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HERMENEUTIC PERSPECTIVES OF PRE-SERVICE SCIENCE TEACHERS ABOUT SCIENCE

Bilge Can,
Asiye Bahtiyar,
Hasret Kökten

Abstract. *Science education emphasizes the development of individuals' ability to make comments, reasoning, and critical reflection while expressing their scientific thoughts. In this sense, future science teachers have great responsibility to develop those skills of the learners and their meaningful learning. Many researches emphasize hermeneutical thinking for disciplines such as mathematics and science to create meaningful learning. The current research aimed to reveal pre-service science teachers' hermeneutical perspectives about science and to determine their existing ideas. For this aim, scientific problems presented to pre-service science teachers via scenarios, and how they developed their approaches to solve these problems, and whether they used hermeneutics in this process were examined. The hermeneutical perspectives of pre-service teachers were selected as a single case -by using qualitative research method- to have a deep understanding of their hermeneutical perspectives. The research group consisted of nine third-year-students. Semi-structured interviews prepared by the researchers were applied before and after the intervention in the research conducted for 14 weeks in Science Teaching Laboratory Applications-I course. The data were analysed by a descriptive analysis method. It has been evidenced that science-related hermeneutical perspectives of the pre-service science teachers have developed as a result of the problem-based scenario studies.*

Key words: *hermeneutics, hermeneutical perspective, scenario-based learning, science education, pre-service science teacher.*

Bilge Can,
Asiye Bahtiyar,
Hasret Kökten
Pamukkale University, Turkey

Introduction

Definition and Historical Development of Hermeneutics

It is both important and necessary to systematically handle and interpret anything about human and produce meaning for human life. In philosophy, the approach and method called as hermeneutic or interpretation has emerged for such purposes as producing meanings. All the thoughts that expressed themselves in any way are considered to be in the scope of hermeneutic. In the simplest way, with this method one can easily reveal "how" s/he looks at "that thing" (Palmer, 2003, p. 12).

In the most general sense, hermeneutics is the theory, in addition to be used as a method, of interpretation which deals with what it means to understand texts, speeches or nature and what they try to tell. In this case, it can be said that there is hermeneutics when one interprets a text, situation or phenomenon (Shaw, 2010). When the definitions included in hermeneutics are examined in detail, it is handled as the art of reporting, informing, explaining, translating, explaining, understanding, analysing and interpreting. One also comes across a definition as an event, a method or an art style which includes the function of communicating a message, transmitting a message. At the same time, hermeneutics also has the task of highlighting the subjective one, reaching the essence and nature of the inner in the context of conditions such as the identification and acceptance of the current situation according to the subject (Gadamer, 2003; Taşdelen, 2008).

According to Henriksson and Friesen (2012), hermeneutics is defined as the "art and science" of interpretation and making a meaning. The emergent meaning which results from using hermeneutics in this context is not static, but something that is constantly open to new perspectives and interpretations. At the same time, the hermeneutic phenomenon means taking the current and first-hand experiences together with their meanings. Hermeneutic, as a methodology, is open to elaborate on, reinterpret and take a different view of any situation to deal with. The meaning here is concerned with the probable experiences and the case of openness. In short, the hermeneutic phenomenon is not only a separate method or program for repeatedly questioning life and its content, but also a tendency and attitude (Henriksson & Friesen, 2012).

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Hermeneutics and Education

With the way in which it is handled in terms of theology, theory and method as well as the historical and philosophical perspectives it contains, hermeneutics has been used as a method in educational research and applications for years (Moules et al., 2011). Hermeneutic understanding defines pedagogical success as initiating the student's ability to interpret; it succeeds when a teacher makes a student interested in the subject and enables him to challenge himself by producing persuasive alternative opinions about the research (Taşdelen, 2002).

It is important that the individual's learning that takes place in the educational environment should not be linked to the explanations provided by an external source but should take place by participating in the process with the individual's own will. In other words, when learning is thought to be a process that is more related to understanding-interpretation determined by the individual's own will, the importance and necessity of revealing his/her hermeneutic thoughts come into prominence. Therefore, the problem of whether science education is an acquisition of information (self-realization) or (should be) a problem of enhancing a problem-solving skill (formation training) can be addressed through hermeneutics (Yılmaz, 2007, p. 164-170).

Hermeneutics and Science

Hermeneutical understanding is an important goal in education. However, hermeneutics tries to show that the process of understanding will never be completed while education usually aims to create a state of understanding that is complete and based on certainty. This part should be reworked with respect to previous section. In this context, science education is not an educational state with a final and definitive recognition. It is important to emphasize that science education in terms of hermeneutics is a state of pedagogical self-update when the scientist realizes that s/he is always on his/her way to achieving a single definition because if there are no different meanings, the development in science and education is also limited (Smith, 1991, as cited in Pelech, 2013). Therefore, ignoring the hermeneutical method for science education means using science textbooks only to serve technical purposes, scientific articles not including the historical understanding of science and conducting science education without understanding the life where science finds its roots. This is one of the obstacles to being able to produce different meanings and to improve students' creativity (Bevilacqua & Giannetto, 1995).

Researchers using hermeneutics as a method have been conducting important studies in the last thirty years in order to find the answer to the question "What is Science?" as stated by Shaw (2010). That hermeneutical approach is also concerned with problems related to science, is seen as important for the development of science. At the same time, it is very important to handle the knowledge about the nature of man and science, to explain the history of science more adequately, and to put forward a reliable science theory in the history of science through hermeneutics. That hermeneutics deals with many problems and the concepts of those problems reveals, interprets and brings together the different applications of scientists in various fields of science. The situation that arises from the use of hermeneutics in science is also compatible with the beliefs of the scientists about their own disciplines that have put forth that scientific theories are more than just grounding a single point of view. In addition, the hermeneutical method tries to get over many deficiencies of the constructivism approach by detailing why scientific information is not just the work of one person's culture. This attitude, as theoreticians say, can also be called as hermeneutic philosophy of science (Shaw, 2010).

The hermeneutics used in science and scientific events are closely related to the applications of scientists and the comprehensive states of scientific discoveries. It has developed a point of view that will take a number of meanings for humanity regardless of the discipline in science. The perspectives and meanings revealed in the disciplines of science are important for every person who wants to receive education and study in the related field. Every generation within educational institutions must progress gradually in order to question the truths and nature of science. In this case, it is also important to think about the concepts and meanings in different ways which science and scientific studies have put forth in educational environment. The fact that science needs individuals in the context of interpretation and meaning production also increases the importance of questioning the nature of science (Shaw, 2010). Nevertheless, there is no comprehensive research of hermeneutical perspective in science education which requires the interpretation of science and scientific knowledge, and the production of different meanings in this way.

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Problem of Research

In the Science Education Program of Turkey which was last updated in 2018, there is a statement as follows: "*Rapid change in science and technology, the changing needs of the individual and society, innovation and development in learning teaching theories and approaches have also directly affected the expected role of the individual. This change defines the qualifications of a person who can produce knowledge, use it functionally in life, solve problems, think critically, behave entrepreneurially and decisively, has communication skills, can empathise, contribute to the society and culture and so on"* (MoNE, 2018).

Science teachers, therefore, have to teach their students not only what they need to know about our world, but more importantly how to learn it in order to be able to raise students with qualities required by the age (Pelech, 2013, p. 5). In addition to this point of view, Elliott emphasized that the hermeneutical method and its understanding principle are important for teacher education programs and for the idea of continuity and progress in vocational education which we have recently begun to perceive and explore (Elliott, 1993). For this reason, it is thought that it is very important to reveal hermeneutical perspectives of pre-service science teachers regarding how they perceive science.

It is important that pre-service science teachers have balanced hermeneutical perspective about the nature of science and should reflect it in the classroom environment by recognizing their future students. In order to understand the tradition of hermeneutics, it is necessary to act on epistemological bases (Saygın, 2009, p. 103). According to Tsai (1999), science teachers and pre-service teachers must have a science epistemology of constructive learning to actualise constructive science education which constitutes science teaching programs of many countries. This can only be taught by teachers with sufficient competencies (Bollnow, 1995, p. 98-99) and high hermeneutical comprehension levels to their students.

Educators who focus on teaching scientific knowledge in an educational setting can be asked the following questions: How does science live in the world as an ongoing phenomenon and what traditions-methods are parts of science education? In addition, hermeneutics asks the question to the educators about how they have adopted science teaching: "Should understanding and interpreting in science be considered as a subjective action rather than a participatory act in a tradition?" (Gadamer, 2003, p. 291). At this point, in the process of raising science teachers, the use of scenarios that do not have a clear answer but rather includes a series of interpretations and probable possibilities will enable them to discuss the evidence for various interpretations and focus on different perspectives (Dalziel, 2012) and thus to reveal their perspectives. Therefore, when teachers with high hermeneutical comprehension levels in the education system are trained in the learning environments where carefully planned and problem-based scenarios are clearly designed with reflection activities, it is thought that not only their own perspectives but also their learners' perspectives about science and scientific knowledge can improve thank to these teachers, and the desired high hermeneutical understanding ability can be gained.

