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Does a course on the history and philosophy of chemistry have any effect on prospective chemistry teachers' perceptions? The case of chemistry and the chemist

G. Sendur, *[a] M. Polat[b] and C. Kazancı[c]

The creative comparisons prospective chemistry teachers make about "chemistry" and the "chemist" may reflect how they perceive these concepts. In this sense, it seems important to determine which creative comparisons prospective teachers make with respect to these and how these can change after the history of chemistry is treated in the classroom. This study seeks to investigate the impact of the basic History and Philosophy of Chemistry course on prospective chemistry teachers' perceptions towards chemistry and the chemist. The study was conducted during the 2012–2013 academic year at a state university in Turkey with 38 prospective chemistry teachers. A creative comparisons questionnaire and semi-structured interviews were used as data collection instruments in the study. This questionnaire was administered to the prospective teachers in the form of a pre-test, post-test, and retention test. Results of the analysis showed that the prospective teachers produced creative comparisons related to chemistry in the pre-test that mostly relied on their own experiences and observations, but that in the post-test and retention test, their comparisons mostly contained references to the role of chemistry in daily life, its development, and its facilitating aspects. Similarly, it was observed that in the pre-test, the prospective teachers made creative comparisons regarding the chemist that related mostly to the laboratory, but that the post-test and retention test rather contained the aspects of chemists as researchers, meticulous persons, facilitators and managers. Also, 18 prospective teachers were engaged in interviews to understand their prior knowledge about chemistry and the chemist, as well as the reasons for the changes in their creative comparisons. The results of the interviews indicated that a large majority of the prospective teachers were able to fully reflect on their inadequacy about their previous knowledge about "*chemistry*" and "*chemist*," and it was seen that they could explain the reason they changed their creative comparisons as an outcome of the History and Philosophy of Chemistry course. In the light of these results, it can be said that the History and Philosophy of Chemistry course may help prospective chemistry teachers in their perceptions about both chemistry and the chemist and may add depth to their knowledge.

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Introduction

Chemistry is an important part of our academic and daily lives. Historical and cultural factors have caused chemistry sometimes to be perceived positively and at other times from a negative viewpoint (Solbes and Traver, 2003). Perceptions that students have about the concepts of chemistry and the chemist may have an effect on their interest in the chemistry course (Bayrakçeken *et al.*, 2011). Also, the perceptions chemistry teachers have of the same concepts may have an effect on how they teach chemistry. Thus, Pickens (2005) stated that perceptions affect the attitudes and tendencies of individuals that are essential for thoughts and actions. Similarly, Van Driel *et al.* (1998) expressed that teachers' beliefs related to science teaching, science learning and science may influence their educational applications in the science classroom. One of the factors that affect the classroom applications of teachers is the stereotypical images they have of science and scientists (Rosenthal, 1993). In fact, some studies assert that the less stereotypical images individuals harbor in their minds about scientists, the more positive their attitudes are about science and the more enthusiastic they are about doing research in a scientific field (Flick, 1990; Bodzin and Gehringer, 2001).

[a] *Dokuz Eylul University, Chemistry Education, Izmir, Turkey. E-mail: gulten.sendur@deu.edu.tr*
[b] *Celal Bayar University, Science Education, Manisa, Turkey*
[c] *Dokuz Eylul University, Educational Science Institute, Turkey*

Moreover, Kahle (1988) points to the great importance of teachers' perceptions about science and scientists, remarking that these perceptions have an impact on the attitudes of their students toward science. When considered from this perspective, it appears to be important to determine the perceptions of both teachers and prospective teachers about science and scientists.

Many researchers have resorted to different methods of determining these perceptions. For example, differential semantic scales (Rodriguez Sala de Gomezgil, 1975), questionnaires composed of open-ended questions (Petkova and Boyadjieva, 1994; Ruão *et al.*, 2012), Likert-type scales (Krajkovich and Smith, 1982) essays (Mead and Metraux, 1957), interviews (Palmer, 1997; Parsons, 1997), WAT (Bovina and Dragul'skaia, 2008), and drawing tests (Chambers, 1983; Rosenthal, 1993; Finson *et al.*, 1995; She, 1995; Fung, 2002) were used to determine perceptions. According to Lakoff and Johnson (1980), one of the ways of identifying how individuals perceive and think is through the use of metaphors.

Metaphors are cognitive devices to help individuals relate to the known and the unknown, providing a window to how individuals understand the world (Kanthan and Mills, 2006; Lancor, 2014a). Metaphors further represent this in the format of comparisons such as "A (unknown) is B (known)" (Nakipoğlu and Taber, 2013). Namely, the comparison in a metaphor is implicit. As a result, metaphors enable us to discover how people think about something (Saban *et al.*, 2006; Zheng and Song, 2010). According to Bullough (2015), people use metaphors to understand themselves, their experiences and the world in which they live. In addition, metaphors give us the ability to find out how students understand science concepts (Lancor, 2014a). Other tools that can be used to relate their scientific ideas to ideas that students find familiar, to determine students' thinking, are analogies and similes. Both analogies and similes allow students to relate their scientific ideas to notions that students find familiar, and as a consequence, the unfamiliar is made familiar by being expressed in the format, "A (unfamiliar) is like B (familiar)" (Coll, 2006). In other words, analogies and similes presented explicit comparisons of structures in two domains (Duit, 1991). In this context, it may be claimed that analogy and simile are the same. On the other hand, analogies and similes can be distinguished from each other in that similes map attributes while analogies map structural similarities; similes are intended as analogies in a narrower sense (Miller, 1993; Israel *et al.*, 2004). According to Kanthan and Mills (2006), a simile is "a figure of speech in which two essentially unlike things are compared." In other words, similes are simpler than analogies since they are limited to identifying similarities.

In the literature, there is much discussion on how "metaphor," "analogy" and "simile" can be defined (Lancor, 2014a, 2014b). Thus, Nakipoğlu and Taber (2013) have stated that the intention behind using these terms is often the same; these terms differ from each other in the context of whether the comparisons are explicit or implicit and whether they include structural similarities or attributes. Also, Sendur (2014) has stated that the term "creative comparisons" can be used as an inclusive term for metaphors, analogies, and similes, and that asking students to generate comparisons about science concepts may reveal their creativity. Thus, Taber (2016) asked students to make comparisons related to some science concepts in the format, "A is like B because…" stating that this activity encouraged the students to be creative in a science-learning context. In addition, Lancor (2014a) asserted that allowing students to make comparisons about science concepts help them to be creative and reveal ideas related to these concepts that they were not consciously aware of.

In this study, the term "creative comparisons" was used as a general term since the prospective chemistry teachers were asked to generate comparisons about the concepts of "chemistry" and "chemist." However, the term "creative comparisons" in the study includes only analogies and similes because the prospective chemistry teachers were asked to generate comparisons in the format "A is like B." Thus, when the prospective chemistry teachers' generated comparisons were examined, it was determined that some of these comparisons were analogies, while some were similes.

In education, asking individuals to generate comparisons about concepts offers them the opportunity to consider educational elements and phenomena by relating these to things formerly experienced (Botha, 2009; Lancor, 2014b; Hamilton, 2016). Additionally, in-service and prospective teachers' creative comparisons provide us with insight as to their perceptions and roles within the classroom (Thomson, 2015). Moreover, since the creative comparisons of prospective teachers reflect their ideas and perspectives about teaching before they became in-service teachers, this knowledge may be used by teacher educators to evaluate teacher education programmes (Hamilton, 2016). In this process, prospective teachers may also evaluate their own education in the context of prior knowledge, beliefs and experiences (Bullough, 2008).

Another important point is how prospective teachers' creative comparisons change over time. In this context, Hamilton (2016) has stated that prospective teachers' generated comparisons will change over time as they gain more experience and knowledge. Also, Skamp and Mueller (2001) reported that prospective teachers' beliefs, ideas and perceptions may be shaped by the effects of their undergraduate programme. In this context, Markic and Eilks (2008) stated that more studies are needed in the future to clarify how students' beliefs change during the course of university studies, and how training units can be used as methods to change beliefs in students' minds.

It is significantly beneficial for this reason to study and examine the changes in prospective teachers' perceptions in the context of creative comparisons.

In the light of this, it seems important to determine what kind of creative comparisons prospective chemistry teachers regarding chemistry and the chemist and to observe how these can change after the study of the historical progress of chemistry. According to Kamsar (1987), learning from history about how our culture has impressed chemistry and how chemistry has impressed history and peoples' ideas can help us to

interrelate chemistry, present social issues and ideas since Chemistry is an important part of our culture. For this reason, Kamsar stated that teaching the history of chemistry is a major contribution to students in developing scientific and critical thought.

Similarly, Kauffman (1987) has expressed the notion that students may accept chemistry as an unchanging, finished product without some history. Kauffman (1987) therefore emphasises that the history of chemistry can help students see that chemistry is a dynamic rather than a static structure. In another study, Justi and Gilbert (1999) asserted that the introduction of the history and philosophy of science into science education may have changed some perceptions related to science. The researchers point out that science was first perceived as a collection of "agreed upon facts," specific acts were accepted without considering their development or relationship to other scientific or nonscientific knowledge, and the methodology for the production of scientific knowledge was perceived as homogeneous and based on empiricism. In their study, Justi and Gilbert (1999) particularly stated that discussing historical models related to topics such as chemical kinetics helps students to understand the dynamism of the construction of scientific knowledge since change from one model to another represents an evolutionary process.

Additionally, Olsson *et al.* (2015) have reported that many students have alternative concepts about how chemistry knowledge is generated, and for this reason science educators must be well versed in the history of chemistry in order to overcome alternative concepts. Researchers have also explained that when in-service and prospective teachers are trained in the field of the history of chemistry, they may incorporate history and content into chemistry courses and teach their students how scientific findings have informed subsequent experiments in chemistry. In another study, Solbes and Traver (2003) stated that a historical focus in chemistry might generate a positive attitude towards scientific knowledge. As a result of this, students may be observed to show an increased interest in participating in the process of teaching and learning.

Although the importance of the history of chemistry has been accepted in many contexts, there is still a need for studies investigating the effects of the history of chemistry on students' perceptions in regard to concepts of chemistry and the chemist.

According to Kubiatko (2015), it is of great importance with respect to ensuring that learners have positive perceptions about chemistry that they are able to form an association between chemistry and daily life, that the significance of chemistry and how chemistry is used is emphasised. From this perspective, reviewing the historical progress of chemistry and the effects of chemistry on individual, social and scientific life has the potential of influencing individuals' perceptions about chemistry and the chemist. Indeed, Büyükekşi and Yavuz (2016) have noted that lessons which underscore the place and effects of chemistry in our lives may exert an influence on students' perceptions about chemistry. Although, it was accepted that the importance of promoting prospective teachers' awareness of their own perception of chemistry in these studies, it was not investigated how prospective teachers' perceptions toward chemistry changed with the effects of lessons which include development of chemistry, importance of chemistry for the individual, society and scientific developments. To fill this gap, the present study thus seeks to identify the effects of the History and Philosophy of Chemistry course on prospective teachers' perceptions related to the concepts of chemistry and the chemist.

In this context, the present study may provide evidence as to how the History and Philosophy of Chemistry course may help prospective teachers' perceptions. At the same time, the study is of importance in terms of enlightening prospective chemistry teachers about how they can become aware of their own perceptions toward chemistry and the chemist, evaluate themselves and accordingly set up their teaching plans for the next period.

For this reason, this study will help chemistry educators and curriculum developers to learn about how the subject of the History of Chemistry has been designed and renewed in teacher and prospective chemistry teacher training programmes.

Purpose and research questions

This study seeks to investigate the impact of the basic History and Philosophy of Chemistry course on prospective teachers' perceptions towards chemistry and the chemist. Toward this objective, answers were sought in the study to the following questions:

(1) Which creative comparisons related to the concepts of chemistry and chemist did the prospective chemistry teachers make use of in the pre-test, post-test and retention test?

(2) Are there common response patterns for the creative comparisons that would allow the responses to be grouped into categories?

(3) Do prospective teachers shift from one category of change to another category of change over the process of pretest to post-test to retention test?

Method

The study was conducted in line with case study methodology. Creswell (2012) has described a case study as an in-depth exploration of a bounded system (*e.g.*, activity, event, process) based on extensive data collection. Gray (2004) also stated that case study methodology is particularly useful when the researcher is trying to uncover a relationship between a phenomenon and the context in which it is occurring. In addition, Gray (2004) asserts that the case study method is ideal when questions are being asked about a contemporary set of events over which the researcher has no control.

In a case study, the researchers cannot select the case randomly since the main features of this methodology requires the researchers to choose their cases purposefully (Taber, 2013). Yin (2003) stated that single case design is appropriate when the case represents something unique. According to McMillan and Schumacher (2001), a case's uniqueness and ability to

illustrate an issue are important factors which determine the selection of cases.

In this study, the class of the prospective chemistry teachers taking History and Philosophy of Chemistry course was selected as the case. In Turkey, there are thirteen faculties of education which include chemistry education as an undergraduate programme. In only one of these faculties, do the undergraduate prospective chemistry teachers take a History and Philosophy of Chemistry course.

The main aims of this study were to reveal the effects of the History and Philosophy of Chemistry course on prospective chemistry teachers' perceptions. Therefore methodology of using a creative comparison questionnaire (pre-, post- and retention tests) complemented by semi-structured interviews was thought to be an appropriate design for this research.

The participants

The participants in the research were 38 prospective chemistry teachers (27 females and 11 males) enrolled in a History and Philosophy of Chemistry course in a public university in Turkey during the 2012–2013 academic year. All 38 prospective chemistry teachers in the class had volunteered to participate in the research. Toward this aim, the prospective chemistry teachers handed in informed consent forms before the study. The ages of the prospective teachers ranged from 20 to 23 years. The prospective chemistry teachers had quite similar backgrounds. The socioeconomic status of the prospective chemistry teachers was similar, with the majority of them coming from low- to middle-income families. All of the prospective teachers were in the fourth year of the five-year chemistry teacher education programme. In this programme, the prospective teachers took major chemistry courses (general chemistry, organic chemistry, biochemistry, analytical chemistry, and physical-chemistry), laboratory courses (analytical chemistry laboratory, organic chemistry laboratory, physical-chemistry, *etc.*), general pedagogical courses (developmental psychology, theories and approaches of learning and instruction, curriculum development and teaching, *etc.*) and courses of pedagogical content (research projects in chemistry education, special teaching methods, scientific research methods in chemistry education, *etc.*). In addition, the content of the courses the prospective teachers took was different from that of the History and Philosophy of Chemistry course.

