

## Article

# Exploring Ethiopian Secondary School Science Teachers' Conceptions about the Nature of Scientific Knowledge (NOSK)

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**Abstract:** This study examined secondary school science teachers' conceptions of the nature of scientific knowledge (NOSK). The participants were convenient samples consisting of 48 ( $M = 38$ ,  $F = 10$ ) teachers from three secondary schools. An open-ended questionnaire was administered to collect data. Qualitative analysis involved comparing teachers' responses to experts' views on NOSK. Frequency counts and percentages were also used to describe the NOSK conceptions of participants. Based on the findings, the teachers held informed conceptions on two NOSK tenets and naïve conceptions on four of them. The participants generally held a naïve conception of NOSK, as evidenced by the fact that their conception aligned with informed conception only on two of the seven assessed NOSK aspects. Future research should use large samples, employing a quantitative approach to reveal secondary school teachers' NOSK conceptions.

**Keywords:** nature of science; secondary school; science teachers; teachers' conceptions



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## 1. Introduction

### 1.1. Background to the Problem

One of the aims of science education is to improve the quality of science teaching and learning to develop scientific literacy [1–4]. This is because the overriding target for science teaching is the development of responsible citizenry through enhancing scientific and technological literacy [5]. Development of an understanding of NOSK is also imperative for a better understanding of science subjects [6]. To this effect, science teaching and learning must go beyond simply teaching science as a body of knowledge (i.e., facts, definitions, concepts, theories, laws). It should address both the development of scientific knowledge and the nature of scientific knowledge (NOSK). This helps students understand the types of questions science can answer, as well as the strengths and limitations of scientific knowledge [1]. The ultimate goal of NOSK instruction is to develop students' ability to critically understand social questions and to take reasoned positions in discourses about the scope and limits of science, the methods used to produce scientific knowledge, and the claims of reliability associated with it [7].

Although science subjects are offered in many countries, the goals of the curricula differ greatly. Because of differences in values and aspirations, different societies might define and organize science differently [8]. Science curricula in developed countries have emphasized on developing students' understanding of the NOSK. However, according to Iqbal et.al. [9], developing students' understanding of NOSK is ignored in developing countries. In these countries, science can be viewed as a fixed set of knowledge, something that stands for absolute truth and something objective. Perceiving science in such a way that it is a fixed and absolute truth is not in line with the notion of an informed understanding of the NOSK. The conception of NOSK in Ethiopia could be naïve, as in other developing countries that call for our attention.

### 1.2. Ethiopian Science Education Context

Ethiopia offers science subjects to its students from primary to secondary levels of education, hoping to improve the lives of its citizens. The Ethiopian Ministry of Education [10] in its curriculum framework for KG–Grade 12 education document described that science is offered from primary to general secondary levels for all students. The benefits of providing science subjects include [10]: better understanding of the physical and biological world around them, a fuller appreciation of how to lead a healthy lifestyle, and good grounding for studying science at higher levels and/or working in scientific and technical careers. Inquiry and experimentation are the methods suggested by MoE [10] for the learning of science subjects. Accordingly, the secondary school teacher education program in Ethiopia stipulates a constructivist approach to learning that emphasizes learner-centered, reflective, and analytical methods and approaches [11].

Constructivism emerged as a new paradigm shift in educational psychology by criticizing behaviorist and information-processing learning theories [12]. Constructivists asserted that students cannot simply receive knowledge from teachers; they are active agents who construct knowledge in their own minds [12]. Literature reviewed by Getahun [13] indicated that inquiry learning can help learners become active problem solvers and critical thinkers, enhancing conceptual understanding. Scientific inquiry also gives context to the development of habits of mind that help to make informed decisions about personal and societal issues [6].

However, the teaching and learning process in Ethiopia is dominated by the behaviorist view of teaching and learning, which emphasizes the transmission of knowledge from the teacher to the student [14,15]. Primary school textbooks in Ethiopia (i.e., Addis Ababa) are characterized by a lack of activities that promote students' science process skills [16]. Moreover, the country's present reality of large class sizes in schools has contributed to rote learning [15].