Research Focus

In general, when looking at the history of science, no field of science develops in a single way. Hermeneutical thinking can be considered as an alternative method for new productions in science education and science studies, where it is thought that the diversity of methods can improve the ability of thinking within each science field. Under favour of hermeneutics, it is very important for the natural sciences as well as the social sciences to understand the information about the nature of human and the nature of science, to explain the history of science in more details and to put forward a reliable science theory in the history of science. Hence, the hermeneutics used in science and scientific events are closely related to the practical work of scientists and the comprehensive state of scientific discoveries. In this context, scenario-based activities were applied to develop pre-service science teachers' understanding, thinking, explanation and interpretation skills by including hermeneutic thought in science education with this research. Thus, pre-service science teachers were asked to question and deepen their views on science.

Although there is a huge volume of research on hermeneutics that are generally theoretical research studies (Bevilacqua & Giannetto, 1995; Fehér, Kiss, & Ropolyi, 1999; Pelech, 2013) and in which hermeneutics was used as a scientific method (Güven & Soydaş, 2011; Nachiappan, Andi, Subbramaniam, & Veeran, 2012), there is no research on the hermeneutic thinking of pre-service science teachers. From this point of view, when the research is examined in detail, it is thought that this research will be the first one to include hermeneutics which has philosophical bases in science education. Hermeneutics, which has the ability to reveal and give meaning to those that have been

dared to be spoken or hidden (Bollnow, 1995, p. 96-97), is thought to be very important in revealing the viewpoints of pre-service science teachers about science who will be especially the leaders of the science education, and in interpreting notions related to science.

Methodology of Research

General Background

This research aimed to reveal pre-service science teachers' perspectives upon hermeneutics about science and the development of hermeneutic thinking before and after the scenario implementations. The case study was adopted from qualitative research methods in order to investigate a situation in depth (Creswell, 2007). In order to understand and examine the hermeneutical perspectives and development of the pre-service science teachers in detail, hermeneutical perspectives of pre-service science teachers were selected as a holistic single case (Yin, 2003). Semi-structured interview form was used to identify hermeneutic perspectives about science of pre-service science teachers. The piloting was conducted upon the senior pre-service science teachers. Pre-service science teachers' development was investigated through questions about science, scientific knowledge, scientist, and socio-scientific directed at pre-service science teachers in semi-structured interviews before and after scenario implementations. During 14 weeks of application, all pre-service science teachers in the course were assured to participate in the activities and answer the interview questions with the help of the researchers. In this way, the soundness and credibility of the research were ensured.

Research Group

The research group of the research include nine pre-service teachers (5M, 4F) who were third year students at Pamukkale University, Science Teaching Department in the fall semester of 2016-2017 academic years. The participants selected by the purposeful sampling method, included three students who were at low, medium and high achievement levels based on their CGPA in each of the three sections to provide maximum diversity. In the purposeful sampling method, it is assumed that the selected participants have the necessary knowledge about the target audience (Frankel & Wallen, 1996). The reason why the pre-service science teachers who were studying in the third year were chosen for the research is that the researcher realized that the hermeneutical perspectives of the pre-service science teachers were very limited in the Lab Practices I-II in Science Teaching conducted by the researcher. In addition, in science teacher education, completion of courses related to science-teaching (Special Teaching Methods, Nature of Science) aside from the basic science courses till the third grades (General Physics I-II-III-IV, General Chemistry I-II-III-IV, General Mathematics I-II and General Biology I-II) is also seen to be important in terms of the purpose of the research.

Instrument and Procedures

When the scales and interview forms in national and international studies were examined, it is seen that there is no scale or interview form which reflects the perspectives of teachers and pre-service teachers about science, scientific knowledge, scientist and scientific method, and is short, easy to apply and evaluate. For this reason, in the semi-structured interview form prepared by the researchers, there were questions to determine ideas about science, scientific knowledge, and characteristics of scientists, scientific method and scientific thinking in order to reveal hermeneutical perspectives of pre-service science teachers. Additionally, the related literature was reviewed and various scales related to the nature of science were examined (Abd-El-Khalick & Lederman, 2000; Lederman & O'Malley, 1990; Abd-El-Khalick, Bell, & Lederman, 1998; Lederman & Khishfe, 2002; Lederman & Ko, 2004; Lederman et al., 2014), and a draft form was created with the inclusion of some questions like "What do you think about the formation of the universe?", "How do scientists form models of atoms even if they do not see them?", "Do you have any habits that affect your scientific thinking process? If so, what are they?" and "Suppose that someone you love is a kidney patient. Also, suppose that a kidney is produced with a cell taken from you and transplanted into him/her via the stem cell method. What do you think about this kind of kidney production?". The prepared draft form was examined by the expert academicians in the field by considering the purpose and scope of the research and the necessary arrangements were made in line with the suggestions received. In order to test the validity of the

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questions, a piloting study was conducted upon the senior pre-service science teachers. Following the implementations, the necessary modifications were made to finalise the interview form (see Appendix 1).

Within the scope of the research, Problem-based Learning Model was applied for 14 weeks with scenarios in Science Instruction Laboratory Applications course. In this process, through the scenarios (Appendix 2) prepared by the researchers about the achievements in the Ministry of National Education Science Curriculum, the pre-service science teachers were expected to determine the problem, decide the hypothesis and variables, design the experiments and make a comment by reaching a conclusion. The data obtained from semi-structured interviews aiming at revealing the hermeneutical perspectives of pre-service science teachers for the purpose of the research were collected in two stages, namely before and after the implementation.

Data Analysis

For the analyses of the data gathered, audio files of the individual interviews made with the pre-service teachers participating in the research were transcribed on the computer and a data set related to the interview data was reached. The pre-service teachers interviewed were coded as "S1, S2, S3, S4, S5, S6, S7, S8 and S9" to prevent ethical problems. Within the scope of the research, the opinions of the pre-service teachers received through the individual interview form were analysed by means of descriptive analysis. Descriptive analysis is the summation and interpretation of the data obtained according to the previously determined themes. The data can be arranged according to the themes set out by the research questions or can be presented by considering the questions or dimensions used in the interview and observation procedures (Yıldırım & Şimşek, 2013). In the analysis of the data, a total of 6 experts, one from Marmara and five from the Aegean region, were consulted for expert opinion.

In this research, the themes and codes were formed by the researchers taking Dilthey's "Comprehension Levels" into account (Figure 1) as a result of examining the chapter called "Expression and Understanding" included in Bollnow's (1995) book titled "Articles on Hermeneutics".

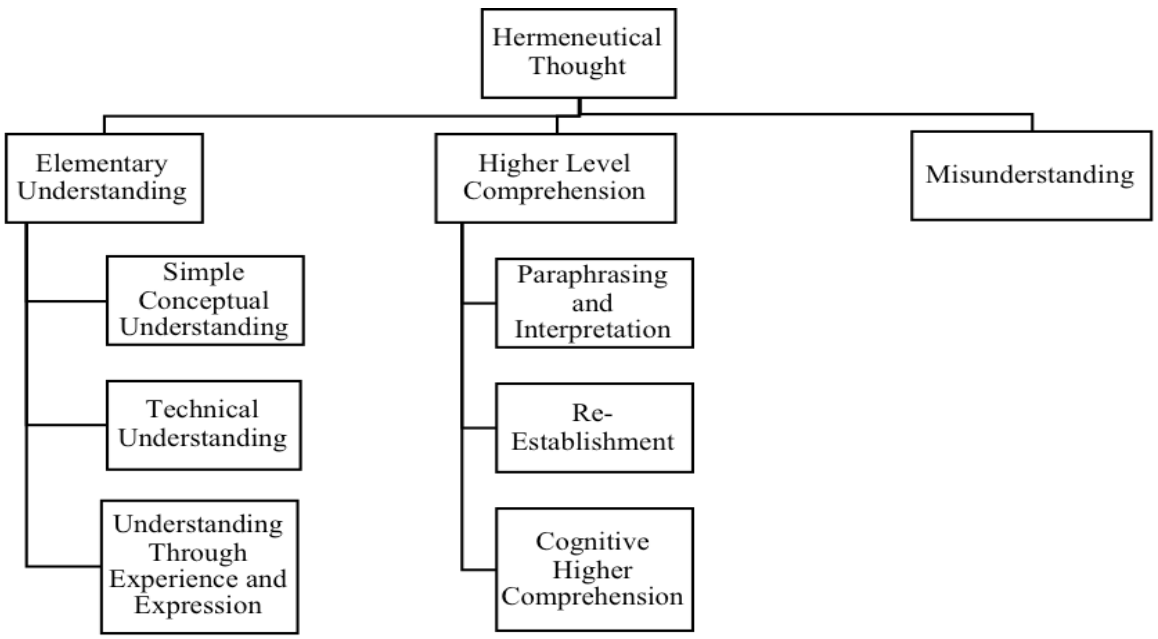

Figure 1. Themes and codes.