Data collection instruments

The research made use of two data collection instruments: a creative comparisons questionnaire and semi-structured interviews. All of the data were collected in Turkish. The first and second researchers translated all data into English and then enlisted the help of a faculty member who was an expert in chemistry education; a native speaker was also called upon to check the material.

Creative comparison questionnaire

The researchers prepared a questionnaire to determine which creative comparisons the prospective chemistry teachers would use to explain chemistry and chemist, and accordingly, what their perceptions were regarding chemistry and the chemist. Similar questionnaires have been used in different studies to determine students' comparisons related to concepts that included school, computer teacher, and knowledge (Saban, 2008, 2011; Yener and Ozkadif, 2010; Dogru and Sarac, 2013). To ensure the validity of the questionnaire, a pilot study was conducted with 10 prospective teachers outside of the sample and it was determined that 15 minutes was enough for each concept. At the same time, two experts in chemistry education were consulted about the concepts. Before filling out the questionnaire, the prospective teachers were informed about creative comparisons and then asked to make creative comparisons about the concepts "chemistry" and "chemist," then to explain the reasons for their creative comparisons by completing the sentences in the questionnaire (example: Chemistry is like ..... because .....; a chemist is like ..... because .....). Thus in the implementation of the study, the teacher candidates were asked to complete the sentence for each concept in 15 minutes. The researchers timed each question, telling the prospective teachers to go on to the next concept at the end of 15 minutes. The questionnaire that was developed was administered to the prospective teachers in the form of a pre-test and post-test, and then a retention test. The retention test was administered four months after the post-test. The purpose of the retention test was to more clearly set out the change in the prospective teachers' perceptions of chemistry and the chemist as a result of the process.

Semi-structured interview

The prospective teachers in the study who had produced different creative comparisons in the pre-test and post-test were engaged in semi-structured interviews to determine their thought processes, perceptions, and why they had changed their minds when making their creative comparisons. At the same time, the interviews were meant to investigate whether or not the course on the history and philosophy of chemistry had an impact on the knowledge of the prospective teachers about chemistry and the chemist. For this purpose, the creative comparisons for the concepts of chemistry and chemist drawn up by the prospective teachers on the pre-test and post-test were examined and the prospective teachers were accordingly divided into three categories: Type 1, Type 2 and Type 3. The characteristics of each category were as follows:

Type 1: the prospective teachers in this category had provided the same creative comparisons and explanations in both the pre-test and the post-test. It was found that 4 prospective teachers could be placed in this category for their comparisons regarding chemistry and 13 prospective teachers could be placed in the same category for their comparisons regarding the chemist.

Type 2: the prospective teachers in this category provided different creative comparisons and explanations on both the pre-test and the post-test. It was found that 27 prospective teachers could be placed in this category for their comparisons

regarding chemistry and 14 prospective teachers could be placed in the same category for their comparisons regarding the chemist.

Type 3: the prospective teachers in this category provided different creative comparisons on both the pre-test and the post-test, but their explanations were the same. Seven prospective teachers were placed in this category for chemistry and 11 prospective teachers for chemist.

Before the process of grouping interviews into categories, the first two researchers paired all the prospective teachers' creative comparisons with the categories. Then an expert in chemistry education was asked to pair the creative comparisons with the defined categories, and the percentage of agreement was calculated. Detailed explanations have been presented in the data analysis section. In the process of grouping interviews into categories, the first two researchers divided the prospective teachers into three categories independently of each other, and in the case of disagreement between the researchers, they made their final decisions together.

After the researchers divided the prospective teachers into these categories, an interview was held with 12 randomly selected prospective teachers from the Type 2 group for each of the concepts. Since the purpose of the interviews was to determine the reason for the difference in the pre-test and post-test creative comparisons set forth by the prospective teachers and to find out what their thought processes were in creating the comparisons, only the prospective teachers in the Type 2 group were interviewed. This was also because only the prospective teachers in this category had displayed differences in both their creative comparisons and their explanations.

The third researcher conducted individual interviews with each of the prospective teachers. Each interview was completed in 15–20 minutes. These semi-structured interviews were held one week after the creative comparisons questionnaire had been administered as a post-test. An audio recorder was used in the interviews and the entire interview was recorded. In the interviews, the researchers asked the prospective teachers four questions that they had formulated. The questions had been reviewed by two experts in chemistry education and revised according to the experts' views. The questions and their objectives are presented in Table 1.

Procedure

The research was conducted in a chemistry education programme of a state university in Turkey during the academic year 2012–2013 and involved the course, "History and Philosophy of Chemistry." The creative comparisons questionnaire that comprised the pre-test was administered to the prospective teachers 4 weeks prior to the instruction.

The topics covered in the course were namely and in order, "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." Among the topics included under these headings were:

Ancient Chemistry: Prehistoric Times, Early Chemical Arts (Glass Production and Processing; Precious Stones; Metals and Mining, Fermentation and Leatherwork, Paints and Cosmetics, Soaps)

The Antique and Hellenistic Eras: Naturalistic Philosophy in Ancient Greece, Ancient Greek Atomism and the Theory of the Four Elements (Thales, Anaximander, Anaximenes, Heraclitus, Empedocles, Leucippus, Democritus, Plato, Aristotle), The Teaching of the Four Humors (Galen), The Alexandrian era

Origins of Alchemy and Islamic Alchemy: the Early Alchemists (Hermes, Cleopatra, Maria Prophetissima), Islamic Alchemy and alchemists (Jabir ibn Hayyan (Geber), Razi, ibn Sina (Avicenna), Al-Biruni)

European Alchemy: important alchemists in Europe (Albertus Magnus, Roger Bacon, Arnold of Villanova)

Alchemy in the Italian Renaissance: important alchemists in the Italian Renaissance (Paracelsus, Georgius Agricola, Andreas Libavius, van Helmont, Basilius Valentinus, Johann Rudolph Glauber).

Table 1 Questions in the interview and their objectives

Question		Objectives
1st question	Did you come across anything after taking the course on the History and Philosophy of Chemistry that made you think that your previous knowledge about "chemistry" had been inadequate or limited?	To understand whether or not the course on the History and Philosophy of Chemistry had an impact on the knowledge of the prospective chemistry teachers about "chemistry."
2nd question	Was there a change in the creative comparisons you made related to "chemistry" after taking the course on the History and Philosophy of Chemistry? What was that change? What are the reasons for the change?	To determine how the prospective chemistry teachers formulated their creative comparisons about "chemistry" on the pre-test and post-test and how they explained the reason for the change.
3rd question	Did you come across anything after taking the course on the History and Philosophy of Chemistry that made you think that your previous knowledge about "chemist" had been inadequate or limited?	To understand whether or not the course on the History and Philosophy of Chemistry had an impact on the knowledge of the prospective chemistry teachers about "chemist."
4th question	Was there a change in the creative comparisons you made related to "chemist" after taking the course on the History and Philosophy of Chemistry? What was that change? What are the reasons for the change?	To determine how the prospective chemistry teachers formulated their creative comparisons about "chemist" on the pre-test and post-test and how they explained the reason for the change.

Chemistry in the 16th and 17th Centuries: Robert Boyle, Transition into the era of the phlogiston theory, important representative of the phlogiston era (Johann Joachim Becher, Georg Ernest Stahl)

Introduction to Modern Chemistry: events leading to the deterioration of the phlogiston theory and famous chemists of the times (Joseph Black, Henry Cavendish, Carl Wilhelm Scheele, Joseph Priestley and Antoine Laurent Lavoisier), Transition into Modern Chemistry in the light of Thomas Khun's paradigm shifts, Important Representatives of the era of modern chemistry (Proust, Gay-Lussac; John Dalton, Amedo Avagadro, Mendeleyev), Treating developments in the history of chemistry in the light of Karl Popper's principle of falsifiability.

These were treated in five steps. The steps were in the following order:

(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 time line

(5) Assessment of the pre-service chemistry teachers' time lines.

Prior to the instruction, the pre-service chemistry teachers were informed about how these steps and how the course would be taught and the students were asked to form groups of 5–6. After randomly deciding which groups would be working on which topics, the students were given a period of 3 weeks to do their research. During this process, the first researcher provided the groups feedback and advice. Particularly, the prospective teachers were asked to emphasise some points in their topics, while they prepared their presentations. These are:

• What is the importance of this period in history of chemistry?

• Who are the representatives of this period?

• What works did the representatives of this period produce (*e.g.*, chemists' hypothesis, experimental design, and inventions)

• What have been the effects of these works on the contemporary world, daily life, societies and scientific developments?

The lessons started with oral presentations prepared by the groups. In their presentations, the prospective teacher specifically described the particulars of the period they were researching, the outstanding scientists belonging to that period and what works they had produced, and also the impact of these works on social and scientific life. The prospective teachers structured their presentations on the basis of the steps (introduction, purpose, sub-problems, *etc.*) included in a scientific article (an example of the prospective teachers' presentations can be found in Appendix 1). Following the prospective teachers' oral presentations, they presented their posters. The aim of the poster presentations was to allow the groups to summarise their research topics. Following the poster presentations of each group, the groups were asked to evaluate the posters according to the rubric, after which the class instructor (the first researcher) made an assessment of each poster. In this process, discussions were held with the prospective teachers who wished to express their thoughts on their posters. After the assessment of each poster, the other groups were asked to draw up a time line on the content of the posters of the other groups. In this step, group members shared their thoughts and drew up the time line based on their discussions. When the time line of all the groups had been completed, the instructor and the members of the group making each presentation assessed the time lines, commenting on any omissions or mistakes.

The course continued to be carried out in this format for 7 weeks (two 45 minute sessions every week). One week after the instruction, the creative comparisons questionnaire was administered as a post-test and then as a retention test 4 months after the post-test. Following the administration of the post-test, semi-structured interviews were held with a total of 18 prospective chemistry teachers randomly selected from the Type 2 group (12 prospective teachers each from Type 2 for both concepts of chemistry and chemist). Due to the fact that 6 prospective teachers ranked as Type 2 for both concepts of chemistry and chemist, in total, 18 different prospective teachers were interviewed.

Data analysis

The data obtained from the creative comparisons questionnaire in the study were analysed based on content analysis. The analysis consisted of tracking the materials in 4 steps: "Naming; developing categories; establishing validity and reliability; calculating, and interpreting percentages and frequencies for creative comparisons" (Saban *et al.*, 2006; Saban, 2008, Ozder, 2013; Sendur, 2014). The steps in the process were:

(1) Naming: in this step, each of the creative comparisons composed by the prospective teachers for each concept were individually examined and checked to determine whether there was anything missing in the creative comparisons or in their explanations. The result of the review determined that all of the creative comparisons formulated by the prospective teachers on the pre-test, post-test and retention test were meaningful. In other words, none of the prospective teachers' creative comparisons were eliminated. Following this step, the prospective teachers' creative comparisons were set up in alphabetical order. At this stage, the creative comparisons composed by the prospective teachers were examined in detail and, since this was treated like coding,

(2) Developing categories: in this step, the prospective teachers' creative comparisons were examined to spot common characteristics, after which categories were defined. The first two researchers then reviewed the creative comparisons and the explanations in detail. The researchers primarily concentrated on how and why the prospective teachers associated the concepts they were given with the particular creative comparisons that they made. This part of the questionnaire that the prospective teachers filled out contained what they wrote in for each concept after the word "because." The researchers set up

Table 2 Categories identified about chemistry in the pre-, post- and retention tests and examples

Name of category	Means of category	Examples
Comprehensiveness (pre-, post- and retention tests)	Chemistry content is wide, meaning it contains many subjects and concepts.	*"Chemistry is like the sea because it holds many concepts in it. Just as the sea holds many living beings, the science branch of chemistry encompasses many concepts. From the bio-molecules in our bodies to radioactive substances and the spectrum." PT-5 (pre-test)*
Progressivity (pre-, post- and retention tests)	A gradually built relationship between subjects; a transition from simple to more complex subjects.	*"Chemistry is like an organism because an organism starts from something simple and transforms into a complex structure. Chemistry too starts from the basics and transits into higher steps." PT-11 (pre-test)*
Significance (pre-, post- and retention tests)	Chemistry's importance in life and in the development of other sciences.	*"Chemistry is like water because 70% of a human being is water and so it is of great importance for the metabolism; it is vital. Chemistry too occupies a significant place in our lives. It is important and as vital as water." PT-28 (pre-test)*
Developmentalism (pre-, post- and retention tests)	Chemistry has always been in development from the past to the present.	*"Chemistry is like the universe because the universe has always exhibited development. When we look at the history of chemistry, we can see that from past to present, it has constantly developed and provided the knowledge about science that the world is interested in." PT-2 (retention test)*
Branch (pre-, post- and retention tests)	Chemistry has many different branches.	*"Chemistry is like food because there are a lot of varieties of food. Chemistry too has many areas, like biochemistry, analytical chemistry." PT-32 (pre-test)*
Sphere of influence (pre-, and post-tests)	Chemistry has a wide sphere of influence over other areas of science.	*"Chemistry is like a mother because a mother nurtures everyone in the family and influences them. Chemistry also has an influence on and nurtures other branches of science." PT-9 (post-test)*
Role (post-, and retention tests)	Chemistry as functions that relate to nature, science and everyday life.	*"Chemistry is like light because light shows us the way; it turns the dark into light. Chemistry too has lit up many concepts that were unknown in our daily lives." PT-5 (post-test)*
Facilitation (post-test)	One aspect of chemistry makes everyday life easier.	*"Chemistry is like the TV remote control because it is easy to use a TV with a remote control. Chemistry is like that too. Many things in our lives are made much easier and more comprehensible because of chemistry. In other words, chemistry makes our lives easier." PT-35 (post-test)*
Sensitivity (retention test)	Especially the experimental processes in chemistry need meticulous attention.	*"Chemistry is like an acrobat because chemistry is a course based on experimentation, and experiments have no room for error. If, when performing titration, the indicator is not dropped in and it is forgotten, the experiment will be unsuccessful. A single error of the acrobat too is the end of the performance." PT-31 (retention test)*

the categories independently of each other and then came together to compare the categories they had drawn up. In the case of disagreement between the categories independently drawn up by the researchers, a consensus was reached and each category was given its final form. Nine categories, namely "Comprehensiveness," "Progressivity," "Significance," "Developmentalism," "Branch," "Sphere of influence," "Role," "Facilitation," and "Sensitivity" were defined for "Chemistry", and again, nine categories, namely "Productivity," "Researching," "Industriousness," "Meticulousness," "Worthiness," Facilitation," "Developmentalism," "Patience" and "Management" were defined for "Chemist". Examples and means of these categories were presented in Tables 2 and 3. Also, detailed examples have been provided in the Results section. At this stage, the creative comparisons were gathered together in accordance with their common characteristics.

