



**PROBING PRESERVICE TEACHERS' UNDERSTANDINGS OF SCIENTIFIC
KNOWLEDGE BY USING A VIGNETTE IN CONJUNCTION
WITH A PAPER AND PENCIL TEST**

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ABSTRACT. The purpose of this study was to examine how prospective middle school science teachers understood and identified types of scientific knowledge in a presented vignette. Also, their definitions and views of the relationships between types of scientific knowledge (i.e. scientific facts, concepts, generalizations, theories, and scientific laws) were investigated through open-ended questions. Additionally, participants were given the Nature of Scientific Knowledge Scale (NSKS) after they responded the open-ended questions. Therefore both qualitative and quantitative data were obtained about their understandings and views about scientific knowledge. Thirty six participants responded the questionnaires at the end of the spring semester 2005. During this semester participants were in their junior year and enrolled in a 'history and nature of science' course in which 16th and 17th century scientific revolution and the historical background leading to those developments were discussed. Participants received no specific instruction about the definitions of types of scientific knowledge like theories and laws. Analysis of the quantitative data obtained via NSKS show that participants hold a view favoring the tentativeness of scientific knowledge and mostly appreciate the developmental nature of science. While, on the other hand, analysis of the qualitative data obtained through the open-ended questions illustrate that participants hold a stepwise development view in science assigning the tentativeness in science to theories and lower steps. Overwhelmingly they emphasize that scientific laws reflect proven truth and in a sense absolute. These findings show the usefulness of utilizing appropriate vignettes for probing views. The results are discussed in the light of existing literature and implications are provided.

KEYWORDS. Nature of Science, Assessment, Vignette, Tentativeness, Science Literacy.

INTRODUCTION

Today science is an inevitable part of our lives and a constant school subject around the world. Educators responding to how science education should be organized around central ideas put forth many proposals. Among them Victor Showalter and his colleagues in the Unified Education Movement determined seven dimensions for scientific literacy (Showalter, 1974 as cited in Bybee, 1997, p.57). These dimensions are i) the nature of science, ii) concepts in science, iii) processes of science, iv) values of science, v) science and society, vi) interest in science, and

vii) the skills of science. Within the nature of science dimension they included tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic, and empirical characteristics of science (Lederman, Wade & Bell, 2000). Later, the National Research Council (NRC) explained the personal relevance of scientific literacy as "[it] entails being able to read with understanding articles about science in the popular press and to engage in social conversations about the validity of the conclusions. (...) A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it" (NRC, 1996, p.22).

Recently, McComas and Olson (2000) qualitatively analyzed eight international science education standards documents to determine the recommendations towards including aspects of the nature of science in teaching and learning. As a result of a qualitative analysis they found that 38 distinct statements could be made to summarize the elements of the nature of science claimed in the documents. They further categorized these statements under four groups: philosophical, sociological, psychological, and historical. These findings show that many aspects of the nature of science are strongly recommended by the standards documents. It is also known that such notions are becoming more and more visible in science textbooks. It then can be concluded that the nature of science is an integral part of teaching and learning science in schools today.

THEORETICAL BACKGROUND

Paper-Pencil Tests in Assessing the Views About the Nature of Science

Several ways of assessing understandings of the nature of science have been developed and used so far. In addition to paper-pencil tests, alternative assessment techniques were also developed and utilized. Lederman, et. al. (2000) list and critique two dozens of nature of science instruments developed and used between 1954 and 1995. Their critique of 13 of them focuses on the validity of the instruments and they suggest using those in conjunction with other more valid instruments. Consequently, they consider the remaining 11 instruments as valid and reliable.

One of such paper and pencil instruments is the Nature of Scientific Knowledge Scale (NSKS) developed by Rubba (1976). He developed a six sub-scale model of the nature of scientific knowledge by reducing the nine factors Showalter previously advocated. Rubba's six sub-scales are amoral, creative, developmental, parsimonious, testable, and unified characteristics of the scientific knowledge. This instrument contains 48 items. The concerns raised by Lederman, et. al. as threats of validity for this instrument center around the high number of items it includes and half of them being just negatively worded versions of the rest. However, the NSKS have been widely used in numerous studies since its development.

