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A Case Study of Iranian Physics Education Students' Understanding of the Nature of Science

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Abstract

This paper studied Iranian Physics education students' understanding of the nature of science. The research is descriptive and was conducted through a survey study method. The sample of our study consisted of 94 students of Physics education in the second and third year of university. They were selected through random sampling from four classes at Isfahan University and Shahid Rajaee Teacher Training University in Iran. For this purpose, 24 statements of the SUSSI questionnaire (Student Understanding of Science and Scientific Inquiry) were translated into Farsi. The statements were randomly arranged to form a new questionnaire. The validity of the new questionnaire was examined and approved and the Cronbach's alpha of the questionnaire was calculated as 0.738. In the data analysis phase, the mean score of each statement was calculated using the frequency and the numerical value of each response. The score of each component of the nature of science was determined by averaging the scores of the statements related to that component. The average score of each component expresses the formal or naïve or transitional view regarding that component. According to the results, while our subjects' attitude to observation and deduction conformed to international standards of science education, they had some misunderstandings regarding the other components of scientific inquiry. As physics education students will become teachers and contribute to the future generation's view of science, it would be better to incorporate more educational activities into teacher education programs with the aim of improving the trainees' conception of science.

Keywords: Nature of science, physics education students, Science education, SUSSI questionnaire

Introduction

The scope of today's science is confined to the description and explanation of merely scientific phenomena. The phenomena are explained using scientific theories. A scientific theory is a set of related concepts, claims, and rules used to explain and predict as exactly as possible the natural phenomena. Scientific concepts are indeed the building blocks of theories. To understand these concepts, the students need to become familiar with issues such as what science is and how scientists work (Ben-Ari, 2005) In other words, they should have some knowledge about the nature of science (NOS).

In his publications and speeches, Albert Einstein has frequently emphasized the importance of our view of the NOS. In his 1918 speech on the occasion of the 60th anniversary of Max Planck's birthday, Einstein stated: "Man tries to make for himself in the fashion that suits him best a simplified and intelligible picture of the world; he then tries to some extent to substitute this cosmos of his for the world of experience, and thus to overcome it." According to Einstein, a theoretical physicist's picture of the world should be characterized by subtle accuracy and logical perfection. However, as the human mind cannot conceive of complicated events with such precision, "he must content himself with describing the simplest events which can be brought within the domain of our experience" in order to achieve "supreme purity, clarity, and certainty" at the cost of a

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complete picture of the physical world. General laws obtained in this way are a basis for theoretical physics and valid for all-natural phenomena. Therefore, the physicist is responsible for discovering the general laws which could be used to make a picture of the world through pure deduction, but there is no straightforward path towards these laws (Einstein, 1954). In another speech at Oxford in 1933, Einstein elaborated on the methodology of theoretical physics. He defines a complete system of physics as a set of assumptions, concepts, basic laws that regulate the assumptions, and logical deductions which act as the building blocks of any theory and which are freely invented by the human mind (Einstein, 1954).

In addition to regarding physics as man’s attempt to understand the nature, Einstein tries in these two lectures to clarify the position of theories and laws. He believes that scientific theories are human inventions and thus imaginary in nature. He conceives of laws as being made by the human mind and strongly emphasizes that they are not derived through a single universal method. The fact that he has frequently mentioned these issues confirms the importance of discussions on the NOS and scientific inquiry. Understanding the NOS has also been stated as an objective of science education in the early 20th century and introduced as a major component of the development of scientific literacy by the science education reform movement (NRC, 1996; AAAS, 1993). Thus, a thorough understanding of the essential components of science is essential for physics students who are supposed to pursue the way of great physicists in the future.

Much research has been conducted over recent decades into the NOS. After a review of this research, Lederman (1992, 2007) concludes that teachers and students often lack a sufficient understanding of science. Below is a brief review of some of the studies that have addressed this issue.

By studying a group of 43 Georgian students, Wilson (1954) arrived at the conclusion that these students believe that scientific knowledge is absolute and the main purpose of scientists is to reveal the natural laws and facts. Wilson's findings were also confirmed by a large-scale study by Mead and Metraux (1957) which studied 35000 students all over the United States. Similar findings have also been reported by Klopfer and Cooley (1961), Broadhurst (1970), MacKay (1971), and Aikenhead (1972, 1973). Bady (1979) differed from the previous studies in that he addressed one of the components of the NOS. According to his findings, students believe that hypotheses are completely confirmed after they undergo numerous experiments (Lederman, 1992).