(3) Establishing validity and reliability: the opinion of an expert was consulted to ensure the reliability of the research. Toward this objective, a faculty member from the department of chemistry education was asked to pair the creative comparisons with the defined categories. Similarly, the first two researchers also paired the prospective teachers' creative comparisons with the categories. The percentage of agreement between the pairing of the categories by the researchers and the expert was calculated, using Miles and Huberman's (1994) formula, as 0.85 on the pre-test for chemistry, 0.92 on the post-test and 0.90 on the retention test; these percentages were 0.87, 0.90 and 0.92, respectively, for chemist. According to Fleiss and Levin (1981), the values above 0.75 are considered "excellent."

(4) Calculating and interpreting percentages and frequencies for the creative comparisons: at this stage, frequencies and percentages were calculated for the creative comparisons falling into each category. These values correspond to the entire sample. At the same time, interpretations were also made of the creative comparisons provided by the prospective teachers on the pre-test, post-test and retention test and of the changes that were seen in the comparisons.

The changes in the categories on the prospective teachers' pre-, post- and retention tests were also determined. For this, similar to pre- and post-tests, the numbers of students in the categories of Type 1, Type 2 and Type 3 in the pre-/retention and post-/retention test were determined (Tables 4 and 7) and the shifts between the categories in Type 2 were recorded (Tables 5 and 8).

The data obtained from the study's second data collection instrument, the semi-structured interviews, were transcribed by the third researcher and then analysed according to content analysis. In this process, these steps were followed:

(1) Reading all the transcriptions to have an idea about the text and dividing the text into segments of information. After that, the segments of information were labeled with codes

(2) Forming categories from codes (Attride-Stirling, 2001)

Table 3 Categories identified about chemist in the pre-, post- and retention tests and examples

Name of category	Means of category	Examples
Productivity (pre-, post- and retention tests)	Chemists produce something with their work.	*"A chemist is like an electric power plant because an electric power plant is constantly producing. The chemist too is always producing something. The chemist never wants to stop and always wishes to achieve high performance in all that is being done. PT-19 (pre-test)*
Researching (pre-, post- and retention tests)	Chemists have an exploring nature.	*"A chemist is like a neighbor who likes to gossip because just as a gossiping neighbor will explore everything that happens in the neighborhood, the chemist will show a topic the same care." PT-32 (post-test)*
Industriousness (pre-, post- and retention tests)	Chemists are always working	*"A chemist is like a mother because mothers constantly work for their families, even if they are met with challenges. A chemist is always working, even if greatly challenged by an experiment, for example." PT-1 (retention-test)*
Meticulousness (pre-, post-and retention tests)	Chemists are meticulous when they are experimenting.	*"A chemist is like a nanny because a nanny is involved in a baby's every problem, from the smallest to the biggest, all of which the nanny deals with showing meticulous care. The same thing holds true for a chemist. A chemist will follow up on all the steps in the process of the experiment that is being performed." PT-32 (pre-test)*
Worthiness (pre-test)	In terms of the work, chemists are invaluable for society, science and their professions.	*"A chemist is like a diamond because a diamond is very valuable. The work the chemist does is very valuable and important for society and for the world of science." PT-2 (pre-test)*
Facilitation (post-test)	Chemists make the life of the community easier with the work they do	*"A chemist is like a maid because from past to present, chemists have always lived their lives under difficult conditions and they have had busy lives but in the end, they have created many inventions that have made other peoples' lives easier. In this sense, they are like maids. Because maids make people's lives easier too." PT-18. (post-test)*
Developmentalism (post-test)	Chemists develop in line with the historical development of chemistry.	*"A chemist is like a student because students are always in a state of development in terms of the knowledge they gain. So do chemists improve and develop in line with the development of chemistry over the course of history. PT-1 (post-test)*
Patience (retention test)	Chemists are patient when they are working.	*"Chemists are like a patience stone because they will sometimes perform experiments and do research for long periods of time. The chemist knows that one has to wait before reaching the outcome of research. The chemist will wait with patience." PT-15 (retention test)*
Management (retention test)	Like managers, chemists have an effect on people.	*"A chemist is like an orchestra conductor because an orchestra conductor manages and leads an orchestra. Chemists, with their knowledge, the work they carry out and the products of their efforts, enlighten individuals in society from the past to the present. In other words, they are the leaders of that society." PT-30 (retention test)*

Table 4 The number of students in Type 1, Type 2 and Type 3 categories on the tests about chemistry

	Tests		
Type	Pre-post	Pre-retention	Post-retention
Type 1	4	1	3
Type 2	27	31	22
Type 3	7	6	15

In this process, the first and second researchers read the entire text and then, dividing the text into segments, formed the codes and categories independently from each other. Afterwards, the researchers compared their codes and categories and calculated the percentage of agreement between them (Cohen *et al.*, 2007). The agreement percentages for the questions in each category were as follows: 0.88, 0.91 (first question); 0.85, 0.90 (second question); 0.92, 0.86, 0.89 (third question); 0.81, 0.83 (fourth question). Landis and Koch (1977) stated a range of agreement of 0.81–1.00 as almost perfect. In the case of disagreement between the researchers, the codes were added, deleted, and combined until a consensus was reached and the final form was achieved.

Results

This section contains the data obtained from the creative comparisons questionnaire and the semi-structured interviews.

Results of the creative comparisons questionnaire

Categories identified in the pre-, post-, and retention tests for chemistry are shown in Fig. 1. It can be seen in this figure that most of the prospective teachers formed creative comparisons about the comprehensiveness of chemistry prior to the History and Philosophy of Chemistry course. Respectively, the categories of significance, branch, progressivity, sphere of influence and developmentalism were revealed in the pre-test. However, the prospective teachers did not form creative comparisons regarding the role, facilitation, and sensitivity aspects of chemistry. Important changes in the prospective teachers' categories were seen after the History and Philosophy of Chemistry instruction. Particularly, it was determined that the frequency of the comprehensiveness category decreased considerably, whereas the frequencies of developmentalism and the role category increased compared to the pre-test.

This result is an indicator of a change in most of the prospective chemistry teachers' perceptions about chemistry

Table 5 Category shifts within Type 2 about chemistry

Category shifts	From pre-test to post-test	From pre-test to retention test	From post-test to retention test
Comprehensiveness – role	8	6	—
Comprehensiveness – developmentalism	7	5	—
Comprehensiveness – significance	1	1	—
Comprehensiveness – progressivity	—	2	—
Comprehensiveness – branch	—	1	2
Comprehensiveness – sensitivity	—	2	—
Progressivity – significance	1	—	—
Progressivity – sphere of influence	1	—	—
Progressivity – role	—	2	—
Progressivity – comprehensiveness	—	—	1
Significance – branch	1	2	1
Significance – comprehensiveness	2	2	1
Significance – progressivity	—	1	—
Significance – role	—	—	2
Significance – developmentalism	—	—	1
Developmentalism – significance	1	—	—
Developmentalism – role	—	1	2
Developmentalism – progressivity	—	—	2
Developmentalism – sensitivity	—	—	1
Sphere of influence – role	—	1	2
Branch – facilitation	1	—	—
Branch – role	1	1	—
Branch – significance	1	2	—
Branch – progressivity	1	—	1
Branch – comprehensiveness	1	2	—
Role – developmentalism	—	—	2
Role – significance	—	—	2
Role – sensitivity	—	—	1
Facilitation – role	—	—	1

after the History and Philosophy of Chemistry instruction. At the same time, this result can be interpreted to mean that the prospective chemistry teachers' perceptions about chemistry were not intensified in one aspect of chemistry after the History and Philosophy of Chemistry instruction. In addition, some of the similar frequencies that were seen in categories in the post-test and the retention test, such as in comprehensiveness, developmentalism, and roles, supported the idea that the effects of the History and Philosophy of Chemistry course on the prospective teachers' perceptions about chemistry continued even after four months had lapsed after the post-test.

It can be seen from Fig. 1 that there was a tendency towards an increase of frequency in the category of developmentalism after the History and Philosophy of Chemistry instruction. According to this result, it can be said that the developmentalism aspect of chemistry became important for prospective teachers after the instruction. Indeed, the closeness of the frequencies of

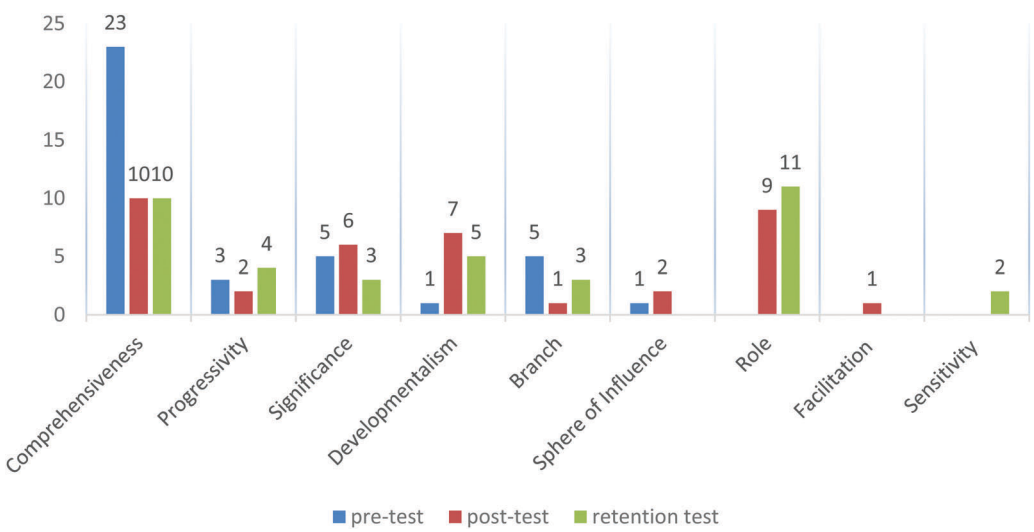


Fig. 1 Categories identified about chemistry in the pre-, post-, and retention tests.

this category in the post- and retention tests may be taken to be an indication of this.

One of the most noticeable changes that occurred in the categories was in the category of role. According to Fig. 1, while the prospective chemistry teachers did not form any creative comparisons in this category before the instruction, one of the most frequently changed aspects of chemistry was the category of role after the instruction. Consequently, the fact that a category exhibited a high frequency on the post- and retention tests even though it did not appear on the pre-test supported the idea that the History and Philosophy of Chemistry instruction can help prospective teachers perceive different aspects of chemistry.

To set forth in the study how the students showed a categorical change over time in the responses they gave related to chemistry, the number of students in Type 1, Type 2 and Type 3 categories on the pre-/post-, pre-/retention and post-/retention tests were first calculated (Table 4).

From an examination of Table 4, it can be seen that the number of students in Type 2, which represents the type of prospective teachers who changed their creative comparisons and also changed the categories of these comparisons, exhibited a more prominent shift from the pre-test to the retention test. In the shift from the pre-test to the post-test too, the number of prospective teachers in this type was high. This may have been caused by the fact that with time, after taking the history and philosophy of chemistry course, the prospective teachers showed a difference in their perception of chemistry. While the number of teachers in Type 2 in the shift from post-test to the retention test decreased with respect to other tests, the number rose noticeably in the group of students in Type 3. From this, it can be said while some prospective teachers showed changes in their perception of chemistry compared to the post-test, some did not exhibit any change and had similar perceptions on the post-test. In other words, the perceptions of chemistry that the prospective teachers had were similar in the post-test and in the retention test.

In order to set forth in more depth the direction of the change in the prospective teachers' perceptions about chemistry, the changes of category between all of the tests within Type 2 are shown in Table 5. A look into the category changes between the pre- and post-tests will show that the shifts in particular from comprehensiveness – role and from comprehensiveness – developmentalism were more striking. This suggests that the perceptions of a large part of the prospective teachers about the comprehensiveness of chemistry changed when they took the course on the history and philosophy of chemistry and that their perceptions of especially the role and the developmental aspect of chemistry had heightened.

In looking at the shifts between the pre-test and the retention test, a similar result is revealed. The most common shifts occurred between the comprehensiveness category and the role and developmentalism categories. In addition to these shifts, the changes between comprehensiveness – progressivity, comprehensiveness – sensitivity and the comprehensiveness – branch categories were seen for the first time between the pre-test and retention tests. It can be concluded from this that the prospective teachers had mostly perceptions about comprehensiveness of chemistry before the instruction, and their perceptions shifted in the direction of, progressivity, sensitivity, role, and development of chemistry.

When the categorical shifts between the post- and retention tests are examined in Table 5, it is understood that there are no remarkable shifts as there were from the pre- to the post-test and also from the pre-test to the retention test. Looking at the categories, it can be concluded that the prospective teachers actually shifted between categories that we can actually call similar. For example, the category shifts of comprehensiveness – branch, significance – role, role – significance, and facilitation – role are similar in terms of perceptions of chemistry. These results show that when the categorical changes displayed by the prospective teachers on the post- and retention tests are examined, it can be seen that the shifts were not as remarkable in terms of perceptions of chemistry as the shifts displayed between the other tests.