Qualitative Research in Nature of Science Assessment

Instead of usual Likert scale measures of views Aikenhead (1987) took a different approach and presented the subjects statements upon which for them to comment and give extended written responses. One pair of such statements (item 15) is about the tentativeness of scientific knowledge and contains the following two opposite statements much like NSKS style:

15.1 When scientific investigations are done correctly, scientists discover knowledge that will not change in future years.

15.2 Even when scientific investigations are done correctly, the knowledge that scientists discover may change in the future.

In the researcher's eyes while 15.1 presented an absolute view of scientific knowledge, 15.2 expressed a tentative view. The analysis of data obtained from the large sample of senior high school students showed that although nearly all of the students believed that today's scientific knowledge is subject to change they accounted different reasons for their respective views (categorized into six main paraphrased codes of student expressions.) Another notable result was that, as the researcher himself admits, percentages of students varied in each category in their responses for the two statements, which shows that student responses were influenced by the wording of the statement. One can also note, by reading the above statements, that it is assumed that the subjects uniformly understand the term "scientific knowledge." As a result statements do not contain terms like hypotheses, scientific law and/or theory. It would be very interesting to see the results if one statement included scientific law and the other theory. In this form the above statements are too generic and coarse to allow a more detailed analysis of students' views about tentativeness in scientific knowledge.

Afterwards Lederman and O'Malley (1990) developed a 7-item open-ended questionnaire and used it in conjunction with follow-up interviews. They noted, by using this method, that there are unavoidable interpretation problems associated with having participants to respond in written form to researcher generated questions. Consequently they validated the questions by follow up interviews. Notably, the seven-item questionnaire included the following two questions:

(Item 1) After scientists developed a theory (e.g. atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to learn about theories. Defend your answer with examples.

(Item 3) Is there a difference between a theory and a scientific law? Give an example to illustrate your answer.

In fact, when examined carefully it can be seen that these seven questions (as listed in Lederman, et. al. 2000, p.342) are lined and worded in a way that they may lead the participants

towards the answer the researchers had in mind. Surely, researchers wished to investigate and understand how participants viewed the tentativeness (or the developmental aspect as Rubba referred to) of scientific knowledge. But asking questions in this way has a great potential of cueing the participants. For example item 1 does not ask participants to tell their views if they believe theories do not change. Therefore it pushes the subjects to respond in one way only. Moreover, the question includes the keyword "change." When a person who has not paid any attention to such issues before reads a question of this sort s/he is inevitably prompted to the change idea in scientific knowledge. Thus, when the paper and pencil test is used alone the researcher will have no means to figure out if the answer totally stems from the respondent's existing understandings (a well considered self view) or if it is the result of cueing (a made up answer at that moment). When all seven items are considered together the questionnaire looks more like a teaching experiment (Steffe & Thompson, 2000) interview protocol, where researchers are also considered as research instruments.

Subsequently another qualitative method was employed by Nott and Wellington (1996). They used critical classroom incidents in their alternative technique in order to elicit teachers' views about science. They wanted to create familiar contexts in which teachers can respond to issues related to the nature of science. These contexts are labeled as "critical incidents" and they portray descriptions of actual classroom events. The incidents are so created as to reveal beliefs when a teacher responds to it in a real like (simulated) classroom setting. This way of assessing views about the nature of science is indeed an indirect one and righteously opens the way to raised concerns (see for example Lederman, et. al., 2000). Another characteristic of this method is that it can only be used with teachers since the method employs teachers' pedagogical content knowledge as the tool to extract their understandings of the nature of science. Therefore it is not suitable for usage in other contexts except perhaps using it with prospective teachers.

