symbolism. One of the striking responses about the pre-service teacher's responses was related to the modern chemistry period. In these responses, the pre-service teachers could explain the developments in modern chemistry period in relation to three different points. These are: "the law of conservation of mass," "the periodic table," and "gas laws."

This result is important since it indicates that the pre-service teachers were able to discuss the development in modern chemistry period from different perspectives. Also, the pre-service teachers stated that the phlogiston period and studies on combustion reactions in this period were important developments. Particularly, these pre-service teachers explained that some chemists were able to identify some gases such as oxygen and carbon dioxide after the phlogiston period. One of the striking responses is the antique period. The pre-service teachers stated that the definition of the atom and theories of matter were important developments in this period. Another important response is the Iatro period since the pre-service teachers explained that the quantitative study of chemical reactions and drugs had gained importance in this period.

Question 4 Could you give examples of stories about life/studies of scientists in chemistry?

Table 5. Pre-service chemistry teachers' responses related to question 4

Stories about Scientists	Pre-test f	Post-test f
Life of Einstein	5	0
Life of Dalton	3	7
Life of Newton	3	0
Life of Marie Curie	2	2
Life of Edison	2	0
Life of Nobel	1	1
Life of Archimedes	1	0
Life of Lavoisier	1	5
Life of Thales	0	7
Life of Cleopatra	0	6
Life of El-Razi	0	5
Life of Maria the Jewess	0	4
Life of R.Boyle	0	2
Life of Paracelsus	0	2
Life of Arnold of Villanova	0	2
Life of Avogadro	0	1
Life of Ibn Sina (Avicenna)	0	1
Life of Valentinus	0	1
Life of Roger Bacon	0	1
Life of Agricola	0	1

Question 4 was prepared to identify which scientists' lives had an effect on the pre-service teachers. When Table 5 is examined, it can be seen that at the beginning of the study, most of the scientists identified worked in the area of physics and also that they were the most well-known scientists. In addition, these scientists commonly were commonly subjects of books, films and documentaries. Similarly, Özgelen and Öktem (2013) have stated that pre-service teachers usually had knowledge about scientists who have been the subjects of books, films, or soap operas. In this question, the pre-service teachers were impressed with the lives of Einstein, Newton, Edison and Archimedes. Some of these responses are presented below:

- "When Newton sat under the tree, the apple fell on his head. He explained gravity as a result of this." PT-27
- "Einstein wrote a letter to the President of the USA. In his letter, he stated his fears about Germany's developing an atomic bomb. It was after that that the USA developed the first atomic bomb." PT-5
- "Archimedes discovered the buoyancy of liquids in the bath and cried out, Eureka! Eureka!" PT-4
- "Edison performed many experiments to invent the light-bulb, but he did not succeed at first. On the other hand, he did not give up experimenting. While he was sitting in his laboratory, he discovered absent-mindedly how he could carbonize the materials, to be used for the filament. Finally, he used carbonized cotton thread filament and succeeded." PT- 16

Also, it was determined that the stories related to scientists in chemistry in the pre-service teachers' responses before the instruction were limited and had been influenced by what the chemistry textbooks said about Dalton, Marie Curie, Lavoisier and Nobel. Some of the responses belonging to pre-test are below:

- "Lavoisier's life is very important since he was the father of modern chemistry. He explained the law of conservation of mass. Unfortunately, he was guillotined." PT-3
- "Marie Curie worked with radioactive elements without knowing the harmful effects of radioactive elements on human health. She died as a result of this." PT-1
- "Dalton identified his own color-blindness and this disease was called "Daltonism" after him." PT-2

- "Nobel developed dynamite but several explosions occurred, and as a result of this, his brother died." PT-15

After the instruction, these pre-service teachers were able to offer scientists' lives in chemistry in their responses, showing that they could provide responses in the light of the history of chemistry. From Table 4, it is understood that the pre-service teachers could provide more of a variety of stories about scientists' lives in chemistry in their examples after the instruction. For example,