Zeidler, Walker, Ackett, and Simmons (2002) studied a sample of 82 subjects. They show that the majority of students are not aware of the fact that scientific knowledge is transient and subjective and incorporates a component of creativity. The study of Kang, Scharmann, and Noh (2004) in South Korea confirms previous research and shows that South Korean students have an empiricist and absolutist attitude towards science (Lederman, 2007).

McComas (1998, pp. 53-70) discussed common myths about science. One such myth was that there is a hierarchical order consisting of observation, hypothesis, theory, and law and that theories turn into laws by means of evidence. Also, it is widely held that scientific laws are absolute and there is a single universal method comprised of problem definition, data collection, hypothesis formulation, observation, testing the hypothesis, conclusion, and producing a report.

In contrast to the international context, there are few studies that have addressed this topic in Iran. Only several local studies have investigated the attitude of university professors, school teachers, and students towards the NOS. As physics education students are likely to have strong effect on the future generation’s view of science, the present study seeks to investigate their opinions about science and scientific inquiry. The results of this study can be used for curriculum development in accordance with international standards of science education.

Nature of science (NOS)

Combination of scientific concepts with discussions on the NOS has been strongly emphasized in recent standards of science education. The newest international standard published in 2013 suggests to focus on the core concepts of science instead of superficial treatment of numerous concepts (NGSS, 2013). Focusing on the core concepts, on the one hand, allows students to allocate sufficient time to in-depth understanding of the concepts and, on the other hand, makes it possible to associate different schemata to learn meaningfully. According to Driver et al. (1996), if scientific concepts are treated without any emphasis on scientific methodology, students will be unable to have a thorough understanding of the notion of research. In addition, knowledge of the NOS will facilitate the learning of all scientific concepts.

As a pioneer of curriculum reform, Schwab (1965) holds that presentation of scientific concepts as decisive propositions will lead to the belief among students that these concepts are indisputable and must be accepted completely. This leaves no room for further investigation on the part of students. He emphasizes that the products of science should be conceived in the light of the processes of science; therefore, we should help students to know how scientists work, interpret data, and formulate theories.

Thus, knowledge of the fundamental concepts is a prerequisite of learning science. To this end, the basic components of the NOS are first introduced to students before they go on to learn more superficial elements.

NOS and Scientific Inquiry

The term 'science' has been variously defined in the literature. Ruubba and Anderson (1978) define scientific knowledge as a nexus of laws, theories, and concepts that is aimed at simplified explanations (Meichtry,1999). McComas et al. (1998. pp.511-532) define science as the attempt to explain natural phenomena. According to Bell (2009), science educators often view science as three interrelated areas. The first area, which is the most commonly discussed one in textbooks, is based on the assumption that science is a body of knowledge that contains facts, definitions, concepts, theories, and laws. The second area incorporates a wide variety of methods and processes which scientists use to produce content in the first area. Among these processes are simple and complex skills such as observation, inferencing, hypothesizing, etc. In the third area where science is regarded as a method for obtaining knowledge, the components of the NOS are addressed.

The NOS is a field that draws upon social sciences and epistemological research. In fact, this field is the intersection between history, sociology, philosophy, and psychology. It deals with questions such as what science is and how it works, how scientists work as a social group, and how society interacts with science (McComas et al., 1998, pp. 3-39). According to Lederman (2007), the NOS refers to the epistemology of science as well as essential values and beliefs that contribute to scientific progress.

Although there are still disagreements about the components of the NOS, there is general consensus concerning some of these components. McComas et al. (1998) present a list of the components of the NOS based on eight international documents of science education. The present study makes use of those components that have been mentioned by NSTA (2000), AAAS (1993), McComas et al. (1998), Liang (2008), and Bell (2009). They include observation and inference, tentativeness, creativity and imagination, society and culture, and the role of laws and theories in scientific methods. Following is a brief description of each component.