Defining the Tentativeness of Scientific Knowledge

The National Research Council (NRC) explained how the tentativeness should be understood: "Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, *in principle*, subject to change as new evidence becomes available. The core ideas of science such as the conservation of energy or the laws of motion have been subjected to a wide variety of confirmations and are therefore *unlikely to change* in the areas in which they have been tested" (p.201, emphasis added). This is the very definition adopted in this research study.

National Academy of Sciences (NAS) (1999) defined the terms of law and theory as follows:

Law: A descriptive generalization about how some aspect of the natural world behaves under stated circumstances.

Theory: In science, a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypothesis.

These definitions are in line with the NRC's position and complement it.

McComas (2003) further dealt with the issue of defining these terms sufficiently in considerable length and effort. So those issues will not be taken further here. When he examined 15 U.S. secondary school biology textbooks by designing model definitions of both "law" and "theory" and comparing these definitions to those found or portrayed in the textbooks he noted that

"The term "law" is rarely defined in any text but various laws such as those found in genetics are frequently included as examples. The term "theory" is frequently defined but with a wide range of completeness of the definitions. Only rarely are theories in biology included as examples."

He also noted that some of the examined books included misleading language about theories suggesting the notion that as support mounts hypotheses become theories and as more evidences are gathered eventually they become laws. In order to draw attention to important points in teaching and learning the nature of science McComas (2000) determined and explained 15 "myths" (widely -held and incorrect ideas) about the nature of science. Six of them refer to the views about tentativeness in science: Hypotheses become theories that in turn become laws (myth 1); scientific laws and other such ideas are absolute (myth 2); evidence accumulated carefully will result in sure knowledge (myth 5); science and its methods provide absolute proof (myth 6); science is procedural more than creative (myth 7); science models represent reality (myth 13).

Blanco & Niaz (1997), Bell, Lederman, & Abd-El-Khalick (1998) and Lederman (1999) also found that the concepts related to the tentativeness of scientific knowledge are very confusing and that such understandings are common among both students and teachers.

All these previous works and Lederman's 1992 review clearly show that although teaching and learning about the nature of science is encouraged, attaining desired outcomes is not straightforward and there are still problems ahead of us. Attempts in measuring understandings have shown a way to follow and much has been learned from them. The messages derived here from the previous works are that instruments need to measure what the subjects know, how they know it, and how they apply it. Creating newer valid and reliable techniques that show a potential in measuring parts of nature of science notions can help overcoming the difficulties in interpretation and can make contributions by showing the right directions.

Usages of Vignettes in Assessment and Learning

Vignettes so far were utilized to collect data in various forms in studies from different areas in education in recent years. Their advantages particularly in qualitative, in-depth, small sample studies are obvious as will be seen below.

Case (1997) investigated the relationship between teacher beliefs and attitudes and the implementation of cooperative learning. She showed a videotaped vignette of teacher's classroom practice and interviewed the participants subsequently about its meaning for them. Bodur (2003) investigated preservice teachers' beliefs and attitudes about teaching culturally and linguistically diverse students. As part of his data collection strategy he used three multicultural vignettes in addition to other data sources. He applied certain criteria to choose the vignettes. By conducting an extensive search for them he chose the ones that best portray the issue in hand; that are relatively short (3 vignettes 143, 111 and 204 words in length); and that come from credible outside sources rather than being created by the researcher. This last criterion was mandated in order to avoid researcher bias. For each vignette he directed two short questions "Issues present in the vignette: (space below)" and "Your personal response to the issues you identified: (space below)" and provided half page blank space for each. As seen he does not mention any aspect of the issue at all in the questions, not even a key word.

As complementary data sources Harlan (1996) used three vignettes (around 500 words in length) in her study that represented distinct approaches to teaching art. Participants were asked to study each vignette and then respond to six Likert type questions. After completing this part they were also asked to respond to 3 final questions to compare and contrast their ideas and experiences about teaching to the ones presented in the vignettes. Veal (1997), on the other hand, focused on a small sample of prospective chemistry and physics teachers (two of each) and studied their development by utilizing multiple data collection methods. Among them he created content specific, situational vignettes in order to follow prospective teachers' development of pedagogical content knowledge. The vignettes in this study were rather lengthier as compared to the ones used in previously mentioned studies (around 2500 words). Participants in this qualitative study were asked 11 questions after reading the vignettes. The questions asked them to speculate (what would happen, how would happen, what would they do) and explain their ideas on specific points.