- "El-Razi applied a practical, scientific approach to chemistry. He avoided mysticism, but the people said that he found an "elixir," and succeeded in converting base metals into gold. At the same time, it was said that he used a golden plate and pot." PT-35
- "Cleopatra's life is very interesting because she was an intellectual woman since she could speak many foreign languages, and she also wrote a manuscript to explain the gold-making process." PT- 24
- "Maria the Jewess was one of the greatest alchemists. Marie as a woman affected many alchemists with her intents. Marie invented the water- bath (Bath of Maria) which even today is used in chemical laboratories and kitchens."PT-26
- "Paracelsus gave himself this name to indicate that he was greater than Celsus. He rejected Galen and Avicenna, and he threw their books into the fire. He tried to apply chemistry to medicine." PT-25
- "Thales was a philosopher and he was born in Millet in Turkey. He thought everything was made of water. He believed that water was the "primary substance" of all things. He was also interested in astronomy. It was said that he predicted a solar eclipse. This solar eclipse occurred during a battle between the Persians and Lydians. They were affected by this solar eclipse, and finished the battle" PT- 13.
- "Agricola studied medicine and lived in a city with mines. His medical duties included visiting the mines. As a result of this, he studied mineralogy and today he is known as "the father of mineralogy." PT-28
- "Although Basilius Valentinus was a Benedictine monk, he made important contributions to chemistry. In particular, he talked about antimony in his book. He was the one to supposedly give it its name." PT-22

- "Arnold of Villanova was one of the most important alchemists. He had some problems about the Church. He threatened some important people with medical theories. The church tolerated him because of his works." PT- 17
- "Bacon was apparently imprisoned or placed under house arrest for his works in alchemy. He divided alchemy into the "speculative" and "practical." He emphasized the importance of experimentation and also defined gunpowder in his book." PT- 27
- "Avicenna's extraordinary intelligence and memory influenced teachers in early years. He learned many languages and also mastered a wide range of disciplines, including mathematics, physics, geology, chemistry, alchemy, and medicine. He studied minerals and divided minerals into stones, sulphur, salt and fusible substances. His book about medicine is one of the most important books on medicine in Europe." PT-5
- "Robert Boyle's father was a rich man in Ireland. After college, he travelled to France, Italy and Switzerland for his education in his early years. He wrote a book, The Sceptical Chymist, which was important in chemistry, and in this book, he attacked the Aristotelian theory of the elements, and he also redefined an element as a substance that could not be broken down into component parts." PT-11.
- "Avogadro's life is very interesting. His father was a lawyer. He too studied law and began to work as a lawyer. On the other hand, he was interested in science. He set forth Avogadro's Principle. However, this principle was only accepted after almost half a century by other chemists." PT-8

Question 5 What are the areas of application of chemistry in society and life from the past to the present?

Table 6. Pre-service chemistry teachers' responses related to question 5

Areas of application of chemistry	Pre-test f	Post-test f
Drugs	24	29
Food	10	14
Petrochemistry	10	2
Cleaning products	9	12
Cosmetics	7	28
Paints	3	11
Defense industry	2	3

Immortality	2	15
Laboratory equipment	1	4
Energy sector	1	1
Ornamentation	1	1
Technology	1	1
Metallurgical industry	0	18
Converting base metals into gold	0	11
Leather industry	0	9
Mummification	0	9
Ceramics-glass	0	8
Industry	0	8
Production of alcohol	0	1