In order to more clearly understand the perceptions of the prospective teachers about chemistry, their creative comparisons are shown in a table. The creative comparisons in the categories that emerged in the prospective teachers' pre-, post-test and retention tests as well as their frequencies and percentages are shown in Table 6.

A review of Table 6 shows that the creative comparisons of the prospective teachers on the pre-test fit into the six categories of "comprehensiveness, progressivity, significance, developmentalism, branch, and sphere of influence." It can be seen from Table 6 that the creative comparisons of the prospective teachers mostly fell into the "comprehensiveness" category. The prospective teachers drew creative comparisons with the concepts of "sea," "desert," "soup," "book," "ocean," "human being," "world cuisine," "teacher," "the void," "mixed toast" and "universe," emphasising the content-richness of chemistry. Some of the creative comparisons and the explanations of the prospective teachers are the following:

"Chemistry is like a desert because it goes on endlessly. In a similar way, chemistry contains a great deal of richness, extensive knowledge. It's hard to determine the boundaries of the content of chemistry." PT-8

"Chemistry is like a teacher because a teacher has a lot of knowledge to pass on to you. Chemistry too contains a lot of knowledge." PT-38

"Chemistry is like a book because there are a lot of things you can find and learn in a book. Chemistry is the same way. Its content is expansive. There is a lot to learn." PT-2

"Chemistry is like world cuisine because world cuisine encompasses many different food cultures; it fuses these together and presents them to us. Similarly, chemistry encompasses many concepts of science and chemistry. The content of chemistry is much expanded." PT-31

The prospective teachers generated creative comparisons in the progressivity category on the pre-test, although these were few. This category contained creative comparisons with

Table 6 Creative comparisons formed by the prospective teachers about chemistry

		Pre-test		Post-test		Retention test	
Categories	Creative comparisons	*f*	%	*f*	%	*f*	%
Comprehensiveness	Sea	6	15.8	2	5.3	—	—
	Desert	3	7.9	—	—	—	—
	Soup	2	5.3	—	—	—	—
	Book	2	5.3	—	—	—	—
	Ocean	2	5.3	2	5.3	3	7.9
	Human being	2	5.3	—	—	—	—
	Teacher	2	5.3	—	—	—	—
	The void	1	2.6	—	—	—	—
	Mixed toast	1	2.6	—	—	—	—
	World cuisine	1	2.6	—	—	—	—
	Universe	1	2.6	1	2.6	2	5.3
	People	—	—	1	2.6	—	—
	Internet	—	—	1	2.6	1	2.6
	Rain	—	—	1	2.6	—	—
	White light	—	—	1	2.6	—	—
	Spider web	—	—	1	2.6	—	—
	Life	—	—	—	—	1	2.6
	Rainbow	—	—	—	—	1	2.6
	Outer space	—	—	—	—	1	2.6
	Nature	—	—	—	—	1	2.6
Progressivity	Factory	1	2.6	—	—	—	—
	Organism	1	2.6	—	—	—	—
	Stairs	1	2.6	1	2.6	3	7.9
	The food pyramid	—	—	1	2.6	—	—
	Body	—	—	—	—	1	2.6
Significance	Water	4	10.5	3	7.9	3	7.9
	Breathing	1	2.6	—	—	—	—
	Bread	—	—	2	5.3	—	—
	Spirit	—	—	1	2.6	—	—
Developmentalism	Baby	1	2.6	2	5.3	—	—
	Life	—	—	3	7.9	—	—
	River	—	—	2	5.3	—	—
	Universe	—	—	—	—	2	5.3
	Life	—	—	—	—	2	5.3
	Seed	—	—	—	—	1	2.6
Branch	Tree	3	7.9	—	—	2	5.3
	Lego	1	2.6	—	—	—	—
	Food	1	2.6	—	—	—	—
	Salad	—	—	1	2.6	1	2.6
Sphere of influence	School principal	1	2.6	—	—	—	—
	Mother	—	—	1	2.6	—	—
	Foundation of a building	—	—	1	2.6	—	—
Role	Cooking	—	—	5	13.1	3	7.9
	Light	—	—	2	5.3	1	2.6
	Building	—	—	2	5.3	2	5.3
	Painting	—	—	—	—	2	5.3
	Cement	—	—	—	—	1	2.6
	Puzzle	—	—	—	—	1	2.6
	Staple	—	—	—	—	1	2.6
Facilitation	TV remote control	—	—	1	2.6	—	—
Sensitivity	House of cards	—	—	—	—	1	2.6
	Acrobat	—	—	—	—	1	2.6

"factory," "organism," and "stairs." Some of these creative comparisons are as follows:

"Chemistry is like stairs because you can't go up the stairs without stepping on the first step first. In chemistry, too, topics cannot be understood or executed without having preliminary knowledge." PT-6

"Chemistry is like a factory because there is a transition in a factory from smaller units to larger ones. In the topics of chemistry too,

there are step-by-step transitions from sub-atoms to the atom, the molecule and to matter. PT-3

It was seen that these creative comparisons of the prospective teachers were based on the progressivity relationship between the topics in chemistry and also on the step to come after this.

Some of the creative comparisons drawn by the prospective teachers fell into the category of "significance." In this category, the prospective teachers made two different creative comparisons to describe the importance of chemistry in daily life, likening chemistry to "breathing" and "water." One of these is the following:

"Chemistry is like breathing because breathing is essential for life. Chemistry too is of great importance in our daily lives; we can use a lot of things, thanks to chemistry." PT-1

Another category of creative comparison that the prospective teachers generated in the pre-test was the category of "branch." This category comprised creative comparisons with "tree," "Lego" and "food." Some of these creative comparisons and their explanations are the following:

"Chemistry is like a tree because just as a tree has a lot of branches, so too does chemistry have a lot of branches. Like biochemistry, organic chemistry, analytical chemistry." PT-35

"Chemistry is like Lego because Lego has a lot of pieces that make up a whole. Chemistry too has many areas, inorganic, physical...all of these constitute chemistry." PT-37

The prospective teachers also generated creative comparisons on the pre-test in the categories of "developmentalism" and "sphere of influence." The creative comparison of "baby" stressed the development process of chemistry from past to present. This creative comparison and its explanation was the following:

"Chemistry is like a baby because the minute a baby is born, it constantly develops and grows. Chemistry has gone through the same process." PT-18

In the category of "sphere of influence," creative comparisons were made with the concept of "school principal." This creative comparison accepted chemistry as taking the other branches of science into its sphere of influence. This creative comparison and its explanation was the following:

"Chemistry is like a school principal because a principal is a school administrator. A principal also manages students and teachers. In other words, the principal has a wide sphere of influence. Chemistry too influences other branches of science." PT-9

When the creative comparisons that the prospective chemistry teachers generated in the post-test are considered, it is seen that, differing from the pre-test, two new categories – "facilitation" and "role" – are introduced. At the same time, it was also found that compared to the pre-test, more creative comparisons in the same categories had been generated, and in larger numbers (in the categories of significance, developmentalism and sphere of influence). One of the categories that stood out in the pre-test was "comprehensiveness" and although this category displayed a decrease in terms of frequency compared to the pre-test, on the post-test, it appeared before us as the category that had the most frequent creative comparisons. Among the creative comparisons in this category, the creative comparisons of "seas," "ocean" and "universe" had been generated in the pre-test as well. In addition to these, the concepts of "people," "Internet," "white light," "spider web" and "rain" were generated in the post-test. Some of these creative comparisons and explanations are the following:

"Chemistry is like the Internet because the Internet contains a lot of information, concepts, events. Chemistry too contains a lot of information and concepts." PT-1

"Chemistry is like the universe because the subject of chemistry has such a wide scope – like outer space, there is no end to it." PT-32

"Chemistry is like the ocean because the ocean is very deep, there is no end to it. The subjects to be learned in chemistry too have no end to them." PR-28

"Chemistry is like a spider web because a spider web is made up of a lot of sections and they are all connected. Chemistry too contains many subjects that connect all of these together." PT-23

"Chemistry is like white light because white light has different colours in it; they are all different. Chemistry is the same way. It comprises many concepts, and subjects and all of these are different." PT-14

"Chemistry is like rain because when rain starts to fall, you never can tell when it will stop. Chemistry is something like that too. It has a very wide scope. This is why we can't say that chemistry is only limited to a certain content." PT-20

"Chemistry is like people because people make up many different communities. Chemistry is the same way. It harbours many different topics. The content of chemistry is very rich." PT-7

In "progressivity," one of the categories on the post-test, the two creative comparisons of "stairs" and "the food pyramid" were found. In these creative comparisons, it was seen that the prospective teachers emphasised the characteristic of chemistry that meant progressing from the simple to the more complex. The explanation related to the creative comparison of the food pyramid is as follows:

"Chemistry is like the food pyramid because there is a passage from the lower step to the others. So too in chemistry, concepts go from the simple to the complex, in a progressive system." PT-3

One of the categories that the prospective teachers generated in more numbers and provided different creative comparisons for compared to the pre-test was the category of "significance." Differing from the pre-test, this category included creative comparisons using "bread" and "spirit." It was found that the prospective teachers meant these creative comparisons to emphasise the importance of chemistry, especially in the development of other branches of science and its significance in life. Some of these are the following:

"Chemistry is like the spirit because the spirit gives meaning to the body. Chemistry is important for the other branches of science; it has contributed greatly to their development." PT-11

"Chemistry is like bread because you can't think of life without chemistry. Bread is the same for us. It is a food that is indispensable." PT-18

Some of the creative comparisons generated by the prospective teachers on the post-test fell into the category of

"developmentalism." Differing from the pre-test, the creative comparisons that emerged in this category were "life" and "river." It was found that in these creative comparisons, the prospective teachers emphasised the main theme that chemistry was in constant development. These creative comparisons are the following:

"Chemistry is like a river because a river is constantly flowing and in constant movement. Chemistry too constantly develops; it is never stagnant." PT-38.

"Chemistry is like life because chemistry develops by adding new things on top. There is constant development in chemistry. There is also continuous development in life." PT-8

One of the categories in which the prospective teachers' creative comparisons diminished compared to the pre-test was the category of "branch." In this category, only one prospective teacher generated a creative comparison with "salad." This creative comparison and its explanation was as follows:

"Chemistry is like salad because there are a lot of varieties of salad. Chemistry too has a lot of varieties or branches (organic chemistry, biochemistry, physical chemistry)." PT-4

One of the categories in which the prospective teachers generated differing creative comparisons and in more numbers compared to the pre-test was the category of "sphere of influence." The creative comparisons in this category using "mother" and "foundation of a building" were found for the first time on the post-test. These creative comparisons of the prospective teachers explained the effect of chemistry on the other branches of science. These creative comparisons and their explanations were as follows:

"Chemistry is like the foundation of a building because chemistry is the foundation of the sciences. The other branches of science (physics, biology, etc.) developed in connection with chemistry. The main foundation of a building is the main structure; the other parts are built on this." PT-6

One of the categories that emerged for the first time on the post-test, "role," contained creative comparisons using "light," "cooking" and "building." The prospective teachers understood chemistry in these creative comparisons to be on the molecular level while also having a role in daily life. Some of the creative comparisons that the prospective teachers generated were as follows:

"Chemistry is like building because you put together small pieces of materials to construct a huge and tall building. This is actually the main role of chemistry. It brings atoms together to create complex structures." PT-31

"Chemistry is like cooking because when you cook, you bring together a lot of ingredients and create something entirely different. Chemistry has the same role. Different substances are brought together to create new substances." PT-12

The last category to be found on the post-test was the category of "facilitation." In this category, one prospective teacher drew a creative comparison with the "TV remote control". As can be seen from Table 2, PT-35 emphasised the facilitating effect of chemistry on our lives with this creative comparison.

When the categories on the retention test are reviewed in Table 6, it can be seen that the categories of "sphere of influence" and "facilitation" do not exist, but in their place, the category of "sensitivity" has emerged. At the same time, some categories appearing in the pre- and post-tests (such as significance and branch) do not have different forms of creative comparisons on the retention test. The category of "comprehensiveness," which contained the largest number of creative comparisons by the prospective chemistry teachers on the pre- and post-tests, was also to be found in the retention test. This category in the retention test, however, was not the category that contained the greatest number of creative comparisons generated by the prospective teachers. Differing from the pre- and post-test, this category contained creative comparisons made with "life," "rainbow," "outer space" and "nature." One of these was as follows:

"Chemistry is like nature because it contains all living things. Chemistry too holds many sciences in it." PT-14

"Chemistry is like a rainbow because the rainbow is made up of more than one colour; since chemistry is a multidisciplinary field, it also contains other subjects such as biology or physics. It has a very wide scope." PT-1

"Chemistry is like life because a human being is confronted with many different things in a lifetime. Chemistry is like that too; it has a wide scope." PT-28

"Chemistry is like outer space because outer space contains many different elements. Chemistry is made up of many different concepts and phenomena." PT-37

One of the categories found on the retention test was the category of "progressivity." Two creative comparisons were made in this category: "stairs" and "body." The creative comparison and explanation about "body" was as follows:

"Chemistry is like the body because it is made of cells, tissue, organs, systems, which make up the body. In other words, there is a transition from the simple to the complex. In chemistry, everything starts from the simple and as research is carried out, new information is gathered and we pass into a higher level." PT-34

Differing from the pre-test and post-test, one of the categories in which the prospective teachers made different creative comparisons was the category of "developmentalism." In this category, creative comparisons using the concepts of "universe," "seed" and "life" made their way into the retention test for the first time. It was found that the prospective teachers used these creative comparisons to emphasise the development of chemistry from past to present. Some of these are the following:

"Chemistry is like a seed because a seed is tiny at first but it grows and matures with time. Chemistry too is in constant development." PT-30

"Chemistry is like life because life is always developing with experience, and research. Chemistry is like this too. It has constantly developed with the experienced gained from past to present." PT-15

The retention test displayed another category, which was the category of "role." The prospective teachers used creative comparisons with "cement," "painting," "puzzle" and "staple" in this category, emphasising the role of chemistry in science and nature. These creative comparisons and their explanations belonging to the prospective teachers were as follows:

Fig. 2 Categories identified pertaining to chemist in the pre-, post-, and retention tests.