In contrast Roach, (1993) and Chan (2000) used interactive historical vignettes as teaching tools rather than assessment tools and obtained desirable results for students' learning and understanding the nature of science without impeding their achievement in science as compared to control groups.

In the light of this literature base the researcher in this study wished to pursue the following research questions:

How do prospective science teachers,

- 1) understand and identify different types of scientific knowledge (i.e. scientific facts, concepts, generalizations, theories, and laws)?
- 2) define and view the relationships between different types of scientific knowledge?
- 3) view the tentativeness of scientific knowledge?
- 4) make their views evident by responding to open-ended questions about a vignette and NSKS? How do the two types of responses compare to each other?

It is deemed that the methodology employed here will serve as a magnifying lens that will focus on some tinier part of the previous research and by doing so it will enhance our understanding of assessing views about scientific knowledge.

METHOD

This research study took place in Turkey at a large teacher training institution (a university faculty) in a metropolitan city at the end of spring semester 2005. Participants were first asked the following question:

Please explain five most important characteristics of science you determined based on your readings about history of science and in-class discussions by giving examples from historical cases.

After collecting responses students were distributed another sheet containing a vignette. This is still another qualitative technique developed and used by the researcher for assessing understandings of the nature of scientific knowledge by utilizing a one-page piece (Newman, 2005, p.17) from a popular magazine as a vignette (see appendix for the English original). This magazine is published simultaneously as international edition in English and as one of the local editions in Turkish. The vignette was taken from the Turkish edition of the monthly magazine and presented to the participants. Therefore the translation belongs to the publishing company and the researcher made no change in the translation. The following question was directed to the participants about the vignette:

Please carefully read the reading piece given below. Are there any facts, concepts, generalizations, theories and/or scientific laws mentioned in the vignette? Identify the ones directly related to the main theme of the vignette and explain why you think they are. (For example, explain why you think a particular case mentioned in the vignette is a concept or scientific law, etc.) If one or more of them are not present in the vignette, explain why you could not find them.

This particular vignette was chosen because first it was from an outside source rather than being created by the researcher, and second, the story told in the vignette was deemed to be culturally and scientifically entirely new for the participants. So it is thought that they could look at it and evaluate the issue without bias and prejudice.

Following the vignette the 48 item NSKS was administered to the participants to allow a comparison of the results obtained in both ways. The Turkish version was initially based on two separate translations from two native Turkish speaking experts of the field. It was then piloted several times on both undergraduate and graduate students. In two years by continuously giving several try outs and making refinements in the language ensured the reliability (the cronbach alpha was measured to be 0.71) of the Turkish version of the instrument.

While analyzing the extended responses to the two open ended questions the researcher looked for emerging themes. Several passes were conducted over the whole set of data and during each reading new understandings (categories and codes) were formed. The researcher initially did not know what he would face in the data. But the themes became clear slowly as the researcher was immersed in the data.

Data analysis was based on the original participant responses in Turkish. The excerpts given below are the researcher's translations. A verbatim translation without interpretation is presented here for the readers' convenience.

Participants

A course entitled "the history and the nature of science" is offered in spring semesters by the researcher in his institution. In this course various aspects of science and issues in the history of science are dealt with. During the semester in which the data were collected Turkish translations of two books were used: "The Construction of Modern Science" (Westfall, 1977) and "The Double Helix" (Watson, 1969). Thirty seven junior students majoring in middle school science teaching took the course and 36 of them participated in the study (one student was absent during the data collection day). They were prompted to pay attention to and study the relations between the different types of scientific knowledge two weeks before data collection. However, these issues were not covered intentionally or explicitly during the semester. In their responses they solely depended on their own previous knowledge and/or the information that they obtained as a result of their own research.