Question 5 was designed to determine the pre-service chemistry teachers' knowledge about the areas of application of chemistry from the past to the present. When Table 6 is analyzed, it can be seen that the pre-service chemistry teachers 'responses were mostly related to daily life at pre-test. In addition, all of these responses were also identified at post-test. Within these responses, the frequency of some responses increased, some decreased, and some did not change. For example, frequencies of "drugs," "food," "cleaning products," "cosmetics," "paints," "defense industry," "immortality," and "laboratory equipment" showed an increase after the instruction compared to before, whereas the frequency of "petrochemistry" decreased. At the same time, it was determined that the frequencies of the "energy sector," "ornamentation," and "technology" did not change. At post-test, seven new responses were revealed. These were: "the production of alcohol," "the leather industry," "the metallurgical industry," "ceramics-glass," "converting base metals into gold," "mummification," and "industry." When these responses are analyzed, it is understood that most were coherent with the content of the history of chemistry. For instance, the areas of mummification, glass and leather were emphasized in prehistoric times. Converting base metals into gold, the production of glass and ceramics were discussed in the context of the period of Islamic and European alchemy. At the same time, the metallurgical process was discussed in relation to both the Renaissance and the period of alchemy. In the light of these results, it can be said that the pre-service chemistry teachers' knowledge about the areas of application of chemistry had increased at the end of the study.

Results of the semi-structured interview

The pre-service teachers' responses to the first questions in the semi-structured interviews are shown in Table 7.

Question 1 Did active learning applications in the course on the History and Philosophy of Chemistry-I have any effects on you? If so, please explain.

Table 7. Pre-service teachers' views about the first interview question and sample views

Categories	f	Sample views
Improving knowledge of retention	22	"We made our presentation, introduced our poster, also prepared our timeline. These steps helped us to structure our knowledge. We learned how we could interpret the subject differently. In other words, these processes caused knowledge retention." PT-8
Learning how to prepare a poster	9	"We had not prepared a poster before the course. The lessons taught us how we could prepare a poster". PT-1
Learning entertainingly	7	"If we only made a power-point presentation, only the people who prepared the presentation would know the topic, and the other people would listen to the presentation in the first 5-10 minutes. After that, they would be bored. So the lessons included many activities. For example, while we prepared the timeline, we thought about how we were preparing it differently from the other groups. So we learned entertainingly." PT-14
Developing peer assessment abilities	4	"Everything was structured in the lessons. After we presented our poster in class, our friends evaluated our poster. Also, you evaluated our poster. As a result, both our abilities to assess ourselves and our friends were developed." PT- 3
Developing creativity	2	"While we prepared the timeline, we discussed how we can prepare it, what the format should be. This process had an effect on our creativity. In short, our creativity was developed." PT-15
Developing relationships inside the groups and in class	2	"The lessons consisted of many steps such as presentation, poster preparation, evaluation, and timelines. Preparing the timeline was a very important part of the lesson since it was the application step in the lesson. So, while we prepared the timeline, we developed our relationships inside the group and in class." PT-17

This question aimed to determine whether or not active learning applications had any effects on the pre-service teachers such as developing skills. From the interview data, it was revealed that all of the pre-service teachers stated that the active learning applications in the history of chemistry course had a positive effect on them. As can be seen from Table 7, the pre-service teachers' views about this question were grouped in six categories--improving knowledge of retention, learning about the preparation of a poster, learning entertainingly, developing peer assessment abilities, developing creativity, developing relationships inside the groups and in class." According to these results, it can be said that active learning applications helped pre-service teachers to develop some abilities such as peer assessment, creativity, inter-group relationships and preparing posters.

Question 2 Can you compare the instruction in of the History and Philosophy of Chemistry-I course with instructions in other courses?