According to Figure 1, in the theme of "Elementary Understanding", there are "Simple Conceptual Understanding", "Technical Understanding" and "Understanding Through Experience and Expression" codes; in the theme of "Higher Level Comprehension", there are "Paraphrasing and Interpretation", "Re-Establishment" and "Cognitive Higher Comprehension" codes; finally, for the responses aside from these levels, there is the theme of "Misunderstanding".

A brief description of these themes and codes is as follows (Bollnow, 1995, p. 85-104):

1. Elementary Understanding: The thinking skills of the individual are very simple, and the desire to know oneself is quite lacking. His/her consciousness of being an individual is at a low level and mentions very general ideas. It is generally the understanding at a simple level.
    1.1. Simple Conceptual Understanding: The individual remains with external appearance, expresses the concrete, and deals with daily and ordinary behaviours. S/he grounds very simple understandings. S/he makes definitions. S/he gives bookish information, but has difficulty in making explanations. The answers given to the questions in the interview form such as "What is scientific information?", "What is scientific method?" can be expected to be at this level.
    1.2. Technical Understanding: It includes a direct understanding of what is practical and concrete. It allows direct understanding without any need for indirection. In technical understanding, we directly understand that a board is cut with a saw. It is object-based. The individual gives examples of the definitions s/he makes. The answers given to the questions in the interview form such as "What is scientific information?", "What is scientific method?" can be expected to be at this level.
    1.3. Understanding through experience and expression: There is an external situation or a stimulus that mediates the understanding of the inner, and we try to understand the inner by acting externally. The relationship between externalities (behaviours) and spiritual things we encounter in life, as it applies to all understanding in the elemental form, is direct. The immediacy of the link between life and expression corresponds directly to the understanding of an expression. It is subject-based. The answers given to the questions in the interview form such as "What are the characteristics of a scientist?", "Do you have habits that affect your scientific thinking process? If yes, what?" can be expected to be at this level.
2. Higher Level Comprehension: It is a form of comprehension that is systematized, aims to make the individual question in detail and be creative, making it possible to reach the conclusion by the individual combining thoughts with a method, and trying to obtain the big picture via new contexts.
    2.1. Paraphrasing and Interpretation: Paraphrasing is a systematic, intuitive and directional activity. It requires a masterful understanding. The individual understands not only with simple sentences but also with all the details. Interpretation is the ability to express this deep and intuitive understanding with creativity. It has its own concepts, expressions, etc. The cultural environment creates the possibility of interpretation necessary to understand the expression. Therefore, interpretation is the objective understanding of a fixed expression in a cultural setting. The answers given to the questions in the interview form such as "What do you think about the formation of the universe?", "A person who is curious about birds is examining hundreds of kinds of birds fed with different kinds of food. S/he notices that the birds fed with similar food have similar beaks. For example, the beaks of the birds eating hard-shelled food are short and sturdy while the beaks of birds eating insects in shallow water are long and thin. The individual concludes that there is a link between the beaks of the birds and the varieties of food they eat. Can you scientifically accept this person's examination?" can be expected to be at this level.
    2.2. Re-establishment: It involves from piece to the whole and is an expression of high forms of understanding. It requires the individual to reassemble the knowledge and its questioning in a particular way by bringing together the related parts. The answers given to the questions in the interview form such as "How do scientists form models about atoms even if they do not see them?", "Suppose that someone you love is a kidney patient. Also, suppose that a kidney is produced with a cell taken from you and transplanted into him/her via the stem cell method. What do you think of this kind of kidney production?" can be expected to be at this level.
    2.3. Cognitive Higher Comprehension: It requires conceptual creativity at a high level. At this level, the individual builds a new intellectual domain. It requires understanding of the present situation and transition to a scientific concept that is determined by the person himself. Therefore, it requires a new world and a new perspective. The answers given to the question in the interview form "Suppose that someone you love is a kidney patient. Also, suppose that a kidney is produced with a cell taken from you and transplanted into him/her via the stem cell method. What do you think of this kind of kidney production?" can be expected to be at this level.

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3. Misunderstanding: If the interview questions are misunderstood or wrong answers are given to the questions, the "Misunderstanding" code is used.

Validity and Reliability

There are different strategies and classifications in ensuring the validity and reliability of the research. In this research, the concepts *credibility* rather than internal validity, *transferability* instead of external validity, *consistency* rather than internal reliability, *confirmability* instead of external reliability were preferred which were thought to be in accordance with the nature of qualitative research for the concepts of validity and reliability by Lincoln and Guba (Lincoln & Guba, 1985; as cited in Yıldırım & Şimşek, 2013). Thus, in this research:

- To ensure the *credibility (internal validity)* of the research; the researchers clearly demonstrated how they arrived at the results and presented their evidence in a way that other people can reach. The model of the research, the participants, the data collection tools, the data collection process, the analysis and interpretation of the data, and the way in which the findings are organised were described in a detailed, clear and coherent way so that it can be examined by other researchers. The researcher followed the process closely for fourteen weeks as s/he conducted it himself/herself. During the course of the implementation, s/he spent a lot of time in the field and worked with the prospective science teachers in the laboratory both during and after class, which ensures that the participants were sincere in the data collection process while at the same time providing detailed and in-depth data. After the interviews conducted with the pre-service teachers were recorded on the voice recorder, the researchers listened to these voice recordings one by one, and the interviews were transferred to the computer in Word format. The data obtained from the individual interviews were coded by the researcher and sent to four experts on the field. The agreement level among the coders was found to be 81%. At the end of the research, the interview documents were presented to the pre-service teachers who participated in the interview, and they were asked to confirm whether what they intended to say were the same or not. No changes were made to the expressions of the participants, and the words they used during the interview were used exactly. Thus, member checking was also used to ensure the reliability of the interview data (Creswell, 2007). At all stages of the research, there was an interaction with experienced experts on qualitative studies. This was ensured by receiving opinions, suggestions and critiques from more experienced experts as well as intensive peer-expert interactions.
- To ensure the *transferability (external validity)* of the research; the results of the research were tried to be made transferable with sufficient description of the data. Thus, an attempt was made to establish a chain of evidence for the collected data. Due to the nature of qualitative research, direct citations were given without commenting in the findings part to provide a detailed description.
- To ensure the *consistency (internal reliability)* of the research; the coding of the data obtained from the research was carried out separately by the researchers and the views from the experts related to the coding were taken into consideration to benefit from different perspectives. While the themes related to sub-problems were explained, many data sources were quoted. While presenting findings related to the subject, quotations containing different, contradictory, negative and positive statements or descriptions for any code of the theme were provided to give the theme in a broad context. The processes that took place at all stages including the planning, implementation and analysis of the research, and the products that emerged at the end of these processes were examined for consistency with each other and expert assistance was also referred.
- To ensure the *confirmability (external reliability)* of the research; the researchers exhibited objective attitudes and behaviours in the preparation, development, implementation, and analysis of the data collection tools in the research; they tried not to be biased towards the answers given by the pre-service science teachers and to avoid any positive or negative guidance. The data collection tools used in the research and the raw data collected through these tools were stored in such a way that they can be examined by other researchers or can be used in other research studies. Rich representations were made in presenting the findings obtained at the end of the analyses to the reader and in making the patterns clear. Thus, different perspectives were tried to be presented to the readers. This research has helped readers to reach the same or similar interpretations of the researchers' comments.

Results of Research

The results of the research were presented as sub-problems in the context of the questions in the semi-structured interview form. The answers given by the pre-service science teachers in the preliminary interviews and in the final interviews for the question "What is Science?" are given in Table 1.

Table 1. Pre-service science teachers' responses to the meaning of science.