ANALYSIS AND FINDINGS

Responses to the First Open-Ended Question

For the five characteristics of science the most cited ones, related to the current discussion, were the progressive and accumulative nature of science (13 participants) and the changing nature of science (9 participants). Below are excerpts from three different respondents:

"There is nothing like things thought to be true in science will stand like that forever as long as they do not become laws they are not absolutely true. They can be improved and changed by making use of previously proved theories. For example Copernicus believed in the existence of crystal spheres. But later works disproved it."

"Science can change. This is the most outstanding feature of science. Scientific findings and knowledge have continuously changed throughout history. We can see how a scientific fact has changed from Aristotle's understanding of motion to the Newton's laws of motion. (...) Surely this change was based on many experimental and observational facts."

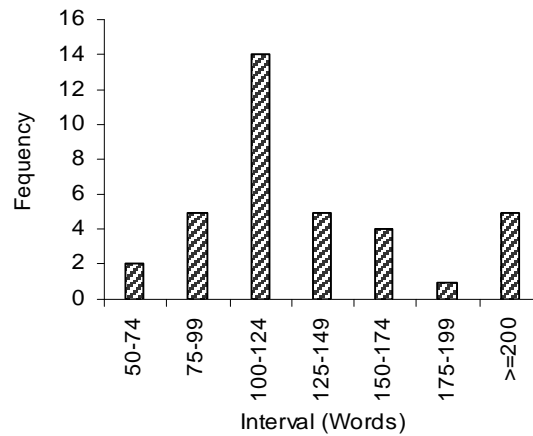
"Science is open to changes: Initially men were being executed when they claimed that earth was spherical. However, this is now a truth accepted by everyone."

These responses clearly indicate that in the past scientific ideas have changed. But there is a certain objective truth (that can be accepted by everyone). Once, by way of science, ideas get tested they evolve to become absolute. This final stage is expressed in scientific laws. Such responses reflect participants' understanding of tentativeness. The tentativeness mentioned here can be regarded as partial: pertaining to "unproven" ideas. It is hard to tell from these findings that they see all scientific ideas being subject to change even in principle.

Responses to the Vignette

Figure 1 below shows the number of words the participants used in answering the open-ended questions about the vignette. While explaining their views in written form the participants used 131 words on the average with a standard deviation of 44 words. The minimum and maximum numbers of words used were 61 and 245 respectively. This analysis shows that they were indeed very articulate and tried to explain their ideas as thoroughly as possible.

When the qualitative data obtained via the vignette are analyzed it is seen that except one student all other participants indicated that laws represent proven, unchanging, certain truth about phenomena and that theories are subject to change since they are not final or proven (therefore tentative). That one participant considered both scientists' conclusions as theories but did not comment on any laws and did not explain his line of thinking about laws and theories. Twenty-nine participants stated that they could not find a law in the vignette, while the remaining seven extracted some definitive sentences (that fugu is poisonous and causes death when eaten) and labeled them as laws. Hence, they did not differ in the definitions but examples of laws present in the vignette.

Figure 1. The distribution of number of words used in participant responses.

Below are examples of participant responses:

Participant #A: "Theory is the developed state of hypothesis. If data confirms the hypothesis, it becomes a theory. For example, experiments were conducted and non-poisonous fish were produced by controlling the food they ate. (...) There is no law here. Because a theory can turn into a law when it is completely and certainly obvious. However, since there is no certain, unchanging idea in this piece, there is no law."

Participant #B: "In the third paragraph it is indicated that the source of the poison of the fugu fish is how it is fed. Research was conducted on this, when fish were fed by different food it became non-poisonous. This was verified by many people. It is confirmed by experiments. However, someday someone can disprove this theory. The reason is that it has not yet become a law. Theories can be disproved."

In the fifth paragraph there is also a theory. It is said that fugu's poison comes from the "poison glands beneath its skin." It is said that "in this case some fugu are poisonous and some are not." This is also a theory. This result was reached through the conducted experiments. But this is not a law either. It can be disproved. Someday, anyone might say that it is not so, and can prove what s/he says.