Table 8. Pre-service teachers' views about the second interview question and sample views

Categories	f	Sample views
An Enjoyable Course	20	"When we make only an oral presentation, I get bored. Also, I usually do not listen to the teachers or our friends. But these lessons were different from the other lessons, and enjoyable. For example, we prepared the timeline based on the contents of that lesson. So, I concentrated the lessons and enjoyed it."PT-33
Including steps such as poster, timeline, and evaluation.	13	"We prepared many oral presentations for many courses. On the other hand, preparing the poster and timeline was the first time for this course. These sequences were very beautiful applications to learn. At the same time, there was an evaluation stage."PT-2
Active participation.	8	"In other lessons, we sometimes listen to our teachers and take notes. Sometimes, we present our presentations to the class. But we are never active like this. We participated in all the activities actively during the lessons." PT- 24
Learning without memorization	5	"The most important difference is that we learned without memorizing and we participated in all the activities and enjoyed it. As a result, we learned without having to memorize." PT- 27
Researching detailed	2	"In other lessons, we usually do not do any research. But the research is necessary for this course since we prepared a poster presentation in addition to an oral presentation. So, we had to research our topics in detail in many resources such as books and journals. It was not easy for me." PT- 36

The second interview question was asked in order to identify the pre-service teachers' comparisons of the instruction in the history of chemistry course with instructions in other courses. According to the pre-service teachers' responses, it appeared that they were satisfied with the active learning applications. Thus, many pre-service teachers stated that they enjoyed these lessons (f=20, in the category of an enjoyable course). From these explanations, it was understood that the pre-service teachers enjoyed the steps in the lessons such as preparing posters and timelines. Particularly, the pre-service teachers mentioned that they sometimes prepared oral presentations for other lessons, but preparing posters, timelines, and evaluations was a first for them (f=13, in the category of including steps such as poster, timeline, and evaluation). Also, the pre-service teachers remarked that they participated in all activities more actively than in other classes (f=8, in the category of active participation), and as a result, they learned without memorizing (f=5, in the category of learning without memorizing). Similar results were identified in other studies (Kalem & Fer, 2003; Karamustafaoğlu, et al., 2006; Aydede & Matyar, 2009). On the other hand, two pre-service teachers explained that doing research for the history of chemistry course was not easy for them since they were not used to doing detailed research. In the light of these results, it can be said that active learning applications helped make pre-service teachers more positive and interested in the History of Chemistry.

Conclusion and discussion

The main aim of the present study was to investigate the effectiveness of a History and Philosophy of Chemistry-I course based on active learning applications on the levels of knowledge of pre-service chemistry teachers about the history of chemistry as well as to explore their views regarding these applications. The results of the study indicated that active learning applications improved pre-service chemistry teachers' knowledge levels about the history of chemistry and that the pre-service chemistry teachers had positive views about the instruction. At the same time, it was revealed that active learning applications help pre-service chemistry teachers develop abilities such as peer assessment, creativity, inter-group relationships and preparing posters.

Depending on the first and second research questions, an open-ended questionnaire was administered as a pre- and post-test. When the pre-service teachers' responses at pre-test were analyzed, it was seen that most of the responses were very limited and related to scientists treated in the content of many chemistry courses in secondary school and the university, or in the field of physics, where they are often mentioned in books and in the media. For example, the pre-service chemistry teachers mostly gave examples of scientists related to atomic structure such as Dalton and Bohr before the instruction (see Table 3). At the same time, some responses in the field of physics, such as Newton-gravity, Archimedes-buoyant force and Tesla-electric power were identified at the beginning of the study. Similarly, many pre-service chemistry teachers stated that the lives of scientists in the field of physics such as Einstein, Newton, Edison and Archimedes had affected them (see Table 5). Another important finding was that many pre-service chemistry teachers did not have enough knowledge about the important periods of the history of chemistry before the instruction. Thus, pre-service chemistry teachers could mention only three periods, the prehistoric, the Renaissance and the period of Islamic alchemy, at pre-test (see Table 4). Also, in the study, it was revealed that most of the pre-service chemistry teachers explained the areas of application of chemistry from the past to the present according to their daily lives. In other words, the pre-service teachers could not consider the areas of application of chemistry in past periods such as in prehistoric times, the period of the Renaissance, or in the period of Islamic and European alchemy before the instruction (see Table 6).