Observation and inference: Science is based on observation and inference. Observations are descriptive statements about natural phenomena that directly result from human senses (or any extension of the senses through instruments) and are subject to general agreement among observers. Inference refers to the interpretation of the observations and involves statements about the phenomena under study which are not directly available to the senses. Inference is directed by the scientist's perspectives and attitudes and, therefore, multiplicity of perspectives will lead to various interpretations of the observations (Liang et al., 2008).

Tentativeness: Scientific knowledge is sometimes durable and sometimes transient, but it is never absolute and decisive. As long as we are aware that scientific knowledge is likely to vary with re-interpretations of the existing evidence, it could be reasonable to trust this knowledge. The history of science shows that changes in science have been both evolutionary and revolutionary. In other words, the accepted knowledge can survive the challenges for hundreds of years but suddenly change with new pieces of evidence and methods of thinking (Lederman et al., 2002).

Scientific theories and laws: These theories and laws are subject to change. Scientific laws state general relationships among natural phenomena under specific conditions. Theories similarly explain aspects of the natural world but, even with more extensive evidence, they do not turn into laws. On the other hand, not all laws completely conform to their explaining theories (Liang et al., 2008).

Social and cultural embeddedness: Scientific knowledge is aimed at generality and inclusiveness. As an inherently human phenomenon, science is affected by culture and society. Cultural values and expectations determine the nature and quality of conducting experiments, interpretation of results, and reception of findings. Social context, power structure, political affairs, socioeconomic factors, philosophy, and religion are some of the major elements that lead to varied views of science (Lederman et al., 2002).

Creativity and imagination: Science is empirical and should progress based on observations. However, the role of creativity and imagination in its evolution is undeniable. In science, explanations are invented using creativity and imagination (Lederman et al., 2002). This resembles composing a poem or a melody or designing a great work of architecture. Scientists use imagination in all their investigations.

Multiplicity of methods: Scientists adopt various approaches to knowledge and there is not any single and universal, step-by-step method for them to follow (Bell, 2009).

Method

This research is descriptive and was conducted through a survey method.

Participants

The sample of our study consisted of 94 students of physics education in their 2nd and 3rd years of university. They were selected through random sampling from four classes at Isfahan University and Shahid Rajaee Teacher Training University.The mean age of students participating in the study was 20.32 year with a standard deviation of 1.29.

Instruments

The Science Attitudes Questionnaire is the first well-known instrument for measuring schoolchildren's understanding of science that was developed more than 60 years ago by Wilson (1954). Since then, many other instruments have been designed for investigation of the components of the NOS. To overcome the issue that the majority of students and schoolchildren provide only brief answers to essay-type questions and may even leave some questions unanswered, Liang et al. (2008) developed another questionnaire called SUSSI (Student Understanding of Science and Scientific Inquiry).

The present authors examined a number of officially published questionnaires including VOSTS (Aikenhead& Ryan, 1992), VNOS (Lederman et al. 1992, 2002, 2007), VOSE (Chen, 2006). Finally, we decided to use SUSSI as the instrument of our study. With its 24 Likert-type statements and six open-ended questions, this questionnaire is intended to assess students' understanding of the six NOS components. The items fall into six groups corresponding to the six components, each with four statements and one open-ended question. In this questionnaire, in addition to simply stating one's degree of agreement or disagreement, the subjects also describe their reason for making a certain choice. SUSSI was developed between 2004 and 2006 by Liang et al. and, after initial piloting, it was revised and became ready for use. The formal and content validity of this questionnaire has been confirmed by nine internationally recognized experts of science education. Their agreement with each statement was between 78 and 100 percent. In 2006, this questionnaire was administered to 209 American teachers at the beginning of their career and its Cronbach's alpha coefficient was calculated as 0.69.

The advantages of this questionnaire are that it covers those NOS components that are agreed upon by the majority of science educators and also contains 24 likert statements.

The Likert scale is one of the most popular and reliable ways of measuring perceptions, attitudes, and opinions. It enables questionnaire takers to express their attitude by choosing one of the given answer options. The term Likert comes from the creator of the Likert Scale, Rensis Likert, a social psychologist who invented the scale in the 1930s.