Overall, the educational system that the Ethiopian teachers experienced focused on teaching science knowledge through memorization and imitation rather than encouraging process skills, which are necessary for the development of NOSK. We are curious about the conceptions that these science teachers hold. Therefore, the purpose of this study was to explore secondary school teachers' NOSK ideas, as they are thought to be in charge of supporting students' NOSK learning.

### 1.3. Theoretical Framework

The nature of scientific knowledge refers to the epistemology of science, the values and assumptions embedded in scientific knowledge, and the development of scientific knowledge [8,17]. To investigate teachers' NOSK conception, it is critical to enumerate the common parameters of the construct NOSK to better understand the nature of the scientific enterprise and the characteristics of the knowledge it generates [8]. Based on these assertions, seven NOSK tenets are considered in this study. The following seven NOSK tenets are the common parameters viewed as most practical in schools and potentially more important in developing scientific literacy [1,8,18].

*Empirical nature:* Scientific knowledge is derived from data and evidence gathered through observation or experimentation. Empirical refers to both quantitative and qualitative data. However, some scientific concepts are highly theoretical in that they are derived primarily from logic and reasoning.

*Theories and laws:* A law is a succinct description of relationships or patterns in nature based on observation and often expressed mathematically. Scientific theories are broadly based concepts that make sense of a large body of observations and experimentation. Thus, theories and laws constitute two distinct types of knowledge. One can never change into the other.

*Tentativeness:* All scientific knowledge is subject to change in light of new evidence and new ways of thinking. That does not mean that we should not have confidence in scientific knowledge; rather, it may change in the future.

*Creativity and imagination:* Creativity and imagination are sources of innovation and inspiration in science. Scientists use creativity and imagination throughout their investigations.

*Objectivity and subjectivity:* Scientists strive to be objective and employ self-correcting mechanisms such as peer review. But intuition, personal beliefs, and social values all play a role in the scientific enterprise.

*Observation and inference:* Science involves more than the accumulation of countless observations; rather, it is derived from a combination of observation and inference. Observation involves gathering information using the five senses, while inferences are explanations based on observation and prior knowledge.

*Social and cultural influences:* Different cultures and belief systems could impact the use of scientific knowledge as well as the way scientific investigations are conducted.

#### 1.4. Purpose of the Study

The purpose of this study is to gain a clearer understanding of the NOSK conceptions of a sample of secondary school teachers. The study was guided by the following research question: What conception do secondary school science teachers have about aspects of NOSK? Do science teachers' conceptions about aspects of NOSK align with an informed, a naïve, or syncretic (has merit) conception of the nature of scientific knowledge?

#### 1.5. Significance of the Study

Understanding of NOSK is very timely, and there has never been a more crucial time that called forth an understanding of NOSK by citizens because of the fact that a number of individuals fail to understand how knowledge is generated and validated and fail to distinguish between facts and alternative facts [19]). It is this understanding of NOSK that will enable individuals to critically evaluate knowledge developed through science and act accordingly [19]). However, research on NOSK aspects that are appropriate for different educational levels is lacking [4]). Therefore, this study could contribute to filling this gap. This could be an important contribution to secondary school teachers' conceptions of NOSK. Additionally, this study could serve as pioneering research in Ethiopia, as NOSK has not been researched in a local context [20].

## 2. Research Methodology

### 2.1. Study Participants

The population of this study consisted of three purposefully selected secondary school science teachers (SSTs) in the Amhara region of Ethiopia. The sampling method was convenient and attempted to involve most of the science teachers teaching grades 9–12. Fifty-two teachers were contacted, with the cooperation of directors (in two schools) and a school guidance counselor in one school. The majority were cooperative towards participating in this research. Among the contacted teachers, 50 agreed to fill out the questionnaire. The majority, except two female teachers, returned the questionnaires.