Concepts are the abstract forms of objects in our minds. It can be said that poison is a concept. In this piece there are examples of facts, generalizations, concepts and theories. But I could not find an example of law. Law is the step that comes after theory. Laws emerge when all scientists reach the same conclusion as a result of their experiments and they cannot be disproved, their truth has been established (proved). In this piece there are assumptions, theories; any moment some people come up and disprove. However, there is no implication that everyone has reached the same conclusion, it has been accepted by the whole world, that is, there is no law."

One participant's point of view is rather interesting and different from all others:

Participant #C: "Tamao Naguchi is saying that fugu's poison comes from the way it is fed. This is a theory. Because he says that blowfish eats organisms that eat poisonous bacteria called vibrio. Naguchi grew fish by controlling their food and obtained non-poisonous fish. This is a law. Because he proved his theory as a result of experiment. That is, he applied and showed the truth of his idea."

She logically applied the "theory becoming a law" myth to the presented case in the vignette and reached her conclusion. In fact 33 students expressed, either by directly stating or explicitly implying, this very idea.

The typical rationale for not seeing a law in the vignette was expressed as follows:

Participant #D: "No law is mentioned in the vignette. The truth of the proposed theories are not proven. The proposed theories do not contain absolute (certain) truths. We call a generalization closest to the truth as law."

Participant #E: "There is no law. Because why the fish kills could not be fully proven. Laws cannot be criticized."

Existence of two different ideas coming from two scientists perplexed the participants. This was the main reason for not finding a scientific law present in the vignette.

As to the presence of theories in the vignette 19 participants regarded only Naguchi's work as a theory while 12 students expressed that both Naguchi's and Matsumara's works are theories. One student understood both works as hypotheses. Two students found different statements as theories in the vignette. The remaining two students did not mention of any theories.

Responses to the NSKS

The results of the NSKS survey for the items related to tentativeness of scientific knowledge yielded mostly desirable outcomes (see Table 1). In this subscale there are 8 items four of which are positive (items 16, 26, 37, and 42) and the remaining four items being negatively worded (items 25, 27, 31, and 43). Participants consistently seem undecided only for items 16 and 27 which are the positively and negatively worded versions of the same idea.

One criticism that can be directed to the above NSKS items is that it puts all eggs in the same basket. Namely it either mentions "scientific knowledge" or as in item 26 contains all types of scientific knowledge in the same statement. The problem with this is that when participants accept this statement we have no idea whether participants mean theories or laws or both as changing. This point has overarching consequences and crucial in determining participants'

understanding and notion of tentativeness. Another criticism is that although participants did not favor unchanging scientific knowledge or belief notions we do not know whether they mean it by only looking at the past or by also ascribing to the future. Here the word future is a keyword that the subjects need to tackle and explain.

Table 1. NSKS items related to tentativeness in science and respective scores.

Item #	Item Expression	Mean Score
16	We accept scientific knowledge even though it may contain error.	2.71
25	The truth of scientific knowledge is beyond doubt.	2.03
26	Today's scientific laws, theories and concepts may have to be changed in the face of new evidence.	4.18
27	We do not accept a piece of scientific knowledge unless it is free of error.	2.18
31	Scientific beliefs do not change over time.	1.76
37	Scientific knowledge is subject to review and change.	4.24
42	Those scientific beliefs which were accepted in the past, and since have been discarded should be judged in their historical context.	4.18
43	Scientific knowledge is unchanging.	1.74

RESULTS

From the qualitative data it is seen that participants make a distinction between scientific laws and other types of scientific knowledge. Although the former is seen as almost absolute the rest is regarded as being subject to change. From this point of view scientific laws are considered as the final destination that a scientific program can reach. Once this point is reached they see no further effort to be put on the same subject. Moreover they hold a naïve conception that a universal consensus can be attained on a scientific issue and it can remain like that afterwards. Although scientists assume that their generalizations are invariant over time and space it does not mean that a universal agreement is/can be achieved. It is a formal basis and a framework for scientific enterprise. They also naively assume that all successful scientific efforts are going to end by establishing a scientific law.