After the instruction, it was observed that pre-service teachers' knowledge levels about the history of chemistry increased, and they provided more diverse and richer examples about the history of chemistry. For example, some responses involving scientists who had important roles in the development of chemistry, such as Ibn Sina, Maria the Jewess, Van Helmont, and Jabir Ibn Hayyan, and their contributions to chemistry were determined at post-test (see Table 2). At the same time, while the pre-service teachers at the beginning of the study mostly mentioned scientists who developed the atomic model, such as Dalton, and Bohr, or scientists in the field of physics such as Einsten, who had the biggest roles in the scientific development of chemistry, after the instruction, responses were recorded of scientists who had important roles in the history of chemistry such as Robert Boyle, Jabir Ibn Hayyan, Ibn Sina, and Democritus-Leucippus (see Table 3). Similar results were identified in question 3; many pre-service teachers mentioned the lives of scientists in chemistry instead of scientists in the field of physics such as Einstein, Newton, and Edison at post-test (see Table 5). Also, the pre-service chemistry teachers' responses related to important periods in the history of chemistry were examined and it was revealed that they emphasized important periods such as the Alexandrian era, the Middle Ages in Europe, modern chemistry, phlogiston, and the Iatro periods differently than before the instruction (see Table 4). One of the striking results was determined in question 5. When the pre-service chemistry teachers' responses were analyzed, it was seen that they could gave responses based on not only their daily lives but also important periods in history of chemistry such as the Islamic and European alchemy eras and the period of the Renaissance (see Table 6). From these findings, it was understood that the History and Philosophy of Chemistry-I course based on active learning applications contributed to improving pre-service teachers' levels of knowledge about the history of chemistry.

Regarding the third, and fourth research questions, the semi-structured interview was conducted with all of the pre-service chemistry teachers. According to an analysis of the interview, most of the pre-service chemistry teachers perceived active learning applications as enjoyable. This result is consistent with related literature (Kalem & Fer, 2003; Aydede & Matyar, 2009). The pre-service chemistry teachers also expressed that active learning applications help them to learn basic knowledge about the history of chemistry without memorizing. At the same time, the pre-service teachers stated that these active learning applications help them to develop abilities such as creativity, relationships between friends, peer assessment and preparing posters. These findings are in agreement with previous research findings that reveal that active learning applications help students develop relationships and improve their learning (Karamustafaoğlu, et al., 2006).

In the present study, firstly, the pre-service chemistry teachers carried out their research topics in small groups. Secondly, they presented oral presentations to the class, and in the third step, the groups summarized the research topics in their posters. After that, the pre-service teachers evaluated their peers' posters according to the rubric, and discussed the positive and missing points of their peers' posters. At the end of the lessons, the groups prepared timelines based on the features of the periods in the history of chemistry, presented these to the class, and had a discussion. At the same time, they shared their ideas with each others, interpreted and discussed. The National Research Council (1997) has stated that discussion, group activities, interesting and enjoyable learning environments are important in promoting learners' learning process. Thus, the findings from the interviews indicated that the pre-service chemistry teachers were generally satisfied with the active learning applications. On the other hand, some of the pre-service chemistry teachers expressed the view that they had difficulty researching for the preparation of the posters since this was new for them. The pre-service teachers held this view even though the researchers had explained how a poster was prepared and presented posters to the class of pre-service teachers one week prior to the study. For this reason, different poster examples were available to examine and help the students in this task.

It would also be useful for studies to be conducted to compare the effects of active learning applications in a class using other teaching strategies in the history of chemistry. This study was conducted with only 38 pre-service chemistry teachers as a case-study. For this reason, it would be beneficial to conduct future studies in larger groups using enriched multiple tools such as observations and students' diaries, which would help to generalize the results. Furthermore, "The History of Chemistry" may be integrated with chemistry lessons in the university and in secondary schools. Particularly, as stated by Wang and Cox-Petersen (2002), integrating the history of chemistry with daily chemistry instruction will contribute to producing more scientifically and culturally literate citizens.