The three schools were selected from the Amhara region of Ethiopia. Amhara's culture has its own traditional beliefs and explanations for natural phenomena. For example, modern explanations for the causes of disorders such as epilepsy are not consistent with traditional beliefs. Religion—especially the Ethiopian Orthodox Tewahedo Church—has a significant impact. Religious convictions and scientific understanding can interact, influencing how people view things like evolution and medical practices. These convictions could lead to skepticism or rejection of scientific principles that contradict these beliefs.

The schools have modern buildings, laboratories, libraries, and sports fields. However, the classrooms are limited, and to overcome this problem, some students attend classes in the morning while others attend in the afternoon shifts. Secondary education in Ethiopia follows a national curriculum set by the Ministry of Education. English is taught as a subject and is the medium of instruction in secondary schools. Teachers' proficiency in the language may affect their comprehension of science concepts. Students in Ethiopian secondary schools, including those in the selected three schools, take the Ethiopian Higher

Education Entrance Exam (EHEE) at the end of grade 12. This may have an impact on shaping the learning–teaching process to meet the demands of passing exams by cramming rather than understanding concepts. This may also affect both students’ and teachers’ levels of understanding of scientific concepts.

Therefore, the teachers’ understanding of the NOSK could be explained at least partly as a function of these socio-cultural forces that need to be investigated.

## 2.2. Data Gathering Tools and Procedures

The data were collected through an open-ended questionnaire. The questionnaire had two parts. The first part required participants to provide their background data. The second part targeted seven NOSK aspects. These were empirical basis, tentativeness, subjectivity, creativity and imagination, social and cultural embeddedness, differences between observation and inference, and the distinction between scientific theories and laws. The present NOSK questionnaire consisted of 10 items adapted from the Views of Nature of Science (VNOS) Questionnaire Form C and Form D+, developed by Lederman et al. [18]. The VNOS questionnaire was adapted and used in different languages and cultures for assessing the NOSK views of college students, primary and secondary school teachers, and secondary school students. Ten items adapted from VNOS-C and VNOS-D+ were used to collect the present data. Open-ended questions have the advantage of exploring participants’ explicit statements about NOSK contextualized in their choice of words [21]. The content validity of the items had been established in previous studies [8]. The validity of this instrument was tested with pre-service and in-service secondary school teachers by the first author.

Since the items were available in English, they were translated into Amharic, which the participants use as an official language and as their mother tongue. The translation was made in the hope of increasing teachers’ understanding and reflection on each question. The translation was made by the first author. Then, the translation was reviewed in terms of meaning and word selection according to the original text by three scholars in the field of educational psychology. Then, two language experts who were competent in both Amharic and English reviewed the translation. The suggestions provided by peers and language experts contributed to improving the questionnaire. Using the translated questionnaire, the first author collected and analyzed data from pre-service secondary school teachers in 2017 as part of a PhD seminar course at Bahir Dar University. In addition, the questionnaire was administered to four secondary school teachers to obtain their comments on its meaningfulness and clarity. The comments were used to improve the questionnaire. These above-mentioned procedures contributed to validating the present data collection instrument.

Teachers in the selected schools were given information about the purpose of the study and were invited and encouraged to participate in it voluntarily. The questionnaire was administered to teachers who were willing to take part in the study. They completed the questionnaire in their own time (i.e., in the office or at home). It took 45 min, on average, to complete the questionnaire. Data were collected from January to February 2021.

## 2.3. Method of Data Analysis

The analytical framework used in this study was inspired by the seven NOSK aspects described by Liu and Lederman [8]. The responses provided by the participants in this study were analyzed question by question. Pre-specified categories, as in this study, in which the researcher was looking for the seven NOSK aspects, are useful if the researcher knows what he or she is looking for [22]. Such an analytic induction method of data analysis was also used by Liu and Lederman [8] to analyze the NOSK questionnaires. A scoring guide was used for the analysis of teachers’ responses to the open-ended questions. If a response was in line with the contemporary views of NOSK, it was rated as informed (score = 3). Syncretic or intermediate (score = 2) responses represented responses that were partially informed or failed to provide reasons for justification. Responses, including misunderstandings or self-

contradictory expressions, were evaluated as naïve views (score =1). Lastly, the following situations were rated as not classifiable (NC): no response was given; the participants stated that they did not know; the response did not refer to the question; or the response could not be rated according to checklist instructions. Similar scoring criteria for the open-ended NOSK items are used by different researchers [23–25].