"Chemistry is like cement because cement is the most important material in construction. It keeps the other materials in a building together. Chemistry does for nature what cement does for a building. Thanks to certain chemical cycles, many living beings in nature can exist together." PT-18

"Chemistry is like a staple because the main function of a staple is to keep papers together and form a whole. Chemistry too keeps the reactions, spectrometric features, the degree of hardness, radioactivity and other fundamental properties of matter together and gives us knowledge about it." PT-6

"Chemistry is like a painting because different colours are mixed together to produce a beautiful painting. The most fundamental characteristics of chemistry are that different substances are mixed together to form different substances and that it is used in all the sciences." PT-5

"Chemistry is like a puzzle because when you put the parts of a puzzle together, they form a whole. Chemistry's role is likewise to unite all the other branches of science." PT-35

Differing from the pre-test and post-test, a category that came up in the retention test was "sensitivity." In this category, the prospective teachers generated creative comparisons with "acrobat" and "house of cards," emphasising the experimental aspect of chemistry. One of these creative comparisons and its explanation was as follows:

"Chemistry is like a house of cards because a house of cards is very sensitive. It can topple down with the slightest error. In chemistry, too, if you make a mistake, the results of your analysis will be wrong." PT-38

As pertains to chemist, the second concept in the creative comparisons, the categories appearing in the pre-test, post-test and retention tests and their related frequencies are shown in Fig. 2.

From Fig. 2, it can be understood that the prospective teachers mostly generated creative comparisons that considered the productivity of chemists on the pre-test. The pre-test also revealed that the prospective teachers generated creative comparisons in the categories of researching, industriousness, meticulousness, and worthiness, but the frequencies of these categories were lower compared to the category of productivity. In addition, the prospective teachers did not form any creative comparisons in the categories of facilitation, developmentalism, patience, or management on the pre-test. When the post-test results are examined in Fig. 2, it can be seen that while frequencies of some categories (industriousness and meticulousness) did not change from the pre-test to the post-test, two new categories (facilitation and developmentalism) were added. Another striking point was discovered in the category of researching. In this category, an increase of frequency was seen from the pre-test to the post-test. This indicates that a large part of the prospective teachers experienced a change of perception about chemist after taking the History and Philosophy of Chemistry course. In other words, the prospective teachers did not focus only on one aspect of chemists on the post-test after the course but instead demonstrated a diversity of perceptions. Also, Fig. 2 showed that similar to the post-test, a decrease in frequency was observed in the category of productivity from the pre-test to the retention test, and two new categories (patience and management) were revealed. Among these new categories, the category of management stood out in particular. This result may be interpreted to imply that the prospective teachers focused more on the managerial aspect of chemists after taking the course. Additionally, there was no change in the frequencies in the industriousness category in the post-test and retention tests. In the light of all these results, it can be said that there was a similarity in the categories on the post-test and retention tests with respect to chemist. All of these results reveal that the prospective teachers demonstrated a change in their perception of chemist after taking the course on the history and philosophy of chemistry but that this change was more clearly pronounced not on the post-test but on the retention test.

Grouping the prospective teachers according to their responses in the pre-, post- and retention test produced Table 7.

According to Table 7, even though there was a greater number of prospective teachers in Type 2 between the pre- and post-tests, it can still be seen that the number of prospective teachers in each of the three types were close to one another. This is however different in the case of the pre-test–retention test,

Table 7 The number of students in Type 1, Type 2 and Type 3 categories on the tests about chemist

	Tests		
Type	Pre-post	Pre-retention	Post-retention
Type 1	13	3	5
Type 2	14	25	23
Type 3	11	10	10

Table 8 Category shifts within Type 2 about chemist

Category shifts	From pre-test to post-test	From pre-test to retention test	From post-test to retention test
Developmentalism – industriousness	—	—	1
Developmentalism – patience	—	—	1
Facilitation – meticulousness	—	—	2
Facilitation – productivity	—	—	1
Facilitation – management	—	—	1
Industriousness – meticulousness	2	—	—
Industriousness – productivity	—	1	—
Industriousness – management	—	1	—
Industriousness – patience	—	—	1
Meticulousness – developmentalism	1	—	—
Meticulousness – researching	1	1	—
Meticulousness – industriousness	—	1	—
Meticulousness – productivity	—	—	1
Meticulousness – management	—	—	1
Productivity – facilitation	3	—	—
Productivity – researching	3	4	3
Productivity – industriousness	1	1	—
Productivity – meticulousness	—	4	2
Productivity – management	—	3	1
Researching – facilitation	1	—	—
Researching – productivity	—	3	3
Researching – management	—	1	2
Researching – meticulousness	—	3	3
Worthiness – developmentalism	1	—	—
Worthiness – industriousness	1	—	—
Worthiness – patience	—	2	—

which displayed a high number of students who had shifted categories. This result may be interpreted as meaning that although the perceptions of the prospective teachers about the chemist changed with the course on the history and philosophy of chemistry, this change was clearer in the long term (on the retention test). While the number of students in Type 2 was higher in the shift from the post- to the retention test compared to the other types, a rise was seen in the number of students responding in the same category and with the same answer (Type 1) from the post-test to the retention test. This suggests that there were similarities in the perceptions of the prospective teachers about chemists from the post-test to the retention test.

Table 8 was drawn up to understand the shift in categories that the prospective teachers displayed with respect to their perceptions about the chemist. A look into the shifts in category between the pre- and post-tests on Table 8 shows that the most common shift was in the productivity category. That the prospective teachers displayed a shift particularly between the categories of productivity – facilitation and productivity – researching suggests that with the course on the history and philosophy of chemistry, perceptions about chemists' work, the way they facilitate everyday life, and their personalities showed a rise.

As can be seen from Table 8, the most prominent demonstration of the change in the perceptions of the prospective teachers about the chemist was seen between the pre-test and the retention test in the categories of productivity – researching, productivity – meticulousness and productivity – management, which indicates that perceptions of chemist concentrated in the productivity category before the course shifted toward researching, meticulousness and management after the instruction. In particular, the far-reaching shift away from the productivity category to the qualities of meticulousness and management show the change in the perceptions about chemist more clearly. Furthermore, it can also be seen that the perceptions about the researching quality of chemists on the pre-test tended to shift on the retention test toward the qualities of meticulousness, management and productivity.

A look at the category shifts between the post-test and the retention test in Table 8 shows that the categories that exhibited the most prominent shifts were productivity – researching, researching – productivity and researching – meticulousness. The categories here, it is seen, are close to each other in meaning. This can be interpreted to indicate that the perceptions of the prospective teachers about the chemist on the post-test and retention test, as with their perceptions about chemistry, did not show any striking change.

To more clearly understand the perceptions of the prospective teachers about the chemist, their creative comparisons and the related categories have been included in the table. Accordingly, the creative comparisons generated by the prospective teachers about "chemist" with related frequencies and percentages can be seen in Table 9.

When Table 9 is reviewed, it can be seen that the creative comparisons of the prospective chemistry teachers on chemist fit into five categories on the pre-test; these categories are "productivity," "researching," "industriousness, "meticulousness" and "worthiness." Among these, the category in which the prospective teachers generated the most creative comparisons was "productivity."

With their creative comparisons of "cook," "musician," "painter," "bartender," "electric power", "plant," "magician," and "artist," the prospective chemistry teachers emphasised

Table 9 Creative comparisons formed by the prospective teachers about chemist

		Pre-test		Post-test		Retention test	
Categories	Creative comparisons	*f*	%	*f*	%	*f*	%
Productivity	Cook	9	23.7	6	15.8	3	7.9
	Musician	3	7.9	—	—	3	7.9
	Painter	3	7.9	3	7.9	2	5.3
	Artist	3	7.9	2	5.3	—	—
	Electric power plant	1	2.6	—	—	—	—
	Magician	1	2.6	2	5.3	3	7.9
	Bartender	1	2.6	—	—	—	—
	Architect	—	—	—	—	1	2.6
Researching	Child	5	13.1	2	5.3	5	13.1
	Detective	2	5.3	—	—	1	2.6
	Treasure hunter	1	2.6	—	—	—	—
	Miner	1	2.6	—	—	—	—
	Diver	1	2.6	—	—	—	—
	Philosopher	—	—	4	10.5	2	5.3
	Journalist	—	—	3	7.9	—	—
	Archeologist	—	—	2	5.3	—	—
	Tourist	—	—	1	2.6	—	—
	Scout	—	—	1	2.6	—	—
	A neighbor who likes to gossip	—	—	1	2.6	—	—
	Adventurer	—	—	—	—	1	2.6
Industriousness	Farmer	1	2.6	—	—	—	—
	Ant	1	2.6	—	—	—	—
	Football player	—	—	1	2.6	—	—
	Mountain climber	—	—	1	2.6	—	—
	Mother	—	—	—	—	1	2.6
	Clock	—	—	—	—	1	2.6
Meticulousness	Cook	2	5.3	1	2.6	2	5.3
	Nanny	1	2.6	—	—	—	—
	Cleaning woman	—	—	2	5.3	3	7.9
	Goldsmith	—	—	—	—	1	2.6
	Mother	—	—	—	—	1	2.6
	Painter	—	—	—	—	1	2.6
Worthiness	Diamond	1	2.6	—	—	—	—
	Aged wine	1	2.6	—	—	—	—
Facilitation	Maid	—	—	1	2.6	—	—
	Light	—	—	1	2.6	—	—
	Life saver	—	—	1	2.6	—	—
	Hero	—	—	1	2.6	—	—
Developmentalism	Student	—	—	2	5.3	—	—
Patience	Mother	—	—	—	—	1	2.6
	Patience stone	—	—	—	—	1	2.6
Management	Conductor	—	—	—	—	3	7.9
	President	—	—	—	—	2	5.3

the scientific productivity of chemists. Some of these creative comparisons and their explanations were the following:

"A chemist is like a musician because a musician brings notes together to write a piece using different instruments. Chemists too bring substances together and use different methods to perform experiments and create a product." PT-8

"A chemist is like a bartender because a bartender mixes up ingredients to create something new. Chemists too create new products from substances." PT-11

"A chemist is like a cook because cooks create new flavours. Chemists too produce new materials." PT-30

"A chemist is like a magician because magicians can bring about surprising, unexpected products. Chemists too can create different products with the materials they have on hand." PT-23

"A chemist is like a painter because just as a painter puts a lot of colours together to create a masterpiece, so the chemist puts together different substances to make a lot of new substances by using a formula." PT-22

"A chemist is like an artist because an artist always creates new things. Chemists are like that too. They are always making something new." PT-33

The second category that appeared profusely among the prospective teachers' creative comparisons on the pre-test was ''researching.'' The prospective teachers used the creative comparisons of ''child,'' ''treasure hunter,'' ''detective,'' ''miner,'' and ''diver'' to emphasise the researching characteristics of chemists. Some of these creative comparisons and their explanations were the following:

''A chemist is like a detective because chemists perform experiments meticulously, record the data and then come to a conclusion based on these data. In other words, their research brings them to a conclusion. Similarly, detectives too do research.'' PT-18

''A chemist is like a child because children like to explore and test everything. Chemists too like to explore and perform experiments to test things.'' PT-3

''Chemists are like miners because miners explore and uncover valuable things like diamonds. Chemists too explore, find and uncover products.'' PT-34

''A chemist is like a diver because there are many things a diver can dive into the sea and come out with. A diver tries to find new things all through his life. A chemist too looks for and finds many things in chemistry.'' PT-7

''A chemist is like a treasure hunter because a treasure hunter always goes exploring in order to reach the treasure. Chemists are like that too. They continue to search until they find what they're looking for.'' PT-31

In another one of the categories emerging in the pre-test, ''industriousness,'' the prospective teachers generated the creative comparisons of ''farmer'' and ''ant.'' With these creative comparisons, the prospective teachers apparently wished to emphasise the ''industrious'' aspect of chemists. These creative comparisons and explanations of the prospective teachers were as follows:

''A chemist is like an ant because an ant is not lazy. An ant works all the time. A chemist too works all the time.'' PT-35

''A chemist is like a farmer because just as a farmer constantly works hard and labours, so too do chemists. They are industrious.'' PT-24

The prospective chemistry teachers used the creative comparisons of ''nanny'' and ''cook'' to emphasise the ''meticulous'' aspect of chemists. One of these creative comparisons and its explanation was the following:

A chemist is like a cook because cooks are very meticulous when they are cooking. The chemist works in the same way. The materials a chemist uses always have to be clean. The materials must also be of adequate amounts.'' PT-1

The ''aged wine'' and ''diamonds'' creative comparisons the prospective chemistry teachers generated on the pre-test pointed to their emphasis on how ''valuable'' chemists were in terms of their social, scientific and professional worth. One of these creative comparisons and its explanation was as follows:

''A chemist is like aged wine because wine is more valuable the more it ages. The chemist too gains more knowledge as the years go by and reaches a very important and valuable point in his/her career.'' PT-15

When Table 9 is reviewed, it can be seen that while the prospective teachers generated creative comparisons (''productivity,'' ''researching,'' ''industriousness,'' and ''meticulousness'') on the post-test that fit into the same categories as the pre-test, they also generated creative comparisons that fit different categories compared to the pre-test (facilitation and developmentalism). When the categories that are the same as in the pre-test are reviewed, it is understood that the productivity category on the pre-test that contained the most creative comparisons did not contain as many on the post-test and that all of the creative comparisons were in fact the same as on the pre-test. Examining another common category, ''researching,'' it is observed that the creative comparisons were new and decidedly more in number than on the pre-test. Some of the creative comparisons and their explanations in this category were the following:

''A chemist is like an archeologist because archeologists explore and work to find things that exist but are unknown or unfound. The chemist similarly works and does research to uncover new concepts and unknown substances.'' PT-19

''A chemist is like a philosopher because philosophers place importance on knowledge. They have natural curiosity and they explore. Chemists are the same; they are constantly exploring.'' PT-11

''A chemist is like a journalist because journalists do research to reach the news, even if it is dangerous to do so. Chemists too will go after knowledge without turning back; they want to learn and they will take the necessary measures in the laboratory, risking their lives, when they work with dangerous materials.'' PT-3

''A chemist is like a tourist because tourists are curious about everything they see, every building, and they explore and want to learn everything they can about the places they go. A chemist is like a tourist in this way because exploring is a part of his/her nature.'' PT-22

''A chemist is like a boy/girl scout because the scout loves to explore and research the places he/she goes to. The chemist too examines events, does research and finds new phenomena and laws on the basis of what has been learned.'' PT-34

One of the categories found on the post-test, ''industriousness,'' contained creative comparisons that differed from those on the pre-test; these were ''mountain climber'' and ''football player.'' With these creative comparisons, it was found, the prospective teachers revealed the importance they gave to the industriousness and persevering attitude of chemists in their research. These creative comparisons are as follows:

''A chemist is like a mountain climber because as the mountain climber climbs up the mountain, he/she will want to go even further, higher up. This is why he/she will persevere. The chemist too works with perseverance, without being discouraged, to go even further. PT-15

''A chemist is like a football player because football players constantly run and pass the ball. Chemists are like this too. They work constantly.'' PT-33

One of the categories appearing the same on the pre-test was the category of ''meticulousness.'' Differing from the creative comparisons on the pre-test, the prospective chemistry teachers generated the ''cleaning woman'' concept. This creative comparison and its explanation was as follows:

''A chemist is like a cleaning woman because cleaning women work meticulously. Chemists too work with great meticulousness on all their experiments and other work.'' PT-35

One of the two categories that were seen to be different on the post-test compared to the pre-test was ''facilitation'' and in this, the prospective teachers used creative comparisons with ''maid,'' ''light,'' ''life saver'' and ''hero'' to express their belief in how chemists made life easier for society with their work. Some of the explanations are the following:

''A chemist is like a maid because from past to present, chemists have always lived their lives under difficult conditions and they have had busy lives but in the end, they have created many inventions that have made other peoples' lives easier. In this sense, they are like maids. Because maids make people's lives easier too.'' PT-18.