When responding to an item on the Likert Scale, the user responds based explicitly on their agreement or disagreement level. These scales allow determining the level of agreement or disagreement of the respondents. Likert scale assumes that the strength and intensity of the experience are linear. Therefore, it goes from a complete agreement to a complete disagreement, assuming that attitudes can be measured. Finely, A scale can be created as the simple sum or average of questionnaire responses over the set of individual items

In this questionnaire, the statements relating to each component are placed next to each other. Given that our subjects in this study were physics education students and we assumed that their background knowledge might affect their responses, the open-ended questions were eliminated and the order of 24 statements of SUSSI questionnaire in the new questionnaire was randomly arranged.

One of the most important steps in preparing this questionnaire to be administered in the Iranian context was its translation into Farsi. First, it was separately translated by three professional translators. Next, the authors compared the translations with the original and rewrote the questionnaire in Farsi. In the final stage, two other professional translators were asked to compare the produced version with the original questionnaire and validate the translation. The questionnaire appears in Appendix A.

The validity of the Persian questionnaire was examined and approved by three experts of science education and the Cronbach's alpha of this questionnaire was calculated as 0.738.

For data analysis, first the statements were divided into positive and negative. The positive statements were those which conformed to the view held by international documents of science education, or the so-called "formal view". This view was reviewed in this paper through the six components of the NOS. The negative statements are opposed to the positive ones and called "the naïve view". The choice of "I totally agree" and "I agree" in the positive statements and the choice of "I totally disagree" and "I disagree" in the negative statements have been considered as the formal view whereas converse choices have been taken as referring to the naïve view. Determining the numerical value of the formal and naïve views was based on the following table.

Table 1.

Categorization of the Statements into Formal and Naïve Views

View points	statement	TA	A	U	D	TD
Formal (+)	1,5,6,7،9،10,14,15,17,18,19,20	5	4	3	2	1
Naïve (-)	2,3,4،8،11,12,13,16,21,22,23,24	1	2	3	4	5

Note: TA = Totally Agree; A = Agree; U = Uncertain or Not Sure; D = Disagree; SD= Totally Disagree.

Next, the mean score of each statement was calculated using the frequency and the numerical value of each response (Tables 2 to 7). As mentioned earlier, each component of science corresponds to four statements. Therefore, the sum of the scores of each subject on the four statements of a component was used to calculate the mean score of that component. A mean score greater than 4 and towards 5 would indicate a better understanding of the formal view while a mean score less than 3 and towards 1 would indicate a more naïve view of that component. A value between 3 and 4 was taken as a transitional view.

Findings

In tables 2 to 7, the formal view column contains the sum of the percentages of columns 4 and 5 and the naïve view column contains the sum of the percentages of columns 1 and 2. The transitional view column contains the percentage of the responses with a score of 3. In most cases, the precision of the numbers in these tables is only one decimal place. As the complete table of the statements is presented in the appendix, only the statement numbers are mentioned in tables 2 to 7.

Observation and inference (OI): Table 2 shows that 85.2 percent of the subjects hold a formal view of this component. 93.7 percent of them believe that scientists may have different interpretations of a single observation and 87.3 percent explain it as the effect of background knowledge.

Table 2.

The Students' Opinions on the Component of Observation and Inference (OI)

	Item	**Item Kind**	**Numerical Value**					**viewpoints**			**Average**
			1	**2**	**3**	**4**	**5**	**Naïve**	**transitional**	**Formal**	
OI	6	**+**	1.1	2.1	9.6	56.4	30.9	3.2	9.6	87.3	4.14
	13	**-**	2.1	5.3	12.8	62.8	17	7.4	12.8	79.8	3.87
	22	**-**	1.1	6.4	12.8	64.9	14.9	7.5	12.8	79.8	3.86
	1	**+**	0	4.3	2.1	42.6	51.1	4.3	2.1	93.7	4.40
	Total Average		1.1	4.5	9.3	56.7	28.5	5.6	9.3	85.2	4.07

Tentativeness(T): As shown in table 3, most subjects believe that scientific theories are subject to change with newly discovered evidence or re-interpretation of existing observations. However, 35.1 percent of them (i.e. the sum of columns 1, 2, and 3 in statement 7) entertain doubts as to whether theories are constantly tested and revised. 76.9 percent of the subjects hold a formal view concerning the tentativeness of science.