References

Aydede, M.N., & Matyar, F. (2009). The effect of active learning approach in science teaching on cognitive level of student achievement. *Journal of Turkish Science Education*, *6*(1), 115-127.

Allen, E. E. (1995). Active learning and teaching: Improving post-secondary library instruction. *Reference Librarian*, *51/52*, 89-103.

Bonwell, C.C., & Eison, J.A. (1991). Active learning: *Creating excitement in the classroom*. (ERIC Number: ED340272).

Bayrakçeken, S., Canpolat, N., & Çelik, S. (2011). The nature of chemistry and teaching, Paper presented at the II. National Chemistry Education Congress 5-8 June 2011, Erzurum, Turkey.

Coştu, B., Ünal, S., & Ayas, A. (2007). A hands-on activity to promote conceptual change about mixtures and chemical compounds, *Journal of Baltic Science Education, 6*(1), 35–46.

Fayombo, G.A. (2012). Active learning: Creating excitement and enhancing learning in a changing environment of the 21st century. *Mediterranean Journal of Social Sciences*, *3*(16), 107 – 128.Doi:10.5901/mjss.2012.v3n16p107

Fies, C. (2005). *Classroom response systems: What do they add to an active learning environment*. Unpublished Doctoral Dissertation The University of Texas, Austin, TX.

Grace, A. F. (2012). Active learning strategies and student learning outcomes among some university students in Barbados. *Journal of Educational and Social Research, 2*(9), 70-90.

Höttecke, D., Henke, A., & Riess, F. (2012). Implementing history and philosophy in science teaching: Strategies, methods, results and experiences from the european HIPST Project. *Science & Educaton*, 21, 1233–1261. http://dx.doi.org/10.1007/s11191-010-9330-3.

Herron, J. D. (1975). High school forum. *Journal of Chemical Education, 52*(2), 179–180.

Jansen, W.(1995).Das historisch-problemorientierte unterrichtsverfahren einforschungsprojekt [The historical problem-centered conception – A Research Project]. In Günter-Arndt, H., & Raapke, H.G. (Eds.), *Revision der Lehrerbildung*. Oldenburg: Zentrum für padagogische Berufspraxis.

Justi, R., & Gilbert, J. (1999). History and philosophy of science through models: The case of chemical kinetics. *Science & Education, 8*, 287-307.

Jensen, W. B. (2011) Why study history of chemistry. *Tecné, Episteme y Didaxis, 29*, 4-7.

Janes, B. (2004). On the shoulders of giants. *Science Scope, 28*(3), 36–37.

Karamustafaoğlu, S., Coştu, B., & Ayas, A. (2006). Turkish chemistry teachers' views about an implementation of active learning approach in their lessons. *Asia-Pasific Forum on Science Learning and Teaching, 7*(1).

Kalem,S., & Fer, S. (2003). The effects of the active learning model on students' learning, teaching and communication. *Educational Sciences: Theory & Practice, 3*(2), 455-461.

Kalof, L., Dan, A., & Dietz, T. (2008). *Essentials of Social Research*. Open University Press: Berkshire, England

Kubli, F. (2005). *Mit geschichten und erzahlungen motivieren* [Motivating with stories and narratives]. Köln: Aulis Verlag Deubner.

Lin, H. S., Hung, J. Y., & Hung, S. C. (2002). Using the history of science to promote students' problem-solving ability. *International Journal of Science Education, 24*(5), 453–464.

Matuschek, C., & Jansen, W. (1985). Chemieunterricht und geschichte der chemie. [Chemistry education and the history of chemistry]. *Praxis der Naturwissenschaften Chemie, 24*(2), 3–7.

McKinney, D., & Michalovic, M. (2004). Teaching stories of scientists and their discoveries. *Science Teacher, 71*(9), 46–51.