''A chemist is like a life saver because just as life savers come to a person's aid and make their lives easier, so too do chemists review dangerous but beneficial material, become aware of this material to take the necessary measures. They make people's lives easier too.'' PT-8

''A chemist is like a hero because when heroes succeed at things that we can't, our lives become easier. Chemists too make people's lives easier with the things they find.'' PT-30

''A chemist is like a light because light shows the way so that people can find their paths more easily. Chemists too have made people's lives much easier with the experiments they have performed and their discoveries.'' PT-23

Differing from the pre-test, the prospective chemistry teachers generated creative comparisons on the post-test that fit the category of ''developmentalism.'' In this category, the prospective teachers explained the development of the historical progress of chemistry by using the creative comparison of ''student.'' This creative comparison and its explanation provided by the prospective teachers was as follows:

''A chemist is like a student because a student always learns something new all through the education process. Things are like this in chemistry too. From past to present, the progress of chemistry shows us that new knowledge is always being added and chemistry has continuously progressed up until this time. As a result, chemists always learn new knowledge in this progressive process.'' PT-2

As can be understood from Table 9, some of the creative comparisons that the prospective chemistry teachers generated on the retention test fit into the same categories as on the pre-test and post-test (productivity, researching, industriousness and meticulousness) while some appeared for the first time on the retention test (patience and management). At the same time, the categories of ''worthiness,'' ''developmentalism'' and ''facilitation'' that appeared on the pre- and post-tests were not displayed in the creative comparisons generated on the retention test. A review of the creative comparisons of the prospective chemistry teachers that fit into the category of productivity shows that there was a creative comparison – ''architect'' – that was different from the comparisons on the pre-test and post-test. This creative comparison and the explanation of the prospective teacher is the following:

''A chemist is like an architect because an architect always creates new things. An architect makes new drawings. A chemist is like that too; a chemist is always producing.'' PT-23.

It was seen that the creative comparisons of ''adventurer'' appeared in the researching category, unlike the pre-test and post-test. This creative comparison and its explanation by the prospective teacher was as follows:

''A chemist is like an adventurer because an adventurer likes to go, see and explore places he/she has never seen. A chemist too explores unknown truths, does research on things to be uncovered.'' PT-22

Another one of the categories in which the prospective teachers generated differing creative comparisons on the pre-test and post-test was the category of ''industriousness.'' In this category, the prospective teachers generated creative comparisons with ''mother'' and ''clock.'' One of the prospective teachers' creative comparisons and its explanations is the following:

''A chemist is like a clock because a clock constantly works, very rarely goes out of order. A chemist too is in a state of working constantly. PT-33

When the pre-test and post-test are compared, one of the categories to strike the eye was the category of ''meticulousness.'' The prospective teachers' creative comparisons in this category on the retention test showed an increase in number and also in terms of frequency. The creative comparisons ''goldsmith,'' ''mother,'' and ''painter'' appeared on the retention test, differing from the pre-test and post-test. Some of the explanations for these were the following:

''A chemist is like a goldsmith because when a chemist is working, a lot of care has to go into the work. Otherwise the results will not turn out as desired and even dangerous outcomes may result. In other words, the chemist must pay attention to the amounts of chemicals being used. A goldsmith too has to be very meticulous at work so that the job pays well.'' PT-18.

''A chemist is like a painter because a painter has to use the right colour in the right place. He/she has to pay attention to this. This is how a beautiful work of art comes into being. Chemists too have to be very careful how and when to use their chemicals. They can't say, 'Let me mix these two chemicals together.' They have to be meticulous. PT-8

''A chemist is like a mother because just as a mother will show her child care and never miss anything involved in that care, so too does a chemist have to devote his/her life to the field. In other words, a chemist has to follow up on all developments in the field and work meticulously.'' PT-19

One of the categories first seen in the retention test was the category of ''patience.'' In this category, the prospective teachers generated the creative comparisons of ''mother'' and ''patience stone.'' These creative comparisons and their explanations were as follows:

''Chemists are like a patience stone because they will sometimes perform experiments and do research for long periods of time. The chemist knows that one has to wait before reaching the outcome of research. The chemist will wait with patience.'' PT-15.

''The chemist is like a mother because mothers are very patient toward their children. They are patient even when the child errs. The chemist too may not have an experiment come out right. The experiment may have to be repeated. The chemist will repeat the experiment with patience.'' PT-2

Table 10 Categories and codes related to the first interview question

Category	Code	*f*	Sample statement
Not having a background about the history of chemistry	Eras	4	*"Yes, I did. I didn't really know about the historical eras in chemistry, that is, I had no idea about Chemistry in ancient times, the era of alchemy, the Renaissance, or that period of iatrochemistry. . .." PT-5*
	Developments in chemistry	2	*"I didn't seem to have any knowledge about the stages of chemistry's development. In other words, how it transitioned into the next step, what its effects were on that step? How did chemistry develop? I had no idea." PT-18*
Having only a partial knowledge of the history of chemistry	Discovery of fire.	1	*"Yes, there was something. I knew that chemistry had gone through a period of development from past to present but I didn't know that it all started with the discovery of fire. . ." PT-11*
	Alchemy	2	*"I had some knowledge, but It seems I didn't know how important the period of alchemy period was for chemistry. In other words, I did not know that concepts, components, tools and equipment were developed in the alchemy era." PT-37*
	Modern chemistry	2	*"Yes. Previously, we had only paid attention to the modern chemistry part of the chemistry course. I had never looked into past developments in chemistry and I had no knowledge of them. In other words, I knew nothing about the early ages nor the times after that." PT-2*
	Developments in chemistry	4	*"It appears I just had some general information about chemistry. It seems I didn't know anything about what kind of development chemistry went through, who discovered what and under which conditions." PT-1*

The last category that was unique to the retention test was the category of "management." In this category, the prospective teachers generated the creative comparisons of "president" and "conductor," emphasising how chemists worked like administrators in society, taking on this role while also managing their own field of work. One of these was the following:

"A chemist is like a president because just as a president is a leader of a country, a chemist affects society with his/her contributions. For this reason, a chemist is like a leader and president." PT-35

Semi-structured interview results

The categories and codes belonging to the first interview question as well as sample statements in these categories and codes can be seen in Table 10.

Question 1. *Did you come across anything after taking the course on the History and Philosophy of Chemistry that made you think that your previous knowledge about "chemistry" had been inadequate or limited?*

Question 1 was designed to reveal whether or not the course on the History and Philosophy of Chemistry had an impact on the knowledge of the prospective chemistry teachers regarding "chemistry". The results of the analysis showed that all of the prospective teachers interviewed became "aware" of the inadequacy or limitations of their previous knowledge about "chemistry" after taking the History and Philosophy of Chemistry. A review of Table 10 shows that the prospective teachers explained their inadequate previous knowledge about "chemistry" in two categories: not having a background about the history of chemistry and having only a partial knowledge of the subject. When the prospective teachers' responses in the category related to not having a background about the history of chemistry were examined, two codes were revealed. While some of the prospective teachers stated that they did not know the background of chemistry in the context of eras (*e.g.*, PT-5), some expressed their lack of knowledge about the development of chemistry (*e.g.*, PT-18)

In the second category, the prospective teachers said that they had some general knowledge, but this knowledge was limited. For example, some prospective teachers (*e.g.*, PT-2) stated that they mostly had knowledge about the era of modern chemistry but that they had not looked into anything before that. Some of them revealed that they did not know that the discovery of fire and the era of alchemy had important roles in the development of chemistry. Also, the prospective teachers stated that they had insufficient previous knowledge about the development of chemistry.

In the light of these results, it can be said that the History and Philosophy of Chemistry course helped the prospective teachers become aware of their inadequacy regarding their previous knowledge of "chemistry." Thus, the prospective teachers stated their dissatisfaction with their prior knowledge following the History and Philosophy of Chemistry course.

Question 2. *Was there a change in the creative comparisons you made related to "chemistry" after taking the course on the History and Philosophy of Chemistry? What was that change? What are the reasons for the change?*

Question 2 aimed at determining how the prospective teachers explained the reason for the change in their creative comparisons from the pre-test to the post-test. According to the results of the interviews, it was seen that most of the prospective teachers (ten prospective teachers) spoke in the interviews of changes in their creative comparisons in the context of the History and Philosophy of Chemistry course. As can be seen from Table 11, the prospective teachers clarified these changes in the context of understanding the development of chemistry, the impact of chemistry on other fields, the impact of chemistry on peoples' lives, and gaining more knowledge about chemistry. From these results, it is understood that besides changing viewpoints on chemistry, the course on the History and Philosophy

Table 11 Categories and codes related to the second interview question

Category	Code	*f*	Sample statement
The History and Philosophy of Chemistry Course having an impact	Understanding development of chemistry	5	*"I had said previously that chemistry was like the sea because when we dive into the sea, we can see that there are a lot of living creatures. There are many different kinds of living beings. When we dive into chemistry too, we come across a world of great diversity. And then later, I said that chemistry is like light. The light lightens the dark. No one knew very much about chemistry at first but as time passed, chemistry developed and turned its light on many unknown things. So I talked here about processes. I wrote the last while considering the importance of the development of chemistry and its significance in people's lives. I was able to do this because this course allowed us to develop a larger network of knowledge about the development of chemistry." PT-5*
	Gaining more knowledge about chemistry	3	*"First I likened chemistry to Lego because Lego has so many parts. Chemistry has many parts too. In other words, I accepted that the Lego pieces were each a field of chemistry, such as organic chemistry or physical chemistry As I wrote this, I wrote down the first thing that came to mind when we said chemistry Later, I likened chemistry to stairs because the first topics in chemistry are basic subjects, such as the atom. The topics later on were on a higher level; when the basic topics are learned, then we pass onto the higher levels of topics. The steps on a flight of stairs are the same way. At first, my perspective about chemistry was narrow, but with the course, I began to think of the subject more comprehensively." PT-37*
	Understanding the impact of chemistry on other fields.	2	*"Before the course, I used to liken chemistry to the universe because it's hard to draw the boundaries of the universe. The content of chemistry is also very broad, non-ending. After the course, I likened it to water. Just as water is essential for people in order to keep alive, chemistry is a science that people require in order to meet their needs and it has played an important role in the development of many other sciences. Chemistry has played a very important role in the development of medicine, for example. We saw this very clearly in Ibn-i Sina (Avicenna). I think this course was very useful in my understanding this. Because we learned about the impact of chemistry on other fields in this course." PT-15*
	Understanding impact of chemistry on people's lives	2	*"I likened chemistry to a tree. Because a tree has a lot of branches,. Chemistry in the same way has a lot of branches such as biochemistry, organic chemistry and analytical chemistry. Later on, I said that chemistry is like the TV remote control because it is easy to use a TV with a remote control. Similarly, chemistry made peoples' lives easier with various inventions. After I took this course, my awareness about the impact of chemistry on peoples' lives began to increase. And this was reflected in the creative comparisons I came up with." PT-35*
The History and Philosophy of Chemistry Course not having an impact	Field courses	1	*"There was something. First, I had said, "Chemistry is like water because water has great importance for the metabolism. Similar to water, Chemistry is very important for our lives. Later, I likened chemistry to salad since there are so many types of both salads and chemistry. I think the reason for the change in the creative comparisons is the field courses I took this year. I learned that chemistry had much more topics to study in depth. Of course, the history of chemistry course also gave us new information. However, I explain the change in creative comparisons as being connected with the courses in my own field". PT-4*
	Other factors	1	*"First, I likened chemistry to breathing since breathing is very important for life. Similarly, chemistry is important for our lives. Later, I said that chemistry is like the internet because the internet encompasses lots of information, concepts, and events. Chemistry too contains a lot of information and concepts. Yes, there was a change in my creative comparisons. But, I can't say that the course had a clear impact on the creative comparisons I generated. I can say however that the course had a considerable effect on my life. Many factors such as my observations and my experiences with chemistry affected my creative comparisons." PT-1*

of Chemistry also had an effect on the creative comparisons generated.