Table 3.

The Students' Views on the Component of Tentativeness of Science (TS)

	Item	**Item Kind**	**Numerical Value**					**viewpoints**			**Average**
			1	**2**	**3**	**4**	**5**	**Naïve**	**transitional**	**Formal**	
TS	7	+	1.1	5.3	28.7	43.6	21.3	6.4	28,7	64.9	3.79
	19	+	0	10.6	3.2	60.6	25.5	10.6	3,2	86.1	4.01
	10	+	0	2.1	13.8	60.6	23.4	2.1	13,8	84	4.05
	3	-	3.2	9.6	14.9	56.4	16	12.8	14,9	72.4	3.72
	Total Average		1.1	6.9	15.2	55.3	21.6	8	15,2	76.9	3.89

Scientific theories and laws (TL): Table 4 shows that 44.2 percent of the subjects do not have a correct understanding of the role of theories and laws in science and 26.6 percent have not expressed any opinion. Statement 23 in this table indicates that, according to 63.9 percent of the subjects, a theory turns into a law after being proved. 11.7 percent are against this view and 24.5 percent have not expressed their view. Also, more than half of the subjects assume that scientific theories really exist in the natural world and can be discovered by means of investigations. 44.6 percent of them hold the naïve view that, in contrast to theories, scientific laws are not subject to change.

Table 4.

The Students' Views on the Component of Scientific Theories and Laws (TL)

	Item	Item Kind	Numerical Value					viewpoints			Average
			1	2	3	4	5	Naïve	transitional	Formal	
TL	8	-	16	39.4	24.5	17	3.2	55.4	24.5	20.2	2.52
	16	-	10.6	34	17	35.1	3.2	44.6	17	38.3	2.86
	23	-	12.8	51.1	24.5	10.6	1.1	63.9	24.5	11.7	2.36
	20	+	6.4	6.4	40.4	41.5	5.3	12.8	40.4	46.8	3.33
	Total Average		1.15	32.7	26.6	26.1	32	44.2	26.6	29.3	2.77

Social and cultural embeddedness (SC): As can be seen from statement 12 in table 5, 60.7 percent of the subjects believe that scientific research is embedded in culture and society. 80.9 percent believe that cultural values and expectations influence the topic and orientation of research. However, 43.7 percent either doubt the effect of culture and society on the execution and reception of scientific activities or disagree with it.

Table 5.

The Students' Views on the Component of Social and Cultural Embeddedness (SC)

	Item	Item Kind	Numerical Value					viewpoints			Average
			1	2	3	4	5	Naïve	transitional	Formal	
SC	12	-	6.4	22.3	10.6	54.3	6.4	28.7	10.6	60.7	3.32
	5	+	2.1	7.4	9.6	59.6	21.3	9.5	9.6	80.9	3.90
	17	+	1.1	9.6	33	46.8	9.6	10.7	33	56.4	3.54
	24	-	2.1	26.6	26.6	35.1	9.6	28.7	26.6	44.7	3.23
	Total Average		2.9	16.5	20	49	11.7	19.4	20	60.7	3.5

Creativity and imagination (CI): According to table 6, 59.6 percent of the subjects assume that scientists use their creativity and imagination in the analysis and interpretation of data, but 62.7 percent either doubt the effect of this component on data collection or disagree with it.

Table 6.

The Students' Views on the Component of Creativity and Imagination (CI)

	Item	Item Kind	Numerical Value					viewpoints			Average
			1	2	3	4	5	Naïve	transitional	Formal	
CI	15	**+**	8.5	28.7	25.5	31.9	5.3	37.2	25.5	37.2	2.97
	9	+	0	18.1	22.3	51.1	8.5	18.1	22.3	59.6	3.50
	4	-	3.2	9.6	13.8	55.3	18.1	12.8	13.8	73.4	3.76
	21	-	2.1	12.8	26.6	47.9	10.6	14.9	26.6	58.5	3.52
	Total Average		3.5	17.3	22.1	46.6	10.6	20.8	22.1	57.2	3.44

Multiplicity of methods: As shown in table 7, 51 percent of the subjects believe that scientists conduct research using a universal, step-by-step method and 49 percent believe that if a scientist applies this scientific method correctly, the results will be accurate and valid.