Metz, D., Klassen, S., McMıllan, M., Clough, M., & Olson, J. (2007). Building a foundation for the use of historical narratives. *Science & Education, 16*(3), 13–334.

Miles, M.B., & Huberman, A.M. (1994). *Qualitative data analysis*. Thousand Oaks: Sage.

Mulongo, G. (2013). Effect of active learning teaching methodology on learner participation. *Journal of Education and Practice, 4* (4),157-168.

National Research Council (1997). *Science teaching reconsidered: a handbook*. National Academies Press: Washington, DC.

Niaz, M., & Rodríguez, M. A. (2000). Teaching chemistry as rhetoric of conclusions or heuristic principles - a history and philosophy of science perspective. Chemistry Education: Research and Practice in Europe. 1 (3), 315 – 322. Niaz, M., & Rodríguez, M. A. (2001). Do we have to ıntroduce history and philosophy of science or is it already 'ınside' chemistry? *Chemistry Education: Research and Practice in Europe*, *2*(2), 59 – 164.

Prosser, M., & Trigwell, K. (1999). Relational perspectives on higher education teaching and learning in the sciences. *Studies in Science Education, 33*, 31-60.

Quilez, J. (2004). A historical approach to the development of chemical equilibrium through the evolution of the affinity concept: some educational suggestions. *Chemistry Education: Research and Practice, 5*(1), 69-87.

Özgelen, S., & Öktem, Ö. (2013). Preservice science teachers' development of knowledge about history of science during the nature and history of science course. *Mersin University Journal of the Faculty of Education, 9* (1),11-23.

Sanchez, P. J., & Martín, F. (2003). Quantum vs. "classical" chemistry in university chemistry education: A case study of the role of history in thinking the curriculum. *Chemistry Education: Research and Practice, 4*, 131-148.

Şesen, B.A., & Tarhan, L. (2011). Active-learning versus teacher-centered instruction for learning acids and bases. *Research in Science & Technological Education, 29(2),* 205–226.http://dx.doi.org/10.1080/02635143.2011.581630.

Scheffel, L., Brockmeier, W., & Parchmann, I. (2009). Historical Material in Macro– Micro Thinking: Conceptual Change in Chemistry Education and the History of Chemistry. In J.K. Gilbert, D. Treagust (eds.),*Multiple Representations in Chemical Education, Models and Modeling in Science Education 4* (pp 215-250), Springer. http://doi.org/ 10.1007/978- 1-4020-8872-8 11.

Sivan, A., Leung, R. W., Woon, C.C., & Kember, D. (2000). An implementation of active learning and its affect on quality of student learning. *Innovations in Education and Training International, 37*(4), 381-389.

Sivan, A., Leung, R. W., Gow, L., & Kember, D. (1991). Towards more active learning in hospitality studies. *International Journal of Hospitality Management, 10*, 369-379.

Şimşek, L. C. (2011). The effect of student studies in the nature and history of science lesson to the level of the knowledge about history of science. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education*, *5*(1), 116-138.

Tural, G. (2012). Gains of physics teacher candidates in history of science course conducted by research and discussion approaches. *The Journal of Instructional Technologies & Teacher Education*, *1*(1), 52-67.

Wandersee, J. H. (1992). The historicality of cognition: Implications for science education research. *Journal of Research in Science Teaching*, *29*(4), 423-34.

Wandersee, J. H., & Griffard, P.B. (2002). The history of chemistry: Potential and actual contributions to chemical education. In J. K. Gilbert et al (eds). *Chemical Education: Towards Research-Based Practice* (pp 29-49), Kluwer. http://dx.doi.org/10.1007/0-306-47977-X_2

Wang, H.A., & Cox-Petersen, A.M. (2002). A comparison of elementary, secondary and student teachers' perceptions and practices related to history of science instruction, *Science & Education*, *11*, 69-81.