### 3. Results

The first part of this section presents the demographic characteristics of the research participants. The second part presents the participants' responses to the NOSK aspects and describes their responses as informed, syncretic (has merit), or naïve.

#### 3.1. Demographic Characteristics of Participants

Table 1 shows the demographic characteristics of the participants in terms of their sex, school, and field of study. The participants were 48 science teachers, among them 13 biology, 16 chemistry, and 19 physics teachers. The majority (79.17%) were males. All participants had a minimum of a bachelor's degree (BSc/BEd). The participants' ages ranged from 32 to 60, with a mean of 46.60 years. The teaching service years of these participants ranged from 8 to 37 years, with a mean of 26.29 years.

**Table 1.** Demographic characteristics of participants.

| School Name                                      | Field of Study |        |           |        |         |        | Total |
|--------------------------------------------------|----------------|--------|-----------|--------|---------|--------|-------|
|                                                  | Biology        |        | Chemistry |        | Physics |        |       |
|                                                  | Male           | Female | Male      | Female | Male    | Female |       |
| Debre Markos General Secondary School            | 3              | 0      | 1         | 3      | 6       | 0      | 13    |
| Debre Markos Higher Education Preparatory School | 4              | 1      | 4         | 1      | 5       | 2      | 17    |
| Tana Haik Secondary School                       | 4              | 1      | 5         | 2      | 6       | 0      | 18    |
| Total                                            | 11             | 2      | 10        | 6      | 17      | 2      | 48    |

#### 3.2. Teachers' Conceptions of the NOSK Tenets

The research questions were: What conception do secondary school science teachers have about aspects of the nature of scientific knowledge? Do science teachers' conceptions about aspects of the NOSK align with an informed, naïve, or syncretic/intermediate view of the nature of science? Participants' responses to these questions are addressed in two sections. The first part presents the secondary school teachers' understanding of NOSK from the VNOS questionnaire in a summary table. The table presents the proportion of participants whose responses align with either of the response categories on the seven NOSK aspects. The second part presents excerpts from the teachers' NOSK responses to represent their informed or naïve conceptions of the NOSK and their interpretations.

##### 3.2.1. Empirical NOSK

The first and the second items on the present NOSK questionnaire explore teachers' definitions of science and the difference between science and philosophy/ religion. These items are stimulus materials intended to elicit the participants' understanding about the empirical basis of NOSK. Regarding the first question, which required a definition of science, most of the secondary school teachers responded with arguments that aligned with naïve conceptions of NOSK. Among them, 62.50% of respondents provided naïve arguments. No participant demonstrated an informed conception of empirical NOSK. There were, however, some participants (35.42%) who showed syncretic conceptions of NOSK. For example, participant T03, a female biology teacher who had 28 years of service in teaching, stated that "Science examines nature and generates new knowledge and it is a process of improving our way of doing that leads to improved life". To this participant,

science examines nature and generates new knowledge. In this regard, the participant's view fits with the contemporary view of NOSK. However, the participant's explanation of science's goal is naïve. Science seeks to describe, explain, and predict natural phenomena, but its goals go beyond making life better for humans. This participant approaches science from the standpoint of application. In other words, it is a means of refining and upgrading our way of doing. However, scientific research can also be used to address theoretical issues that might not directly benefit our quality of life. Thus, the conception reflected by participant T03 is classified into the syncretic category, meaning that while it is not sophisticated, it has some merit.