1. The meaning of science		Preliminary Interview		Final Interview	
		Participant	f	Participant	F
Elementary Comprehension	Simple Conceptual Understanding	S1, S2, S3, S4, S5, S6, S7, S8,S9	9	S3, S5, S6, S7, S8	5
	Technical Understanding	-	-	S1, S2, S9	3
	Understanding through experience and expression	-	-	S4	1
	Total	-	9	-	9
Higher Level Comprehension	Paraphrasing and Interpretation	-	-	-	-
	Re-establishment	-	-	-	-
	Cognitive Higher Comprehension	-	-	-	-
	Total	-	-	-	-
Misunderstanding		-	-	-	-
TOTAL			9		9

When Table 1 is examined, it is seen that for the question "What is science?", all of the pre-service teachers respond at the level of "Simple Conceptual Understanding" under the theme of "Elementary Comprehension". As to the final interviews, five of the pre-service teachers (S3, S5, S6, S7, S8) went on giving answers at simple conceptual level while three of them (S1, S2 and S9) went up one level and gave answers at the level of "Technical Understanding", and one of them (S4) gave answers at the level of "understanding through experience and expression" which is the last level of elementary understanding.

Some quotations from the interview data of the prospective science teachers are presented below:

> *"S1: I think science is to clarify and understand the events in the world, to struggle ... to be able to explain the events in the world…" (Preliminary)*
>
> *"S1: It is an effort to understand the facts and phenomena in the nature. They are making observations and, doing experiments. They reach a theory with assumptions. They can understand. For example, they say that when you throw the apple, it falls down and it is Newton's discovery of Gravity Force. It's like weight. It's like one can understand that there is a gravitational force on Earth." (Final interview)*
>
> *"S2: Science is the systematic application of events in the nature or our purpose to realize it" (Preliminary)*
>
> *"S2: Science is the systematic application of events in the nature or our purpose to achieve it. For example, astronomy is a field of science. It examines events in space." (Final interview)*
>
> *"S4: For me, science is the study of the earth, the planet, our universe in a systematic framework, with some curiosity, from the past to the present. (Preliminary)*
>
> *"S4: At first science meant more like technology for me. But now it's like a stack of information that keeps technology moving forward." (Final interview).*

When the above quotations are examined, it is seen that S1 and S2 made only the definition of science in the preliminary interviews, but in the final interviews they went up the level of technical understanding from the level of simple conceptual understanding, by giving examples about science in addition to its definition. Although S4 adhered to the book definition of science in the preliminary interview, s/he stated what it meant for himself/herself in the final interview considering the place of science in his/her daily life. In this case the student was able

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to present additional information on the use of the object in technical terms to go beyond the definitions s/he made in light of the skills s/he gained via the courses. It is therefore seen that scientific process skills and inquiry skills have improved significantly.

The answers given by pre-service science teachers in the preliminary interviews and in the final interviews for the question "What is scientific knowledge?" are given in Table 2:

Table 2. Pre-service science teachers' responses to the meaning of scientific knowledge.

2. The meaning of scientific knowledge		Preliminary Interview		Final Interview	
		Participant	f	Participant	F
Elementary Comprehension	Simple Conceptual Understanding	S1, S2, S3, S4, S5, S6, S7, S8, S9	9	S3, S7, S8, S9	4
	Technical Understanding	-	-	S4, S5, S6	3
	Understanding through experience and Expression	-	-	-	-
	Total	-	9	-	
Higher Level Comprehension	Paraphrasing and Interpretation	-	-	S1, S2	2
	Re-establishment	-	-	-	-
	Cognitive Higher Comprehension	-	-	-	-
	Total	-	-	-	2
Misunderstanding		-	-	-	-
TOTAL			9		9

When Table 2 is examined, it is seen that in the preliminary interviews all the pre-service teachers gave answers at the level of "Simple Conceptual Understanding" under the theme of "Elementary Comprehension" for the question "What is scientific information?" As for the final interviews, four of the pre-service teachers (S3, S7, S8 and S9) continued to give answers at simple conceptual level while three of them (S4, S5 and S6) gave answers at technical understanding level and the other two (S1 and S2) gave answers at "paraphrasing and interpreting" passing to "Higher Level Comprehension" theme.

Some quotations from the interview data of the prospective science teachers are presented below:

> "S4: Scientific knowledge is the knowledge obtained by scientific methods (Preliminary interview)"
> "S4: Scientific knowledge, as the name suggests, is the knowledge supported by scientific facts rather than random estimates in accordance with rules and orders…There may be some unscientific traditions. Because of the casual beliefs, this is not scientific knowledge, for example believing in the bad luck of passing under the stairs. (Final interview).
> "S2: Scientific knowledge includes accurate knowledge, and the knowledge that can be changed later and we use in our daily lives (preliminary interview)"
> *"S2: Scientific knowledge is the knowledge which is based on reason and logic, keeps its validity and it is the systematic knowledge. Non-scientific knowledge covers random knowledge. For example, something that I have made up myself, which is non-universal, i.e., person-specific, individual-specific differences, society-specific, and they do not fall into scientific knowledge. But scientific knowledge is accepted by all nature and people. (Final interview).*

In light of the above quotations, S4, who made a simple description of scientific knowledge in the preliminary interview, revealed the difference of scientific knowledge by giving examples of less scientific information in the final interview. In the same way, it is seen that S2 also made a more superficial description of the scientific information in the preliminary interview, went up to higher level comprehension, mentioned about its characteristics in more details and reached a generalisation by comparing it with non-scientific knowledge adding his/her own sentences, expressive form and interpretation into the answer.

Pre-service science teacher's answers to the questions "What is scientific method? What are the features that distinguish it from other methods?" in the preliminary and the final interviews are given in Table 3 below:

Table 3. The meaning of scientific method, and its features that distinguish it from other methods.

3. The meaning of scientific method, and its features that distinguish it from other methods		Preliminary Interview		Final Interview	
		Participant	f	Participant	f
Elementary Comprehension	Simple Conceptual Understanding	S1, S3,	2	S3, S9	2
	Technical Understanding	S2, S5, S6, S7, S8	5	S1, S2, S5, S7	4
	Understanding through experience and Expression	-	-	-	-
	Total		7		6
Higher Level Comprehension	Paraphrasing and Interpretation	-	-	S4, S6, S8	3
	Re-establishment	-	-	-	-
	Cognitive Higher Comprehension	-	-	-	-
	Total	-	-	-	3
Misunderstanding		S4, S9	2	-	-
TOTAL			9		9

According to Table 3, while two of the pre-service teachers (S1 and S3) gave answers at the "simple conceptual" level and the five (S2, S5, S6, S7 and S8) gave answers at "technical understanding" level, it seems that the other two (S4 and S9) had "misunderstandings" about the question. In the final interviews, it is seen that one (S1) pre-service teacher has gone from "simple conceptual" level to "technical comprehension" level, and two (S6 and S8) pre-service teachers have gone from "technical understanding" level up to "paraphrasing and interpreting" level. However, according to the final interview, it was revealed that one (S9) of the two (S4 and S9) pre-service teachers who were found to have "misunderstandings" in the preliminary interviews answered at the "simple conceptual" level and the other (S4) answered at the level of "paraphrasing and interpretation".

Some quotations from the interview data of the prospective science teachers are presented below:

"S1: Scientific method is the way we will follow while conducting a research. (Preliminary interview)"
"S1: Scientific method is the way followed to gather data. These ways may change; some may be experiments, some people make an observation. These observations should be qualified observations…there is a problem, a situation, a question. There are progress stages according to these scientific methods. I think it's the existence of the problem that distinguishes it from other methods. (Final interview) "
"S8:..scientific method is a path followed for obtaining scientific knowledge .. A certain way is followed, and it is systematic. The data are collected, and a problem statement can be made. With steps like these .. (Preliminary interview) "
"S8: The scientific method identifies what the problem is, builds the hypothesis, collects the data, and tests the assumptions following a specific order. I think it is a scientific method to proceed in this direction… these are absolutely vital. For me, *if everyone else acts as they wish, it is not reliable and valid. There must be a specific method. (Final interview)"*
"S4: …many things we do in our lives, especially during our education period, we take many things as a precondition, so we accept them as a boundary and try to act upon them. It would be harder to make progress if they did not exist. So, I think the scientific method is important, to be able to move forward. (Preliminary interview)"
"S4: They are the means which enable scientific information to be obtained. Some things need to be repeatable and in a more provable way for scientific knowledge… If we want to obtain scientific information, of course scientific method is also important. The method is an observation that we know, it is an experiment, it is useful in the emergence of scientific knowledge. Ultimately, it prevents random knowledge. (Final interview) "

When the above quotations are examined, it is seen that the S1 defined the scientific method as a way which is simply followed at the preliminary view, but at the final interview, s/he went up to the level of technical understanding by giving examples about these methods and some of their phases. It is seen that in the preliminary negotiation, S8, who defined and divided scientific method into stages at the level of technical understanding, additionally mentioned the importance of scientific method in the final interview. S4, who was seen to have misunderstandings about the scientific method in the preliminary view, made paraphrasing and interpretation

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because s/he tried to make explanations with his/her own terms and words by touching upon both the features and importance of scientific methods in the final interview.