On the other hand, two of the prospective teachers stated that there had been a change in their creative comparisons but they did not explain this change in the context of the course on the History and Philosophy of Chemistry. For example, one of the prospective teachers (PT-4) expressed this change in his creative comparisons as associated with field courses. The other prospective teacher (PT-1) explained the reason for the change in terms of other factors such as observations and experience about chemistry. The explanations of the prospective teachers who fit into these categories are presented in Table 11.

Question 3. *Did you come across anything after taking the course on the History and Philosophy of Chemistry that made you think that your previous knowledge about "chemist" had been inadequate or limited?*

Question 3 was prepared to reveal prospective teachers' views about whether or not the History and Philosophy of Chemistry course had an impact on the knowledge of the prospective chemistry teachers about the "chemist." The findings from the interviews showed that all of the prospective teachers were able to explain their inadequacies about their prior knowledge of chemist. Thus, it was understood from Table 12 that the prospective teachers expressed their insufficient prior knowledge of chemist in terms of the three categories of not knowing anything about chemists and their work, not knowing the personal characteristics of chemists, and having only a partial knowledge about chemists and their work.

Table 12 Categories and codes related to the third interview question

Category	Code	*f*	Sample statement
Not knowing about chemists and their work	Fields of study	4	*"It seems I didn't know about chemists, their lives and what they contributed. I never knew before that Jabir ibn Hayyan, for example, was a chemist. I found out that the system we use to melt chocolate had been invented by chemists. I didn't know that a female chemist had invented this. There seems to have been very important chemists in every era. I didn't know this. This is what I learned." PT-22*
	Chemists' lives	2	*"I understood that I did not know chemists. Their studies and lives were very interesting. These chemists played important roles in the development of chemistry." PT-18*
Having only partial knowledge of chemists and their work	Alchemists	3	*"Yes. Apparently I didn't know that alchemists had shed light on some very big issues and that they had produced works on many matters in order to meet people's needs." PT-30*
	Natural philosophers	1	*"It seems there are chemists who were also philosophers, especially in ancient times. I didn't know any of this." PT-2*
	Chemists working on the structure of the atom	2	*"Before, all we did was learn about atomic models and the chemists involved in the structure of the atom. We never looked into anything before that. I previously had no idea about what chemists had achieved, what kind of work they did." PT-35*
Not knowing the personal characteristics of chemists	Curiosity	2	*"I didn't know anything about the personal characteristics of chemists. For instance, that chemistry developed so much because of the natural curiosity of chemists. Chemists have been curious, have explored, thought about the future and tried to do something better than before." PT-33*
	Explorative	1	*"Chemists, even in ancient times, experimented continuously to discover the causes of things. The history of chemistry course helped me a lot in learning about how explorative chemists are." PT-19*

In the category of not knowing about chemists and their work, the prospective teachers particularly stated that they did not know about chemists, chemists' lives or their contributions to chemistry. This indicates that, as in chemistry, the prospective teachers did not have a solid knowledge about chemists or their historical background before taking the course on the History and Philosophy of Chemistry.

In the second category of having only a partial knowledge about chemists and their work, it was seen that the prospective teachers in particular did not have a full understanding of the importance of alchemists in the history of chemistry. Another striking aspect of the prospective teachers' responses was their lack of knowledge about the way the natural philosophers of the ancient world defined matter. In this category, it was observed that the teachers frequently expressed knowledge of the chemists who worked on discovering the structure of the atom, but disclosed that they had no knowledge of the chemists that came before and their works. In fact, the fact that in the interviews about chemistry as well, the prospective teachers expressed their knowledge of the era of modern chemistry but admitted that they knew nothing about previous periods is a similar observation.

In the last category, the prospective teachers emphasised the personal characteristics of chemists. Some prospective teachers mentioned the curiosity chemists had (*e.g.*, PT-33), while some dwelled on their explorative traits (*e.g.*, PT-19), saying that this had an important influence on the development of chemistry and that they had not known this prior to taking the course on the history and philosophy of chemistry.

From these explanations, it can be understood that the prospective teachers were dissatisfied with their prior knowledge about chemist. In another words, the History and Philosophy of Chemistry course can help prospective teachers become aware of the limitations of their prior knowledge about chemists. This result was similar to chemistry.

Question 4. *Was there a change in the creative comparisons you made related to "chemist" after taking the course on the History and Philosophy of Chemistry? What was that change? What are the reasons for the change?*

Question 4 was designed to determine how the prospective teachers explained the reason for the change in their creative comparisons about "chemist" on the pre-test and post-test. From the findings of the interviews, it was determined that only three prospective teachers did not explain the changes in their creative comparisons in the context of the History and Philosophy of Chemistry course. When these prospective teachers' explanations were examined, it was revealed that these prospective teachers accepted that their field and laboratory courses were the main reasons for this change.

On the other hand, the other prospective teachers stated that there had been a change in their creative comparisons after the course on the history and philosophy of chemistry, and they expressed the cause of this change as a result of their understanding the curiosity that chemists have, their impacts on people's lives, and their increased perceptions about chemistry and the chemist. In particular, the explanations that pointed to the fact that chemists' curiosity play a major role in the development of chemistry showed that the stories related to the personalities and lives of chemists that they had learned about in the course has an impact on the prospective teachers. In addition, the prospective teachers' emphasising the effects of chemists' works on people's lives was a reflection of the effects of the history and philosophy of chemistry course. Apart from these explanations, one prospective teacher (PT-32) stated that their perceptions about Chemistry and the Chemist had increased during the history and philosophy of chemistry course, and as a result of this, their creative comparisons had changed. All of these explanations provided evidence about the effects of the history and philosophy of chemistry course on the

Table 13 Categories and codes related to the fourth interview question

Category	Code	*f*	Sample statement
The History and Philosophy of Chemistry course having an impact	Understanding the curiosity of chemists.	5	*"I first likened the chemist to a painter. Because a painter produces a work of art. The chemist similarly puts chemicals together and creates new products using chemical reactions. Later on, I likened the chemist to a tourist because when a tourist goes somewhere, he/she will explore everything in sight, being curious about where people came from, why they are the way they are, researching everything. Chemists similarly are continuously exploring; they are always curious. They are impatient to get to the result. I can see that this course in particular broadened my horizons. In particular, I was aware of chemists' curiosity. I saw that chemists' curiosity played a major role in the development of chemistry. That is, chemistry is what it is because of some people's curiosity; they asked why something happened and how and they didn't stop there. They always thought of the next step." PT-22*
	Understanding the impact of chemists on people's lives	4	*"Yes. When I compare the creative comparisons before and after the course, I can see its effect. I can see that I have taken up a scientific perspective after the course. I especially understood during this course how chemists make life easier for society with their work. In other words, before the course, I first likened the chemist to a magician. In making this comparison, I had taken into consideration the fact that both were creating a product. These products are sometimes surprising. After the course, I likened the chemist to light. When there is no light when we enter a room, we cannot see anything in the dark. But when there is light, we see everything and we can find our way. The work of chemists and their inventions have made people's lives easier." PT-23* *"I first likened the chemist to a detective. Because a detective has to check up on many things at once and make careful observations. And the chemist working in the laboratory is required to notice the temperature of the environment in the context of chemical reactions. Then I likened the chemist to a maid. In making this comparison, I thought about what I had learned from the history of chemistry. Because chemists have always made people's lives easier with their accomplishments". PT-18*
	Increasing perception about chemistry/chemist	1	*"Yes. I first likened the chemist to a nanny. Because nannies are extra careful and continuously observant when they take on the responsibility of a baby since the baby is not their own. Chemists too work under sterile conditions in the laboratory in the same way and are required to be extra careful. Otherwise, they may end up with compromising results. That is why I wrote up a comparison like this. Later, I likened the chemist to a neighbor who likes to gossip. Because the gossiping neighbor is curious and does some research. The chemist too does research on whatever he/she is curious about, wishing to know what the result will be. I think that the course on the history of chemistry increased our perception of chemistry and had a big impact on thinking about these comparisons. In other words, with the course, our perceptions about chemistry and chemists were expanded." PT-32*
The History and Philosophy of Chemistry Course not having an impact	Field courses	1	*"I first likened a chemist to an electric power plant. This was because I thought chemists are always generating something. Afterwards, I likened the chemist to an archeologist. This was because I considered how chemists must always be explorers. My creative comparisons did change of course because my thoughts about chemistry and chemists are changing too. I'm learning new things every day. This change might have been affected by many courses or by what I have been reading." PT-19*
	Laboratory courses	2	*"Yes, there was a change. But I think this involved the laboratory more than the course. I, for instance, took the laboratory work more into consideration when I was making my creative comparisons about chemist. I first likened the chemist to a farmer because chemists in a laboratory are constantly moving about; they're always working. Later, in the cook creative comparison, I wrote that the chemist must be very careful of the materials used in a laboratory experiment." PT-24* *"I first likened the chemist to an ant because chemists are always busy as bees as they work in their laboratories. Afterwards, I said they were like cleaning women. Because chemists have to be very careful when they work in the laboratory. I wrote these comparisons as I thought about our work in the laboratory." PT-35*

prospective teachers' creative comparison and their perceptions (Table 13).

Conclusions and discussion

The current study basically aims to reveal how the History and Philosophy of Chemistry course affects prospective chemistry teachers' perceptions regarding chemistry and the chemist. In line with this aim, a creative comparison questionnaire was firstly administered before the instruction in order to reveal the prospective teachers' perceptions about the chemistry and the chemist.

The findings of the pre-test showed that prospective chemistry teachers produced creative comparisons related to chemistry based on their own experiences and observations (see Table 6). Thus, most of these creative comparisons fell into the category of comprehensiveness, and the prospective teachers formed these creative comparisons by considering the content-richness of chemistry. Similarly, the creative comparisons in

the categories of progressivity, significance and chemistry branches reflect the prospective teachers' perceptions based on conceptual structure in chemistry, different branches of chemistry, and the importance of chemistry. On the other hand, the creative comparisons in these categories were extremely limited.

Important points were revealed in the creative comparison analysis about the chemistry in the post-test. One of these was about categories. In the post-test, two new categories – facilitation and role – emerged. When the creative comparisons in these categories were examined, it was seen that the prospective teachers emphasised the effects of chemistry in daily life and on a microscopic level of chemistry. Another important result in the post-test was that there were different and more creative comparisons in some categories (such as significance, developmentalism and sphere of influence) as compared to the pre-test. At the same time, these creative comparisons showed that the prospective teachers had started to think of the chemistry in more detail. For example, some explanations, such as the importance of chemistry in the development of other branches of science, its significance in life, the constant development of chemistry throughout history to the present, supported these conclusions.

Also, the category changes between the pre- and post-tests were examined in the light of the third sub-problem that was drawn up to more clearly set forth the change in the perceptions of the prospective teachers. A review of the results shown in Table 5 indicates that the perceptions of the prospective teachers, which were concentrated on the comprehensiveness of chemistry before the instruction, shifted toward the role and developmentalism categories. In particular, it is striking to note that these perceptions are considerably dissimilar to each other. In other words, it can be said that the perceptions of the prospective teachers about chemistry shifted towards other aspect categories after taking the course on the history and philosophy of chemistry.

The consistency between the content of the History and Philosophy of Chemistry course and the categories and creative comparisons can be interpreted as an indication that the History and Philosophy of Chemistry course helped to change the prospective teachers' perceptions of chemistry. In particular, exploring the areas of the applications of Chemistry from past to present, and discussing the effects of chemistry on societies in the History and Philosophy of Chemistry course may cause a change in prospective teachers' perceptions about chemistry. In this context, Ucar (2012) has stated that educational courses may affect prospective teachers' beliefs regarding science, scientists and science teaching.

According to the analysis of the retention test on chemistry, it can be seen that the prospective teachers mostly produced creative comparisons regarding the role of chemistry in science and nature, the development of chemistry from past to present, and progressivity. When these creative comparisons were compared in the pre- and post-tests, it can be said that the results of the retention test were similar to those of the post-test. In fact, as it was in the shifts between the pre- and post-tests, the category that exhibited the most shifts between the pre-test and the retention test was comprehensiveness. The fact that the shifts were particularly seen in comprehensiveness – role and comprehensiveness – developmentalism points to the change of perception in four months from the comprehensiveness of chemistry to rather the role and developmental aspect of chemistry. This result also showed that the effects of the History and Philosophy of Chemistry course on the prospective teachers' perceptions about chemistry could be observed even at four months after the teaching. The similarity between this result and the result of the post-test sets forth the consistency between the post-test and the retention test. Indeed, an examination of the category changes between the post-test and retention tests in Table 5 shows that these changes, as in the pre-/post-test and pre-test/retention test, were not that pronounced. At the same time, it can be seen that the category shifts took place between areas similar to each other as far the perception of chemistry was concerned, namely shifts between comprehensiveness – branch, significance – role, and facilitation – role. All of these results support the finding that the prospective teachers' perceptions of chemistry were along the same lines on the post-test and retention tests.

Additionally, the analysis of the prospective teachers' creative comparisons about the chemist revealed important findings (see Table 9). Particularly in the pre-test, it was determined that the prospective chemistry teachers mostly produced creative comparisons based on chemists' experimental procedures in the laboratory. For instance, the prospective teachers explained productivity as chemists' productivity in the experimental process. Similarly, they emphasised the researching characteristics of chemists in the context of exploring and performing experiments. In another category, the prospective chemistry teachers portrayed the chemist as a meticulous person since a chemist has to be careful while performing experiments.

When the post-test results about chemist were examined, it was seen that both new categories and creative comparisons had been generated when compared to the pre-test. Particularly, in the new categories of facilitation and developmentalism, the prospective teachers explained how chemists made life easier for society, and referred to the development of the chemist based on the historical progress of chemistry. In the light of these findings, it can be said that the prospective chemistry teachers' perceptions about chemist were expanded after the History and Philosophy of Chemistry course. One of the reasons for this was that the History and Philosophy of Chemistry course may have helped the prospective teachers better understand chemists' lives, work and personalities. In fact, when the category shifts between the pre- and post-tests are examined in Table 8, it can be seen that the most striking shifts were from productivity – facilitation and from productivity – researching, which can be interpreted to mean that the course on the history and philosophy of science enhanced perceptions about the work of chemists, the way

they facilitated everyday life and about the researching aspect of their careers. The fact that the perceptions about the categories of productivity and facilitation in particular were relatively far away from each other indicates that the prospective teachers' perceptions about the chemist shifted to different directions.