Another example under the syncretic category is the one provided by female physics teacher T11, who stated that "Science is a study supported by laboratory testing which studies relationships among phenomena, their differences and their characteristics". Here, it is important to note that science studies relationships among phenomena, the differences that exist between them, and their characteristics, and scientific research is also supported by laboratory work. In this regard, this participant provided an informed conception of what science studies. However, studies in science may or may not be supported by laboratory testing. Hence, this participant ignores those scientific issues studied without the laboratory setting. Consequently, the view this participant held is categorized as syncretic.

In defining science, the majority of participants held naïve conceptions. Let us see the following two excerpts:

*It [science] is truth confirmed by experimentation.* Participant T02

*Science is a field of study based on concrete knowledge.* Participant T10

The participants' naïve conceptions of NOSK were revealed by these two definitions, provided by T02, a male teacher with 30 years of experience teaching biology to students in grades 9 through 12, and T10, a male chemistry teacher with 29 years of experience. They described scientific knowledge either as a confirmed truth or exclusively based on concrete knowledge. However, scientific knowledge is not confirmed truth, contrary to the participant's response (T02); scientific knowledge can be produced by the imagination of the scientist (contrary to the argument of participant T10) and hence cannot be defined as concrete.

The arguments in the SSTs' responses to item #2 of the VNOS questionnaire asking them to explain the difference between science and other fields of study, such as religion and philosophy, revealed inadequate understandings of the empirical basis of NOSK. A male biology teacher with 29 years of experience teaching biology in grades 9 through 12 provided the following quote, which exemplified the teacher's syncretic knowledge of NOSK:

*Science is supported by research and evidence, whereas other fields of study (example, religion & philosophy) are based on belief which we cannot prove but continue believing in it.* Participant T04

The participant's conception indicated a syncretic conception of the empirical-based NOSK. The participant indicated that scientific knowledge is based on evidence and can be tested.

*The main reason that makes science different from other fields of study is that it is supported by laboratory. Science is based on laboratory work (like NMR, UV, IR ...) not on collecting information from people.* Participant T08

While the above participant's (a male physics teacher with 32 years of experience) argument indicating that scientific knowledge is supported by laboratory testing is true, the respondent's further explanation by giving examples of scientific laboratories by comparing with other fields is not an informed view of NOSK. This is because some scientific concepts are highly theoretical and are derived primarily from the logic and reasoning of scientists. Hence, the response of participant T08 reflects a naïve conception of the empirical NOSK. Furthermore, many responses to the question regarding teachers' conceptions of

the empirical NOSK revealed naïve conceptions. The following three quotations represent the naïve conceptions held by the participants:

*It is a truth tested and confirmed by experimentation.* Participant T32

*Science is based on confirmed findings but religion and philosophy are processes based on an individual's thinking and level of belief.* Participant T33

*It is a branch of knowledge confirmed by concrete evidence and through experimentation. It is truth that can be observed and touched.* Participant T36

The above three quoted excerpts were given by a male biology teacher with 32 years of service (T32), a female physics teacher with 25 years of service (T33), and a male chemistry teacher with 37 years of service (T36). The excerpts were chosen to represent those SSTs who held naïve conceptions about the empirical aspect of NOSK. They conceptualized science as either confirmed knowledge and/or a truth confirmed by experimentation. Such views of NOSK ignore the aspect of scientific knowledge that is based on scientists' explanations of the relationships among phenomena that emanate through inference. In summary, the secondary school teachers generally held naïve conceptions, and no teacher demonstrated an informed conception of empirical NOSK.

### 3.2.2. The Tentative NOSK

The tentative NOSK was explored based on participants' responses to the stimulus question: "Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example". The enterprise of science operates under the implicit assumption that scientific knowledge develops, builds upon itself, and changes over time. In line with this basic assumption, some teachers demonstrated informed conceptions of NOSK. More than half (58.33%) of the participants demonstrated informed conceptions of tentative NOSK. The following two excerpts represent teachers' informed conceptions of tentative NOSK.