The answers given by pre-service science teachers in the preliminary interviews and in the final interviews to the question "What are the characteristics of a scientist?" are given in Table 4 below:

Table 4. Pre-service science teachers' perspectives on characteristics of a scientist.

4. The characteristics of a scientist		Preliminary Interview		Final Interview	
		Participant	f	Participant	f
Elementary Comprehension	Simple Conceptual Understanding	S1, S5, S6, S7, S8, S9	6	S6, S7	2
	Technical Understanding	S2, S3, S4	3	S1, S2, S4, S5, S8, S9	6
	Understanding through experience and Expression	-	-	S3	1
	Total		9		9
Higher Level Comprehension	Paraphrasing and Interpretation	-	-	-	-
	Re-establishment	-	-	-	-
	Cognitive Higher Comprehension	-	-	-	-
	Total	-	-	-	-
Misunderstanding		-	2	-	-
TOTAL			9		9

According to Table 4, six pre-service teachers (S1, S5, S6, S7, S8 and S9) gave answers at the simple conceptual level in the preliminary interviews and three (S2, S3 and S4) gave answers at the level of technical comprehension. In the final interviews, the pre-service teachers coded S1, S5, S8 and S9 went from the simple conceptual level up to the level of technical understanding while the pre-service teacher coded as S3 went from the level of technical understanding up to the level of understanding through experience and expression. Quotations retrieved from the interview data are exemplified below:

> "S1: A scientist is objective, open to criticism, ethical, mustn't have prejudices, and must obey ethical rules. I think s/he must be open to every kind of opinion. (Preliminary interview)"
>
> "S1: The scientist, first of all, should not have prejudices. I mean, I think s/he should be able to look at events objectively, be honest, open and sceptical. Because s/he mustn't always accept the fact as it is. Because facts are changing. Even the laws are changing. (Final interview)"
>
> *"S3: …I think the scientist, first of all and definitely must be objective, but it is not the case. So, in no way s/he should add his/her own thoughts and feelings into the project or whatever s/he is involved in. Other than that, I think the level of morality must be very high. Additionally, I think his/her level of morality must be very high. S/he should be efficient in terms of ethics. Apart from that, scientists are usually already researchers, intelligent, etc. (Preliminary interview)"*
>
> *"S3: The characteristics of a scientist must be in a certain academic level in the present age, but at the very beginning of the old history there was no such thing, but now it is expected that current scholars should have certain academic levels… I mean, for example, you say something that is worth something, because you are a scholar at university. But if a casual citizen from the society says something, it may not be worth much. (Final interview)"*

When the above quotations are examined, it is seen that the S1-coded pre-service teacher listed the features that only the scientist should bear in the preliminary interview but explained the reason for the necessity of carrying these features in the final interview. It is seen that S3-coded pre-service teacher talked about the possible features of a scientist in the preliminary interview, but in the final interview, s/he gave an example from real life and concretized it by referring to a particular feature. What is important here is that how the pre-service teacher's learning life and his/her ability to understand the diversity of that life are affected is revealed rather than the correctness or inaccuracy of the thinking of the pre-service teacher.

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The answers given by pre-service science teachers in the preliminary interviews and in the final interviews to the questionnaire shown in Table 5: "A person who is curious about birds is examining hundreds kinds of birds fed with different kinds of food. S/he notices that the birds fed with similar foods have similar beaks. For example, the beaks of birds eating hard-shelled food are short and durable while the beaks of birds eating insects in shallow water are long and thin. The individual concludes that there is a link between the beaks of the birds and the varieties of food they eat. Can you scientifically accept this person's examination?"

Table 5. Perspectives of pre-service science teachers on observation-based examination.

5. Whether observation-based examination can be accepted as **scientific or not**		Preliminary Interview		Final Interview	
		Participant	f	Participant	f
Elementary Comprehension	Simple Conceptual Understanding	-	-	-	-
	Technical Understanding	S3, S4, S6, S7	4	S2, S3, S5	3
	Understanding through experience and Expression	-	-	-	-
	Total		4		3
Higher Level Comprehension	Paraphrasing and Interpretation	Ö8	1	S1, S4, S6, S7	4
	Re-establishment	-	-	Ö8	1
	Cognitive Higher Comprehension	-	-	-	-
	Total	-	1	-	5
Misunderstanding		S1, S2, S5, S9	4	S9	1
TOTAL			9		9

When Table 5 is examined, it is seen that in the preliminary interviews, four of the pre-service teachers (S3, S4, S6 and S7) gave the answers at the level of technical understanding and one of them (S8) gave the answer at the level of paraphrasing and interpretation while the remaining four (S1, S2, S5 and S9) had misunderstandings about the question. In the final interviews; the pre-service teachers coded as S4, S6 and S7 went up to the level of paraphrasing and interpretation, S8-coded pre-service teacher went up to the level of re-establishment, S1, who was one of the pre-service teachers at the level of misunderstanding, gave answers at the level of paraphrasing and interpretation, while S2 and S5 gave answers at the level of technical understanding. Quotations retrieved from the interview data are presented below:

"S8: I accept it scientifically. And s/he has already examined a lot of birds and seen the difference in all of them, and how it happens. Because s/he has tried it on a lot of birds but haven't done so only on a few kind of birds, S/he has noticed that they are all the same. I mean, s/he has done a lot of experiments, let's not call them experiments, s/he has made observations. S/he has observed them, and as a result of these observations, s/he has reached this conclusion. Can I say s/he is doing an experiment, probably I cannot, because doesn't it mean that s/he has reached a conclusion at the end of his/her observations? In fact, s/he is observing a lot of birds; I mean s/he is doing a direct measurement. (Preliminary interview)."

"S8: I accept it scientifically. Why, because s/he is investigating a lot of things. S/he *has identified a problem for himself and investigated such things. And s/he is observing a lot of birds in this direction. And I think that all of them cannot be a coincidence. So, it is an adaptation, that is, animals' adaptation of life for them to survive. There must be a harmony. I accept it because it is conducted in line with these principles. But I do not accept it as an experiment because, for example, usually in the experiments we do, we set up a control group and progress going through certain steps. But here s/he has explored a lot of things against any problem. (Final interview)"*

"S2: I accept it. Because the organs that living things use more are identified and those organs develop more. For example, the body muscles of a sports person develop more. This means, for example, that the structures they use must be sturdy to break or eat hard-shelled food faster. This is completely scientific. But can I accept it as an experiment? There must be a certain observer to do the experiment… S/he *does not observe by herself/himself, but s/he must have a guide. S/he must be controlled. S/he can make observations on his/her own, but I do not know whether it is an experiment or not. (Preliminary interview)."*

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"S2: Do I accept it scientifically, of course I do. However, I cannot state that it falls into scientific knowledge. Because these are the person's own observations…S/he makes observations, conducts research on it and reaches a conclusion… (Final interview)"

When the above quotations are examined, it is seen that in the preliminary interview, the pre-service teacher coded S8 made paraphrasing and interpretation by explaining why s/he accepted the given example as scientific while in the final interview, s/he added a new dimension to the interpretation by referring to the issue of adaptation related to the given example and went up to the level of re-establishment. It is revealed that in the preliminary interview the pre-service teacher coded S2 had misunderstanding about the scientific side of the result of the given example because of his/her statements but in the final interview s/he made an explanation at the level of technical understanding about the scientific side of the observation process.

The answers given by pre-service science teachers in the preliminary interviews and in the final interviews to the question "What do you think about the formation of the universe?" are given in Table 6 below:

Table 6. Pre-service science teachers' perspectives on the formation of the universe.