It can be understood from the findings of the retention test about chemist that the prospective teachers mostly emphasised the characteristics of chemists such as productivity, researching and meticulousness. These results were similar to the post-test results. Differing from the post-test, the prospective teachers produced creative comparisons in the categories of patience and management on the retention test. In particular, the prospective teachers expressed their perceptions of chemists' roles in society during the historical process. According to these explanations, it can be said that prospective chemistry teachers can incorporate their perceptions and the insights they gained from the History and Philosophy of Chemistry course long after taking the course.

An examination of the categorical changes taking place between the pre- and post-tests and the retention test gives a clearer picture of the change in perceptions of the prospective teachers of the chemist. The change was most prominent in the pre-test and the retention test, indicating that the difference in the perception of the prospective teachers about chemist was more evident in the longer term. The perceptions of the chemist before the instruction were concentrated in the productivity category and later shifted on the retention test to the categories of researching, meticulousness and management. Especially the shift from the category of productiveness to what we can interpret to be the more distant categories of meticulousness and management demonstrate a change in the perceptions about the chemist. Similarly, the perceptions of the prospective teachers about the researching aspects of the chemist in the pre-test displayed various changes in the retention test. Among these, one of the categorical changes in perception took place in the category of management.

An examination of the category shifts between the post-test and the retention test shows the finding that, similar to the perceptions of the prospective teachers about chemistry, no remarkable change was seen in their perceptions about the chemist. In fact, the most common shifts were between categories that were perceptually close to each other: productivity – researching, researching – productivity and researching – meticulousness.

In order to determine whether the course on the history and philosophy of chemistry had an impact on the prospective teachers' knowledge and perceptions, semi-structured interviews were also conducted. In line with this aim, the prospective teachers were stratified according to creative comparisons and their meaning, and 18 prospective teachers who were in Type 2 were selected randomly for semi-structured interviews. According to the interview results, all of the prospective teachers expressed their dissatisfaction with their prior knowledge about the concepts of chemistry and chemist (see Tables 10 and 12). In particular, the prospective teachers stated that their prior knowledge about the concepts of chemistry and chemist was inadequate and limited and that they only realised this while taking the History and Philosophy of Chemistry course. Tables 10 and 12 demonstrates that a large part of the prospective teachers explained the insufficiency of their prior knowledge about the concepts of chemistry and chemist by referring to their lack of knowledge or their partial knowledge about the historical process. The responses of the prospective teachers about chemistry particularly indicated that they had no knowledge about the stages and eras of the development of chemistry prior to their taking the course on the history and philosophy of chemistry. Another striking point was that the prospective teachers said they had a general knowledge about the chemistry but that this knowledge was concentrated primarily in a particular era such as the period of Modern Chemistry. The prospective teachers' responses showed that the prospective teachers realised that their knowledge about the importance of alchemy in the history of chemistry was inadequate.

For chemist, some of the prospective teachers revealed that they had knowledge about the lives of chemists, their fields of work or their contributions to chemistry prior to taking the course on the history and philosophy of Chemistry. As with respect to chemist, a group of prospective teachers said that they were familiar with certain chemists (especially those who worked on the structure of the atom) but that they realised they had no knowledge about other chemists (*e.g.*, alchemists, philosophers of nature) or about their works and individual characteristics. All of these findings indicate that the prospective teachers expressed their dissatisfaction with their prior knowledge. The results of the study by Rubin *et al.* (2003) revealed that prospective teachers were not familiar with leading scientists of the Renaissance and Middle Ages (Bacon, Copernicus, *etc.*) and did not recognise the names of renowned chemists such as Lavoisier, Dalton, and Priestley. It was for this reason that the researchers underlined the need for including the history of science in the sciences curriculum.

Another objective of the interviews was to explore how the prospective teachers explained the change in the creative comparisons they generated about chemistry and chemist and in this context, to examine whether or not the course on the history and philosophy of chemistry had an effect on their perceptions about chemistry and chemist. It was observed in the interviews that a large majority of the prospective teachers explained the change in their creative comparisons in the context of the history and philosophy of chemistry. From the answers that the prospective teachers gave with regard to chemistry, it could be seen that with the course, what they had learned about the development of chemistry, the influence of chemistry on other sciences and on people's lives had had an impact on their creative comparisons. Indeed, an examination of the category shifts in the creative comparisons that the prospective teachers generated between the pre-/post-test and their pre-test/retention tests

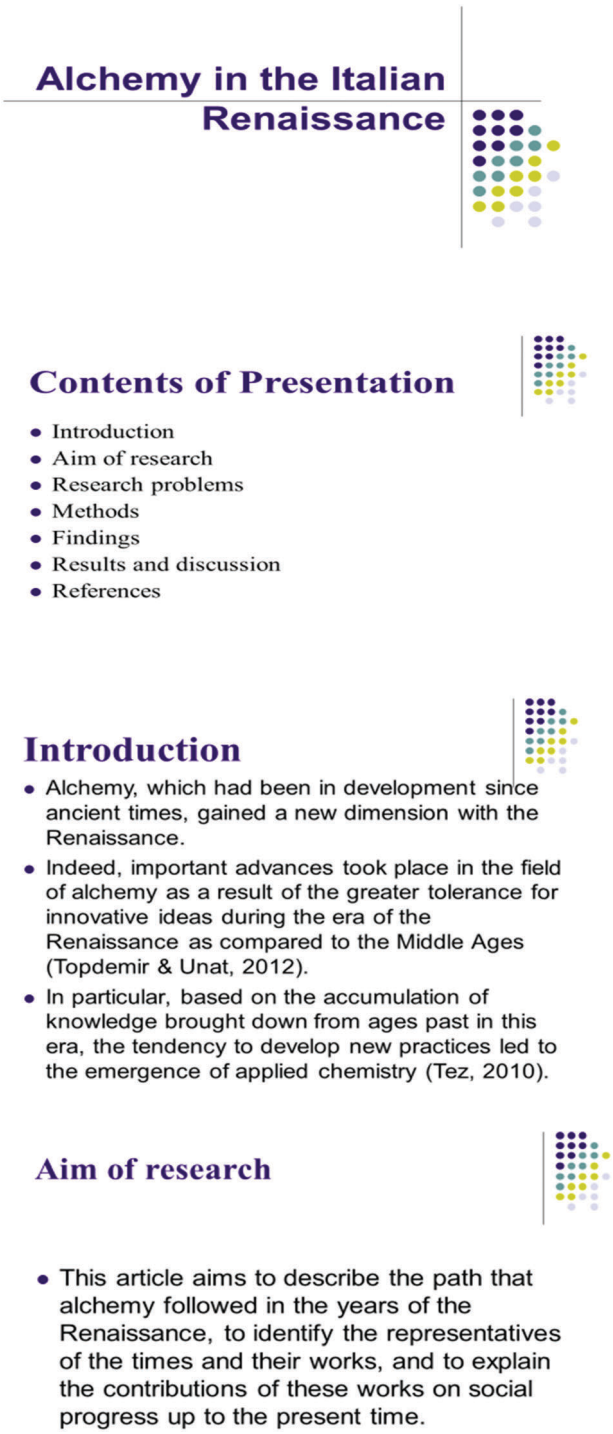
shows that the shift from the comprehensiveness category to the role and developmentalism categories was more concentrated, supporting the finding that their perceptions had shown a change of direction.

Also, it could be seen that the prospective teachers stressed that the contents of the course regarding chemist influenced their creative comparisons by what they had learned about the curiosity of chemists and their impact on people's lives. These findings reveal the category changes that the prospective teachers exhibited in the creative comparisons they generated from the pre-test to the post-test and from the pre-test to the retention test. The shifts evident in Table 8 demonstrate that the category changes, which were more in the direction of the productivity of chemists before the instruction, shifted more toward perceptions on the post-test about the facilitation aspect of chemists and later toward the meticulousness and management characteristics of chemists on the retention test. These findings, as expressed also by Hamilton (2016), indicates that as prospective teachers gain knowledge and experience about the history of chemistry, their creative comparisons change and they are able to reveal their knowledge in this way.

Consequently, the results of the examination of both the creative comparisons and the interviews revealed that the prospective teachers' perceptions about chemistry and the chemist changed after taking the course on the history and philosophy of chemistry. In fact, Stuckey and Eilks (2014), stated that in terms of its importance for the individual, for society and the profession, it was possible for individuals learning chemistry to experience a positive shift in their perceptions. Similar consistent findings were reported by Büyükekşi and Yavuz (2016). Furthermore, the awareness of the change in their perceptions may well be, as Markic and Eilks (2008) have stated, a legitimate starting point for prospective teachers to indulge in self-reflection.

On the other hand, there were some limitations to this study. The first of these was the fact that no exploration was made of whether the prospective teachers' other courses had an effect on the change in their perceptions. The impact of other courses may be a subject for future research. The study also did not examine how and why the course affected the prospective teachers' views of the nature of chemist and chemistry. For this reason, future studies may aim to examine whether or not specific events, readings, and knowledge gained during the History and Philosophy of Chemistry course can be effective in modifying prospective teachers' views of the nature of chemist and chemistry. At the same time, it would be useful to observe prospective teachers' views of the nature of science during the process. Moreover, this study did not observe the effects of different educational strategies used in the History and Philosophy of Chemistry course on prospective teachers' perceptions about chemistry and the chemist. Future studies should be conducted in this context. Also, this study was limited to only 38 prospective chemistry teachers. For this reason, future studies with larger populations should be carried out to generalise the results. Although in this study, the prospective teachers' creative comparisons were re-examined after the post-test, these prospective teachers may be followed up after the completion of the programme to compare their creative comparisons and their perceptions.

Appendix 1



Research problems

- What are the Scientific Revolution and Iatrochemistry? Who are the representatives of this era?
- What works did the representatives of this era produce and what have been the effects of these on the contemporary world?

Methods

- This study was based on the literature and conducted as a review.

Findings

What is the Alchemy of the Period of the Renaissance?

- Chemiatry, which aimed to use chemistry to produce medicines, and the emerging iatrokimya, which used these medicines in the treatment of diseases, were considered the rebirth of the Age of Antiquity (Tez, 2010).

Findings

Who were the Representatives of Renaissance Alchemy?

- Paracelsus
- Georgius Agricola
- Basillius Valentinus
- Andreas Libavius
- Van Helmont
- Johann Rudolf Glauber

Findings

What were the works of these representatives of the era?

- Paracelsus (1493-1541) was the most prominent representative of the period. He opposed the alchemy movement and opened the way for the era of iatrochemistry. He associated four elements (fire, earth, air, water) with "three principles (tria prima)," believing that salt represented the body, sulfur the soul, and mercury the spirit, thus opening the way to a different perspective (Tez, 2010).

Findings

- Paracelcus (1493-1541) said that the stomach was a chemistry laboratory (Tez, 2010). He was the pioneer of pharmacology and contributed to the science by experimenting with copper, lead, mercury, arsenic, antimony and its salts (Gürel, 2005). He asserted that the medicines that would be used to restore health must be made of pure substances such as metals, ametals and compounds consisting of these. He initiated the first vaccination programs in Europe.

Findings

- Georgius Agricola (1494-1555) was a pioneer of mining, metallurgy and chemical technologies (Tez, 2010). He disproved the faulty knowledge set forth by the alchemists and defended the methodology of experimentation. His works De Nature Fosillium and De Re Metallica are important contrib

Findings

- Basillius Valentinus (1565-1614) was the first to correctly identify antimony and in his work "Triumphal Chariot of Antimony," he maintained that the eternal Philosopher's Stone could be obtained from mercury, sulphur and salt, the contents of antimony. He was also the first to describe Aqua Regia (water of kings), a mixture of sulfuric acid and nitric acid.

Findings

- Basillius Valentinus (1565-1614) worked on the symbolization of chemistry and wrote his "Twelve Keys" with this objective.

Findings

- Andreas Libavius (1540-1616) wrote the first textbook on chemistry (Alchymia) and in his book "Syntagma," he described how to prepare sulfuric acid and chlorides. He colored glass with various metal oxides to produce artificial precious stones.

Findings

- Van Helmont (1579-1644) believed in alchemy and worked to turn mercury into gold. He used a scale in his experiments, providing his work in chemistry with a quantitative quality. He was the first to realize the production of gas. He discovered the gas carbon dioxide (Gürel, 2005). He synthesized sulfuric and hydrochloric acids. He discovered that the stomach produced acids and described the role these played in digestion.

Findings

- Van Helmont (1579-1644) believed that water was a basic element and attempted to prove this with his willow tree experiment. In this, he asserted that a plant's weight after attaining growth is derived from water and the earth.

Findings

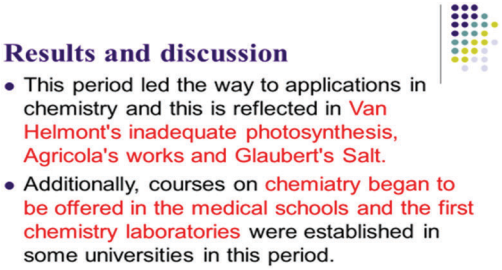
- This work of Van Helmont (1579-1644) was the first in which the components and measurements taken in an experiment were documented. Named inadequate photosynthesis today, the process Van Helmont worked on formed the basis of photosynthesis instruction. He was the first to provide a modern interpretation of the process of submerging a piece of iron into blue vitriole that Paracelsus had described as transmutation.

Findings

- Johann Rudolf Glauber (1604-1668) discovered sodium sulphate (Na_2SO_4), what is known today as "Glaubert's Salt." He is also responsible for the first production of nitric acid (HNO_3) and for the discovery of malt extract as a medical preparation..

Results and discussion

- When the alchemy of the Renaissance is generally considered, it can be seen that many chemical substances and their production were defined and significant works were produced in the areas of chemical representation, mining, pharmacology and other disciplines.



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