Participants see a hierarchical relationship between different types of scientific knowledge. In their scheme scientific laws lie at the top and are not disprovable. Theories hierarchically come after scientific laws and can be disproved. In this view both theories and scientific laws are in fact the same sort of scientific knowledge but with different levels of acceptance.

As to the tentativeness of scientific knowledge different positions are expressed in qualitative and quantitative responses. When the NSKS item 26 is considered it can be concluded that participants highly favor the tentativeness idea in science. But this item includes all types of scientific knowledge. On the other hand, it is evident from the qualitative data that participants do not see scientific laws as changing. This result shows that the different data sets are contradicting on participants views of tentativeness of scientific knowledge.

DISCUSSION

This study showed that first, carefully selected vignettes can be used as powerful tools for probing understandings of the nature of science. This is also meaningful in that subjects were asked to apply their knowledge to a novel case. Hence, by this method, not only rote memorization of formerly presented ideas about the nature of science, but also meaningful understanding was probed. Analyzing and evaluating such vignettes also has a potential to promote and teach higher order thinking skills.

Secondly, participants have expressed that theories can be disproved while laws cannot. The support for this opinion was that there were two contradicting explanations coming from two different scientists. They understood this situation as "not yet proven" but could be proven once and for all at some point in time later. This position is distinctively different from the one favored by NRC as stated above.

It is obvious from the data that the participants' minds were preoccupied with the false hierarchical relationship between facts, hypothesis, theories and laws (McComas, 2000). In this view laws are discovered by almost an automatic process (or machinery) starting from observations and ending up with laws (this notion is also related to myth 7). The findings that support this conclusion are that participants were overwhelmingly seeking whether a definitive conclusion about the problem was reached and stated by scientists. If they had not seen a difference of findings and hence difference of opinion in the vignette about the same phenomenon (i.e. if only one of the works of the mentioned researchers was to be presented to them or both scientists had agreed) they would most probably call it a new law since it is a result of a scientific work and no objection was being raised.

This way of regarding laws is in fact a large deviation from actuality. Laws in science are the core ideas. Although scientific laws are a special class of generalizations, not all generalizations are called laws in the scientific enterprise. For example the earth's shape is spherical. Although it was debated in the history we now have some undeniable data (e.g. the earth's picture taken from outer space) that show us that the shape of the earth is without doubt spherical. All physicists agree on this as well (there is no current contrary view or effort to prove otherwise). The problem is settled and the case is closed. However, this definite statement is not

regarded as a scientific law. Moreover, there is not a law that states that all planets are (or must be) spherical in shape. Another example that can be given is the statement "all human beings die." There is no exception to it that we know of or we expect to see in the future. Yet this generalization is not called or labeled as a scientific law either. Not because it is not as much certain as we would like it to be to gain universal validity or research/debate is continuing on the issue. But just because scientific laws represent core ideas in science and in a way they are just some labels for some of the scientific generalizations (inductions).

Lederman et. al. (2000) took in their categorization an either/or approach for a students view and accordingly coded individual student responses as being "absolute" or "tentative" as a whole as a result of their interpretation of the interview data. However, the distinction between theory and law and their relationship to each other is a central and crucial point in understanding the nature of science as McComas (2000) has explained. Another way to explain the Lederman et. al. data could be to look at them from a different perspective as they partially did. As data from the current study also shows contrary to the accepted view subjects may adhere to an alternative notion that some scientific knowledge are tentative (i.e. hypotheses and theories) while others are absolute (i.e. scientific laws) since the former evolves into the latter under certain conditions (myth 1) and becomes absolute (myths 2, 5, and 6). Viewing the data from this perspective shows a potential to resolve the interpretation problems and conflicts in the analysis of data obtained via paper and pencil tests mentioned by Lederman et. al. They state that:

"The data gathered during the pretest seem to indicate that the students, as a group, do not uniformly adhere to either an absolute or tentative view of scientific knowledge. That is responses to questions two and three strongly favored an absolutist view while the responses to questions one and four were more aligned with a tentative view. This might indicate that it is possible for students to compartmentalize their views with respect to the type of scientific knowledge or it could simply indicate that students are in a state of transition."