Table 7.
The Students' Views on the Component of Multiplicity of Methods (MM)

	Item	Item Kind	Numerical Value					viewpoints			Average
			1	2	3	4	5	Naïve	transitional	Formal	
MM	18	+	0	1.1	13.8	54.3	30.9	1.1	13.8	85.2	4.15
	2	-	7.4	43.6	18.1	22.3	8.5	51	18.1	30.8	2.81
	11	-	6.4	42.6	23.4	22.3	5.3	49	23.4	27.6	2.78
	14	+	1.1	7.4	20.2	59.6	11.7	8.5	20.2	71.3	3.73
	Total Average		3.7	23.7	18.9	39.6	14.1	27.4	18.9	53.7	3.37

In figures 1 and 2, the mean scores of the statements and the subjects' formal and naïve view 2 to 7. This comparison shows that the subjects' view of scientific theories and laws is naïve and their view of observation and inference is formal. Their view of scientific methods, creativity and imagination, tentativeness, and social and cultural embeddedness is of a transitional nature.

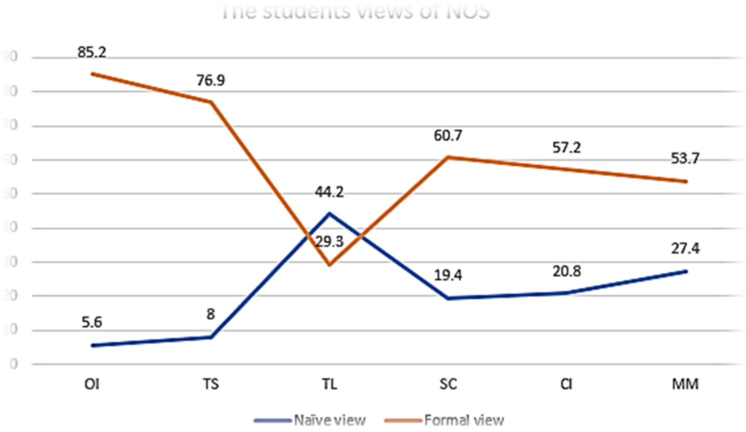

Figure 1.
The Students' Formal and Naïve Views of the NOS

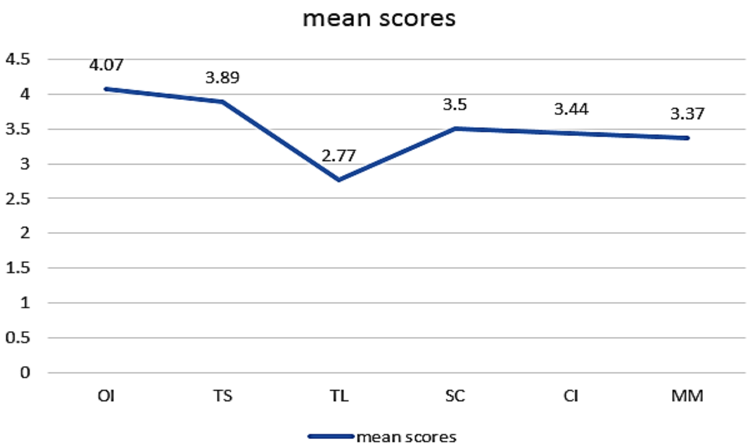

Figure 2.
Mean Scores of the Components

Discussion

From among the six NOS components investigated in this study, the highest percentage of the formal view among the physics education students belongs to tentativeness of science and observation and inference. The highest percentage of the naïve view belongs to the components of scientific theories and laws. These results are consistent with the findings of the study by Liang et al. (2008). However, there is a difference between the results of the present study and Liang's research regarding the frequency percentages of the formal and naïve views. That is to say, results of this study indicated that as compared to the preservice elementary American teachers studied by Liang et al. (2008), a larger percentage of physics education students have a formal viewpoint on the role of observation and inference as well as the transient nature of science. Moreover, a smaller percentage of physics education students have a naïve viewpoint on the role of theory and law in science. Partial existence of these views among physics education students seems to be explained by the fact that their major has seen fundamental changes over the last century. In fact, they have done many experiments in the laboratory to practice the skills of observation and inference and have become familiar with the evolution of atomic models in their textbooks. More generally, the paradigms of general and special relativity and quantum mechanics have introduced them to the transformable nature of science.