6. The perspectives on the formation of the universe		Preliminary Interview		Final Interview	
		Participant	f	Participant	f
Elementary Comprehension	Simple Conceptual Understanding	S2, S9	2	-	-
	Technical Understanding	-	-	-	-
	Understanding through experience and Expression	S3, S5, S6, S7	4	S2, S3, S7	3
	Total		6		3
Higher Level Comprehension	Paraphrasing and Interpretation	S1, S4, S8	3	S1, S5, S6, S8, S9	5
	Re-establishment	-	-	S4	1
	Cognitive Higher Comprehension	-	-	-	-
	Total	-	3	-	6
Misunderstanding		-	-	-	-
TOTAL			9		9

According to Table 6, in the preliminary interviews, two pre-service teachers (S2 and S9) gave answers at the level of simple conceptual understanding while four (S3, S5, S6 and S7) gave answers at the level of understanding through experience and expression, and finally three (S1, S4 and S8) answered at the level of paraphrasing and interpretation to the question "What do you think about the formation of the universe?" When the data obtained from the final interviews are examined, it is seen that S2-coded pre-service teacher went up to the level of understanding through experience and expression, S5, S6 and S9-coded pre-service teachers went up to the level of paraphrasing and interpreting and S4-coded pre-service teacher went up to the level of re-establishment. Quotations retrieved from the interview data are given below:

"S2: …about the formation of the universe, it was previously a cloud of dust. After that, I think that it happened with a big explosion. I know there was just a cloud of dust before it. (Preliminary interview)"

"S2: …about the formation of the universe, dear lecturer, I think the universe was formed with a big explosion in ancient times. With BigBang. Whether it is about this World or the universe, I think that all of them take place in line with a gravitational field. It is already impossible to imagine that the universe was formed without an order or a cycle. If we were to think about it like this, our teacher has already told us that; s/he compared it to a wool pillow and stated that when it is left, whether on any World or the Moon, it creates a loop by forming a hole in the middle of it and pulling smaller objects around it. I think it was formed with such an order. There was something before it in any case. Nothing happens by itself… If we put it in that way, since every painting has a master, the universe has already an owner or a creator (God). Because nothing happens by itself. So is that existence, I think so. (Final interview)"

"S6: I do not have much in-depth knowledge about BigBang. But I believe in BigBang. After all, yes, we have a religious faith, and it may have happened due to it, yes. But it has to be projected into something and formed in some way. There is a saying as to be reflected and to descend from the sky, I do not believe that it descended in that way. BigBang was formed, BigBang happened, and I think that the universe was formed in that way, I think the world was formed. (Preliminary interview)"

"S6: … I think the formation of the universe is a very long process, a time. BigBang is actually a very large and comprehensive issue. Honestly, I do not actually have too much information. But we had some research studies in the courses and there are reasonable thoughts. There are logical theories. I mean I am in between believing and not believing… I do not believe that, I think there is no such thing as absence. There must have been something before it. Nothing can be formed with the help of absence. Instead, everything has a creator. This is a matter of faith, a matter of values, may vary from person to person. I believe that it has a creator. For example, in the Qur'an, we are told that we are created from clay, and to exemplify it, by the way the Qur'an is a book written years ago, they conducted a search on human DNA and it was found out that amino acids are produced from clay in a certain place, DNA of a human. I think this is a proof of the precision of the Qur'an, I think so. With regard to the formation of the universe, yes, I believe that yes previously there is a process absolutely, too and it has got a creator. Nothing can happen by itself. For example, certain materials exist, they are concentrated by constantly coming together, and various things have happened. That's how the explosion happened. But there was absolutely something before BigBang in that way, there were certain materials, maybe there was no certain formation, but it is thanks to those things that BigBang happened. In any case, BigBang also has a cause, that is, it has got a process of formation. (Final interview)"

"S4: What I think about the formation of the universe. Frankly, I neither support nor believe in BigBang, that is I am undecided about this issue. Because I think that the World did not occur randomly. In other words, the World did not occur abruptly. There must have been certain events to cause it to happen. It came along through formation. The World did not occur abruptly, but it did so at the end of certain things. How should I know, even the water needs heat to evaporate? There was also a need for certain bases for the formation of the World, like gravity, soil, etc. I cannot say that it has got no foundation, but yes, there is soil. However, there may be certain molecules and atoms so that the World occurred in this way. (Preliminary interview)"

"S4: About the formation of the universe? I think very deep things. Geographically it has a lot of influences. And it does so scientifically. But, of course we have learned so much about it, we touch on it maybe because it is taught us in this way, but after a certain geological event, the universe was formed as a result of an explosion. But, in fact I do not believe in that BigBang much. It may be scientific, but it doesn't make sense to me. Before that, it started to be formed slowly. Suddenly all of them, like milk does not boil or spill over without being heated, there was absolutely this phenomenon before the formation of this universe so that it occurred in this way later. My thought, in fact, I can actually arrive at such a perception or conclusion by comparing it to each other. As I said previously, it may just be related to heating or overflowing of water. It means a specified boiling or formation of soil for the universe to come up. Even the formation of soils is not less than 200 years. However, I think that there are no living things before. That is to say, according to the data we have gathered at the end of our experiments, there must be soil, water, etc. for living things to occur. Thus, they are said to be a condition or a precondition. I do not think that there were living things at the time when these were happening. (Final interview)"

When the above quotations are examined, it is seen that in the preliminary interview S2-coded pre-service teacher only explained his/her thoughts about the formation of the universe without mentioning the causes, whereas in the final interview s/he made an explanation by giving the knowledge s/he had learnt from a course an example. S6-coded pre-service teacher responded at the level of understanding through experience and expression by mentioning his/her religious beliefs included in the statements in the preliminary interview while s/he made comparisons and added interpretations into his/her thoughts by giving examples about his/her religious beliefs. In the preliminary interview, it is seen that S4-coded pre-service teacher defended his/her thoughts with reasons, whereas in the final interview s/he did so by showing scientific bases, explaining his/her thoughts by linking the parts with the whole, making connections and putting forward his/her unique interpretations.

The answers given by pre-service science teachers in the preliminary interviews and in the final interviews to the question "How do scientists form models of atoms even if they do not see them?" are given in Table 7 below:

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Table 7. Pre-service science teachers' perspectives on the mechanism under the fact that scientists form models of atoms even if they do not see them.

7. The mechanism under the fact that scientists form models of atoms even if they do not see them		Preliminary Interview		Final Interview	
		Participant	f	Participant	f
Elementary Comprehension	Simple Conceptual Understanding	S6, S8	2	S7	1
	Technical Understanding	S3, S9	2	S3, S8, S9	3
	Understanding through experience and Expression	-	-	-	-
	Total		4		4
Higher Level Comprehension	Paraphrasing and Interpretation	S1, S4, S5	3	S4, S5, S6	3
	Re-establishment	-	-	S1	1
	Cognitive Higher Comprehension	-	-	-	-
	Total	-	3	-	4
Misunderstanding		S2, S7	2	-	-
TOTAL			9		9

According to Table 7, in the preliminary interviews, it is seen that two pre-service teachers (S6 and S8) gave answers at the level of simple conceptual understanding while two (S3 and S9) gave answers at the level of technical understanding, three (S1, S4 and S8) answered at the level of paraphrasing and interpretation and finally two (S2 and S7) gave answers at the level of misunderstanding. As for final interviews, it was found out that S6-coded pre-service teacher went up to the level of paraphrasing and interpretation, S8-coded pre-service teacher went up to the level of technical understanding, S1 went up to the level of reestablishment, and S7 went up to the level of simple conceptual understanding. Quotations obtained from the interview data are presented below:

"S6: I think their creativity and imagination are very effective in this regard. (Preliminary interview)"

"S6 :…imagination…Let me put it in this way, as I said before, they compile previously formed knowledge, building on previous knowledge, drawing conclusions, making certain predictions, but I absolutely have no idea on what they grounded these predictions, it seems surprising. Despite the fact that they were far away from technology, had no specific resources, and no specific tools at the time, the deductions they made are great I think. So, I don't have much idea from this point of view. But I think their imagination is effective (Final interview)"

"S1: Now it has a granular structure, wood, say, s/he knows that the structure wood has a structure. S/he knows that s/he will reach a small structure when s/he divides it. So, it means human being can reach the smallest unit s/he can see. But s/he doubts that s/he can reach smaller units. I think he can progress in that route. There could be smaller units. (Preliminary interview)"

"S1: Probably people's sense of curiosity affects this. Even if we do not see it s/he thinks that something exists, granular structures move, questions what causes it and force their imagination with this thought to see what can happen. They are doing experiments. For instance, we do not fully see the universe, but we observe it. We find out that it expands. Even if we cannot see our galaxy fully, we make models. That's why I think it is a result of the curiosity of scientists. (Final interview)"

When the above quotations are examined, it is seen that in the preliminary interview S6-coded pre-service teacher gave answers at the level of simple conceptual understanding without making any explanations, but s/he made an interpretation about the question by putting forward his/her ideas in the final interview. As to S1-coded pre-service teacher, in the final interview s/he is seen to have added a new dimension to his/her thoughts by giving a different example on his/her interpretation in the preliminary interview.

The answers given by pre-service science teachers in the preliminary interviews and in the final interviews to the question "Do you have any habits that affect your scientific thinking process? If so, what are they?" are given in Table 8 below:

Table 8. Habits that affect pre-service science teachers' scientific thinking processes.