Lederman and O'Malley emphasized over and over again that using paper and pencil alone has crucial pit falls that often mislead researchers. Hence they conducted follow up interviews in order to elicit in depth what the participants had in mind when they used specific words like 'theory' and 'law'. This way they were able to elicit in depth the participants' views. In the present study the vignette provided a context for the students to respond. So that the questions were not just some "dry stuff." It can be claimed that the story took the role of the interviews in that study without the presence of the researcher.

Furthermore we cannot explicate participants' views as tentative or absolute just by looking at what they say about the state and role of change in scientific knowledge. Their understandings of scientific laws and theories and most importantly the relationship(s) between the two are, indeed, crucial in making such inferences as the current study shows.

Implications for Further Research

Lederman and O'Malley showed that students' understandings and use of scientific proof was in line with practicing scientists' use. In that study it was shown that students did not mean to use the word in an absolute sense. However in this study students' views cannot be regarded as tentative. They regard theories as tentative and laws as absolute as the presented data shows. Future research should take the responsibility to find the source of this discrepancy: Namely, why the Turkish preservice middle school science teachers hold an absolutist view? Is this view common among Turkish high school and college students and science teachers? How are such notions, if any, presented or described in Turkish curricula and textbooks? How practicing Turkish scientists view the tentativeness in science?

Future research should also address several issues about views of tentativeness. While probing understanding of tentativeness of scientific knowledge participants must be explicitly questioned on whether they see a distinction between hypotheses, theories and scientific laws; whether they see a distinction between results of scientific work belonging to the past, present and future; and whether they hold a hierarchical view between different types of scientific knowledge. This way a more holistic understanding can be obtained and subjects' mental models about tentativeness can be extracted.

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APPENDIX

Vignette

12 TOXIC TALES "a delicacy to die for"

(...) Fugu, or puffer fish, as it is commonly known, is a delicacy in Japan. It can also be deadly. Those who eat the liver, ovaries, gonads, intestines, or skin swallow tetrodotoxin, a powerful neurotoxin that jams the flow of sodium ions into nerve cells and stops nerve impulses dead in their tracks. They run the risk of suffering the fate of the famous Kabuki actor Mitsugoro Bando, who in 1975 spent a night feasting on fugu liver because he enjoyed the pleasant tingling it created on his tongue and lips. The tingling was followed by paralysis of his arms and legs, difficulty breathing, then, eight hours later--death. There is no known antidote.

(...)

The source of the fugu's poison is a subject of debate. Tamao Noguchi, a researcher at Nagasaki University, believes the secret lies in the fugu's diet. Puffer fish, he explains, ingest toxins from small organisms--mollusks, worms, or shellfish--that have in turn ingested a toxic bacterium known as vibrio. In experiments, Noguchi has raised fugu in cages, controlled their diet, and produced toxin-free fish.

He hopes his research will result in the state-sanctioned sale of fugu liver. "A great delicacy; once you eat, you cannot stop," he says. Japan has forbidden the sale of fugu liver since 1983; before the ban, deaths of those who overindulged in the liver, or ate it by mistake, numbered in the hundreds.

(...)

Kendo Matsumura, a research biologist at the Yamaguchi Prefectural Research Institute of Public Health, discounts Noguchi's deadly diet explanation*. He says the fugu's toxicity comes from poison glands beneath its skin. Some fugu are poisonous, he says, some aren't, but even experts can't tell which is which.

Place your bets. Matsumura has never eaten fugu. "I am not a gambling man," he says. However, Noguchi considers it the ne plus ultra of fine dining.

When it comes to fugu, one man's poisson is another man's poison.

* In the original text "theory" was used here. It was purposefully replaced by "explanation" in order not to cue the participants.

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