These results suggest that the most serious misunderstanding among physics education students is concerned with the role of theories and laws in science. As opposed to Einstein's (1933) views, the subjects assume that scientific theories exist a priori in the natural world and should be discovered through research. In other words, they do not have a clear understanding of the fact that theories are constructed by the human mind and only used to explain natural phenomena. This false belief, according to Einstein, was common among the natural philosophers of the 18th and 19th centuries. However, this study indicates that the misunderstanding still strongly pervades the minds of the students. The students also assume a hierarchical relationship between laws and theories so that a theory turns into a law after being proved. This is in line with what McComas (1998) has reported.

The results also suggest that, in contrast to the belief of the majority of students, scientists use multiple methods instead of a single, universal step-by-step method of research. This conforms to what McComas (1998) has reported.

In addition, although the subjects believe that the orientation and topic of research is affected by cultural values and expectations, they either doubt the effect of society and culture on the execution and reception of scientific activities or disagree with it. Their general view is that scientists use their creativity and imagination in the analysis and interpretation of data, but they doubt the effect of this component on the process of data collection. Although the subjects in this study were limited, the two findings in the current research are noteworthy and significant.

Conclusion

In this study, the point of view of a number of Physics education students regarding the components of the nature of science was analyzed. The achieved results (figure 2) show that in five from six components under study, the students' views are changing from transitional towards formal view. Since these components are closely related to curriculum and social interactions, they can be led to formal views through purposeful instructions and goal-oriented conferences, and in this way, it can increase the level of scientific knowledge of education students from the nature of science. In this regard, it is essential that the authors of textbooks, the associations for popularization of science and the developers of educational sites design and construct activities based on expanding concepts related to the nature of science. because various studies have shown when teachers have not understood the NOS, they do not have a clear understanding of the scientific methods and time allocation in teaching and assessing students' achievements. Also, they may not have any clear step in preparing instructional materials for assessing the scientific methods from the easiest to the most difficult ones. On the other hand, a science teacher must bring to the classroom the attitude and worldview of a scientist, because experiencing the processes of science alone is not sufficient (Hun-Young et al., 2018).

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Appendix A

No	Statements	SA	A	U	D	SD
1	Scientists may make different interpretations based on the same observations.					
2	Scientists follow the same step-by-step scientific method.					
3	Scientific theories based on accurate experimentation will not be changed.					
4	Scientists do not use their imagination and creativity because these conflict with their logical reasoning.					
5	Cultural values and expectations determine what science is conducted and accepted.					
6	Scientists' observations of the same event may be different because the scientists' prior knowledge may affect their observations.					
7	Scientific theories are subject to on-going testing and revision.					
8	Scientific theories exist in the natural world and are uncovered through scientific investigations.					
9	Scientists use their imagination and creativity when they analyze and interpret data.					
10	Scientific theories may be changed because scientists reinterpret existing observations.					
11	When scientists use the scientific method correctly, their results are true and accurate.					
12	Scientific research is not influenced by society and culture because scientists are trained to conduct pure, unbiased studies.					
13	Scientists' observations of the same event will be the same because scientists are objective.					
14	Experiments are not the only means used in the development of scientific knowledge.					
15	Scientists use their imagination and creativity when they collect data.					
16	Unlike theories, scientific laws are not subject to change.					
17	Cultural values and expectations determine how science is conducted and accepted.					
18	Scientists use a variety of methods to produce fruitful results.					
19	Scientific theories may be completely replaced by new theories in light of new evidence.					
20	Scientific theories explain scientific laws.					
21	Scientists do not use their imagination and creativity because these can interfere with objectivity.					
22	Scientists' observations of the same event will be the same because observations are facts.					
23	Scientific laws are theories that have been proven.					
24	All cultures conduct scientific research the same way because science is universal and independent of society and culture.					

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