8. Habits that affect pre-service science teachers' scientific thinking processes		Preliminary Interview		Final Interview	
		Participant	f	Participant	f
Elementary Comprehension	Simple Conceptual Understanding	-	-	-	-
	Technical Understanding	-	-	S8	-
	Understanding through experience and Expression	S5, S6, S7	3	S1, S3, S6, S7	4
	Total		3		4
Higher Level Comprehension	Paraphrasing and Interpretation	S4	1	S4	1
	Re-establishment	-	-	S5	1
	Cognitive Higher Comprehension	-	-	-	-
	Total	-	1	-	2
Misunderstanding		S1, S2, S3, S8, S9	5	S2, S9	2
TOTAL			9		9

According to Table 8, in the preliminary interviews, it is seen that three pre-service teachers (S5, S6 and S7) gave answers at the level of understanding through experience and expression while one (S4) gave answers at the level of paraphrasing and interpretation, and five (S1, S2, S3, S8 and S9) answered at the level of misunderstanding. As to the final interviews, it is seen that S8-coded pre-service teacher went up to the level of technical understanding; S1 and S3 went up to the level of understanding through experience and expression, and S5 went up to the level of reestablishment. Quotations obtained from the interview data are presented below:

> *"S3: My habits that affect my scientific thinking process…Actually I do not think scientifically much. Actually, if I talk about myself, I like to understand something with its logic. But of course, the things I'm doing now, my life, it certainly does not permit it. Whether it's my school life, my private life, etc. But I normally like to think reasonably more, I say. (Preliminary interview)"*
>
> *"S3: … that affect my scientific thinking process…For example, the theory of evolution, I cannot say it sounds absolutely ridiculous, but there are many ways rejecting its probability according to my belief. So, it influences some of my scientific thoughts. (Final interview)"*
>
> *"S8: My habits that affect my scientific thinking process… I think there is none, probably. (Preliminary interview)"*
>
> *"S8: Exactly scientific thinking… I think it influences people's thoughts, beliefs, attitudes and behaviours. It depends on the person, I think. Because everybody has different beliefs, in some people this can get ahead of science while in some other people they pave the way for science and help it flourish. (Final interview)"*
>
> *"S5: namely there were a lot in the past. It was so till I attended the courses here, but of course there are things that these courses contributed. Previously I was an impulsive person, but it has started to change. Here I go into science and approach it as a student of science and now I evaluate events a little differently because I am thinking about my academic career. I don't go off half-cocked about events immediately. First of all, I must think about it...but if we consider scientific thinking from a religious perspective only, of course, religion does not question much, and it is not in favour of questioning. Obviously, I don't question some religious dimensions too much. But I absolutely question other worldly things. (Preliminary interview)"*
>
> *"S5: My beliefs. For example, nobody can convince me about the theory of evolution. Because, according to my belief, I did not descend from a monkey. I think this is the biggest example… according to my belief, this is just one example. For example, of course there is a scientific explanation of what we call Sunnah in Islam. When we look at it from two different perspectives. But the issue of evolution, for example, only affects me about that issue. Apart from my belief, of course, the environment I live in and my family can also affect me. After all, the way people grow up is not the same. That's why everyone's point of view about science is different. (Final interview)"*

When the above quotations are analysed, in the preliminary interview S3-coded pre-service teacher talked about his/her normal thinking style rather than his/her scientific thinking process, whereas in the final interview

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s/he explained how his/her beliefs affected his/her scientific thinking process by giving an example. In the preliminary interview, S8-coded pre-service teacher did not have any idea about his/her habits that affected his/her scientific thinking process, while in the final interview s/he put forward his/her interpretation that individuals' beliefs and attitudes could affect their perspectives on science. In the preliminary interview S5-coded pre-service teacher explained his/her opinions about scientific thinking based on both school experiences and beliefs, whereas in the final interview s/he gave examples of himself by taking the issue more comprehensively, and clearly indicated what an individual perspective is and what is unique to him/her by making interpretation about the fact that individual differences can create differences in terms of perspectives about science.

The answers given by pre-service science teachers in the preliminary interviews and in the final interviews to the question "Suppose that someone you love is a kidney patient. Also, suppose that a kidney is produced with a cell taken from you and transplanted into him/her via the stem cell method. What do you think of this kind of kidney production?" are given in Table 9 below:

Table 9. Pre-service science teachers' perspectives on kidney production via the stem cell method.

9. Perspectives on kidney production via the stem cell method		Preliminary Interview		Final Interview	
		Participant	f	Participant	f
Elementary Comprehension	Simple Conceptual Understanding	-	-	-	-
	Technical Understanding	-	-	-	-
	Understanding through experience and Expression	S1, S2, S5, S6, S8, S9	6	S1, S5, S7, S8, S9	5
	Total		6		5
Higher Level Comprehension	Paraphrasing and Interpretation	S3, S4, S6	3	S3, S6	2
	Re-establishment	-	-	S2, S4	2
	Cognitive Higher Comprehension	-	-	-	-
	Total	-	3	-	4
Misunderstanding		-	-	-	-
TOTAL			9		9

According to Table 9, in the preliminary interviews, it is seen that six pre-service teachers (S1, S2, S5, S7, S8 and S9) gave answers at the level of understanding through experience and expression while three (S3, S4 and S6) gave answers at the level of paraphrasing and interpretation. As to the final interviews, it is seen that S8-coded pre-service teacher went up to the level of technical understanding; S2 and S4 went up to the level of reestablishment. Quotations obtained from the interview data are offered below:

> *"S2: I'm actually against kidney transplantation… Religious beliefs… for example when we look from a religious perspective, things like organ transplantation are not very nice and pleasant. Because it is something that is given to a person, when we take it and give it to someone else… and it is an obstacle in its life and it is a problem. For example, if its absorption does not take place later?... But if there is 100% fit when the kidney is taken from the root cell and transferred to someone else, then I think it's not a problem. (Preliminary interview)"*
>
> *"S2: It will be very good. Because in the future organ donation or such things will disappear. Actually, the construction of stem cells is biologically very nice. Like the matching of DNA structures or dissolving their similarity with each other. It will be very good. For that reason, such scientific developments do not bother me. More precisely, that does not bother. For example, donating an organ does not make sense to me, you should get people's organs before they die so that they can be given to other livings. This does not sound good, either. Maybe his/her family does not want it. When we think of it in terms of religious terms, in that sense, it is actually like saving a life, saving all living things. But I do not handle it in terms of faith. When I look at it scientifically, it would be very good to produce it out of its stem cells or the disappearance of its organ donation (Final Interview)*
>
> *"S4: Of course, it is something positive. It makes people happy. To be able to be useful rather than being useless. Especially if there is such an opportunity without subtracting from me, this is a very good thing. If that person has a problem, and*

it is not arbitrary anyway… To be able to find something that can be a remedy for people's troubles allows them to live more comfortably and peacefully, which can happen to everyone. If we think generally. Organ donation is the same way. Frankly, I think positively. After all, no matter how many beliefs I have investigated, there is no clear rule, there are some negative rumours, but when we do some general research, it says that there should not be a donation of a living organ. I do not think I can consider it much when I'm alive, either. But if I can be useful to somebody, after I die it won't work for me. Once I have turned into clay, it won't mean much. Thus, I think it is useful. I am not clearly against it. (Preliminary interview).

"S4: I have a positive judgment… The result of this already results in organ donation, as far as I remember. I already support organ donation. If we turn a blind eye to the suffering of a living human, and do not evaluate the opportunity even if we have it, then it is a crime against humanity I think. Therefore, such scientific developments do not bother me, rather they satisfy me more. Recently there has been even a face transplant via stem cells and it obviously also attracted my attention. Of course, the transfer of another person's face is also a separate situation, but the creation of a face from its own root cell sounds more original and beautiful, frankly speaking. It is more feasible. (Final Interview)"

When the above quotation is examined, it is seen that in the preliminary interview S2-coded pre-service teacher was against organ donation as a result of his/her religious beliefs but as a solution, in the final interview s/he was seen to support the stem cell method and approaches the subject more scientifically. The S4-coded pre-service teacher appeared to develop detailed ideas about the topic specific to his/her life diversity and understanding ability by giving an example of the application of the stem cell method in the final interview while explaining the reasons for his/her positive approach to scientific developments in the preliminary interview.

Discussion

It is very important for pre-service science teachers to understand and analyze that problem-solving and awareness of the problems related to science through hermeneutic thinking is very crucial for the development of science education (Eger, 1992). In general, studies in the field of hermeneutics have shown that even in problem-based learning environments, pre-service teachers' views on science and scientific knowledge do not always tend to develop (Yılmaz, 2007, p. 167). However, as a result of this research, it has been revealed that hermeneutical perspectives of pre-service science teachers showed changes in a positive direction and development after problem-based scenarios applied in Science Teaching Laboratory Applications-I course. The results of the research are discussed in terms of pre-service science teachers' hermeneutical perspectives about science, their comprehension levels with regard to hermeneutical thinking and the research of Irzik and Nola (2011) where they systematically classified the categories that give the structural definition of the nature of science.

When the literature is examined, the emphasis on the understanding of the nature of science in the 1960s is also known as an important component of scientific process skills and science literacy (Lederman, 1992). When the findings are examined from the point of hermeneutical perspectives about science that emerged in interviews with pre-service science teachers, it has been found out that their answers to the questions at the level of elementary understanding such as "What is scientific knowledge? What is scientific method? What are the characteristics of a scientist?" were at the level of simple conceptual understanding in the preliminary interviews while they showed progress positively in the final interviews and went up to the levels of technical understanding or understanding through experience and expression. However, their answers to the questions which require individual interpretation and higher levels of comprehension such as "What do you think about the formation of the universe?", "How do scientists form models of atoms even if they do not see them?", "Do you have habits that affect your scientific thinking process? If so what are they?" were at the level of paraphrasing and interpretation in the preliminary interviews, whereas some pre-service science teachers were observed to go up to the level of reestablishment. Some pre-service science teachers who gave answers at misunderstanding theme in the preliminary interviews were seen to correct their misunderstanding in the final interviews. Therefore, according to the results of the research in general, it can be said that scenario-based education develops hermeneutical thinking of pre-service science teachers and contributes to their understanding levels positively.

The formation of scientific knowledge, that is the high level of understanding in the classification of hermeneutic thinking, take places at the third level according to the epistemological understanding of Carey and Smith (1993). The focus here is to help students be away from the understanding that science is true and produces accurate scientific knowledge, and to point out that research and scientific knowledge are changeable. It is seen

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that at every hermeneutical level, hermeneutical perspectives of pre-service teachers show changes with regard to science, scientific knowledge, studies of scientists and the results they gather, and follow a hierarchical path. When the developments of pre-service science teachers were examined in terms of the themes determined according to the comprehension levels of Hermeneutical perspectives, the following results were obtained:

1) *Elementary understanding:* Simple conceptual understanding: it is seen that the students remained only at the definition level in the preliminary interviews. As for final interviews, the learner was able to better his/her interpretation skills and go up to the level of technical understanding and understanding through experience and expression. Technical understanding: in the preliminary interviews, the students who remained at the level of simple definition and had no viewpoints about details, were seen to make comparisons in their interpretations in the final interviews. Understanding through experience and expression: the learners were at the level of elementary understanding for the questions about the formation of the universe in the preliminary interviews, but they were seen to go up to the level of understanding through experience and expression with regard to understanding and interpretation in the final interviews.
2) *Higher Level Comprehension:* Paraphrasing and interpretation: while the students made only simple conceptual explanations in the preliminary interview, they made their individual and original sentences by mentioning about details in the final interviews. Reestablishment; while the expressions of the students concentrated on the level of technical understanding in the preliminary interviews, it appears that in the final interviews, the pre-service teachers responded to the questions with their own specific statements by bringing together the parts expressing the higher form of understanding (e.g., Question 5). Cognitive higher comprehension; when the research was examined in all dimensions, it was seen that the students were brought to the stage of reestablishment but could not be brought to the level of cognitive higher comprehension, which is the last level of comprehension.
3) *Misunderstanding:* As in the case of Table 5, it is also seen that some students could remain at the level of misunderstanding with regard to their answers to a question about what can be accepted scientifically.

The change in the coding of learners' hermeneutical thinking category at elementary level and their hermeneutical perspectives at cognitive high understanding (Bollnow, 1995: 95) can only be achieved with significant transformations in their scientific process skills and conceptual understanding. When the findings of the research were examined according to the study of Irzik and Nola (2011: 597-601), the following results were obtained:

a) *Methods:* The hermeneutical perspectives of the pre-service teachers who are careful and take the scientific methods or methodological rules into consideration are seen to be at a high level while the ones who do not ignore are seen to be at a lower level. This shows how important the scientific method is for the development of hermeneutical perspectives of pre-service teachers.
b) *Activities:* Observations and experiments carried out in the light of the scenarios given during the courses are very clearly scientific activities. While some scenarios required the observer to classify objects, some others enhanced handcraft skills, or required the observer to use scientific tools; plan, establish and carry out the experiments. These scenarios include formulating problems and finding solutions. Building a new hypothesis-model-theory is at the heart of these scenarios. Solution of some of these scenarios requires the use of mathematical, technological and engineering skills. In the scope of the research, through these scenarios, an environment was provided for pre-service science teachers to use all these skills and thus it was tried to make it possible for them to develop hermeneutical perspectives with the comments they made on scientific activities.
c) *Aims and Values:* The most well-known aims of science are to make assumptions and explanations. The hermeneutic understanding of the students harmoniously varies according to their own values when the aims of the problems given in the scenarios are determined (Yılmaz, 2007: 167). If their hermeneutical perspectives are at elementary level, and the aim of the scenario will be simple, common and broad in nature without any prior knowledge. Differences in their problem identification are due to hermeneutical perspectives of pre-service teachers.

d) Products: Pre-service teachers reach a conclusion and make an interpretation at the end of the scripts using scientific methods. These products are theories, models, observation notes, experimental data, and the like, which they prove or disprove. Pre-service teachers capture the dynamic and open-ended status of science and scientific knowledge and they provide a more comprehensive explanation by combining their observations with their data. By using scientific methods in this way, they systematically reveal the cognitive direction of science and develop their hermeneutical thinking.

Conclusions

In light of the gathered data the present research suggests that probing-based learning environments, which are carefully planned and clearly designed with reflection activities, can support the development of the desired high hermeneutical understanding ability among students. Hermeneutic, often used as a text analysis on written texts or as an interpretation of historically accepted disciplines, has reached the conclusion that science education can be used to develop skills such as understanding, explanation and interpretation. In this context, hermeneutics should be considered as an important method not only in written texts, but also in science that is not used in social sciences.

Therefore, hermeneutics should be seen and used to be important in order to reveal different perspectives within the sciences and to enable the individual to think with different methods. For this reason, all pre-service teachers who will shape the future should be provided with appropriate learning environments so that they can raise individuals with hermeneutical thinking and interpreting skills. In these learning environments, the use of various methods to gain different thinking skills for students is important for the diversity of scientific thinking. This research aims to be the first example of this.

Appendix 1. The interview form

1. What is Science?
2. What is scientific knowledge?
3. What is scientific method? What are the features that distinguish it from other methods?
4. What are the characteristics of a scientist?
5. A person who is curious about birds is examining hundreds of kinds of birds fed with different kinds of food. S/he notices that the birds fed with similar foods have similar beaks. For example, the beaks of birds eating hard-shelled food are short and durable, while the beaks of birds eating insects in shallow water are long and thin. The individual concludes that there is a link between the beaks of the birds and the varieties of food they eat. Can you scientifically accept this person's examination?
6. What do you think about the formation of the universe?
7. How do scientists form models of atoms even if they do not see them?
8. Do you have any habits that affect your scientific thinking process? If so what are they?
9. Suppose that someone you love is a kidney patient. Also, suppose that a kidney is produced with a cell taken from you and transplanted into him/her via the stem cell method. What do you think of this kind of kidney production?

Appendix 2. Sample Scenario

I CANNOT GET THE TASTE!

Müge catches a cold and has a stuffy nose since she leaves the window open at night. She cannot get the taste of the cheese and egg she eats or the milk she drinks at breakfast in the morning. Although her mother cooks her favourite meal for dinner, she does not want to eat it, either. Not understanding the situation, Müge becomes curious: "Why can't we get the taste of what we eat when we have a stuffy nose?" How do you think we can find an answer to the question in which Müge is interested? (Can, Savran Gencer, Yıldırım, & Bahtiyar, 2016).

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Bilge Can	PhD, Associate Professor, Education Faculty, Department of Mathematics and Science Education, Pamukkale University, Denizli, Turkey. E-mail: bilgecan@pau.edu.tr
Asiye Bahtiyar	PhD Student, Research Assistant, Education Faculty, Department of Mathematics and Science Education, Pamukkale University, Denizli, Turkey. E-mail: asiye.bahtiyar@gmail.com
Hasret Kökten	PhD Student, Instructor, Education Faculty, Department of Basic Education, Pamukkale University, Denizli, Turkey. E-mail: hince@pau.edu.com.tr