*It can be changed. Because a long time ago, the knowledge that claims that the earth revolves around the sun was not accepted. But now it is confirmed by evidence. Other findings are also changed; everyday inventions are changing the world; the truth we hold is also changing.* Participant T33

*Yes, we have witnessed many improvements in scientific results. Therefore, even in the future, today's knowledge could be changed with better advancement. For example, when we see [consider the knowledge progression] 'Structure of the Atom', it is changed by improvements made by three different people [scientists].* Participant T34

However, a quarter (25%) of SSTs held naïve conceptions about the tentative NOSK. The following quotes are exemplars of the naïve tentative NOSK conceptions held by some teachers:

*They cannot be changed. These issues are studied based on scientific theories following procedures and reached to the conclusion that they cannot be changed.* Participant T20

*Scientists generate knowledge. Yes, knowledge is generated through research, experimentation, testing, explanation, and critiquing based on previous studies. Knowledge cannot be changed fully but it can be expanded or reduced because knowledge of science is initially based on truth. Example, the starting point of life is the cell.* Participant T35

Participants' perceptions that scientific knowledge is essentially static were reflected by the descriptions provided by T20, a male biology teacher with 17 years of experience, and T35, a female biology teacher with 34 years of experience teaching grades 8 through 10. Conceiving scientific knowledge as unchanging is in line with a naïve conception of the tentative NOSK.

### 3.2.3. Subjective Nature of Scientific Knowledge

Teachers' conceptions of the subjective NOSK were investigated using the stimulus question: "If different scientists use the same data, do you think their conclusions are the same or different? Illustrate with examples". Although the participants' responses fall into the three main categories (namely, informed, naïve, and syncretic conceptions), the majority (54.17%) of them aligned with the naïve conception of NOSK. Only 25% of participants showed informed conceptions about subjective NOSK. The remaining 20.83% held syncretic conceptions. The following two quotations taken from T37 (a male physics teacher) and T46 (a male chemistry teacher) represent informed conceptions reflected by the teachers.

*It can be different because inappropriate use of data can make differences; in addition, a difference in understanding of the data in depth could lead to different conclusions.*

Participant T37

*It can be different because they may interpret the data in different ways.* Participant T46

The above two participants indicated that, although researchers use the same data, they can come up with different conclusions because of individual differences in understanding and interpreting the data. Their arguments are in line with the informed conception of the subjective NOSK.

As presented in Table 2, more than half (54.17%) of secondary school science teachers did not hold adequate conceptions of subjective NOSK. The following quotations showed their naïve conceptions of NOSK:

*If they [Scientists] follow similar steps, similar measurements, etc., and do it with care, they can achieve similar results.* Participant T02

*It can be similar because a right (correct) study is valid, reliable and accurate. But a reliable study may not be valid. A false result may be reliable if we use wrong information (data).* Participant T39

The participants who showed naïve subjective NOSK explained that scientists who use similar data will come up with similar results. According to these participants, differences could emerge if scientists use different data-gathering tools or different data. Such conceptions are naïve in the sense that they fail to recognize that similar data could be interpreted differently based on the researchers' backgrounds, imagination, or creativity.

### 3.2.4. Distinction of Scientific Theories and Laws

The fifth question required teachers to construct their answers regarding the possible differences between scientific theories and scientific laws. The majority of the participants (60.42%), as can be seen in Table 2, held naïve conceptions about the nature of theories and laws. There was no participant who reflected informed conceptions about the distinction between scientific theories and laws. However, there were some (31.25%) participants who showed syncretic conceptions of NOSK.

The following two quotes reflect the participants' naïve conceptions.

*There is a difference. Scientific theory can be changed but scientific law cannot be changed. Example, Newton's First, Second, Third laws; the law of segregation & independent assessment (Mendel's 1st & 2nd laws).* Participant T39

*Theory can be changed or improved but law cannot be changed.* Participant T48

Participant T39 and Participant T48 are both male teachers teaching biology and physics, respectively, showing naïve conceptions of the distinction between scientific theories and laws. The quoted excerpts from these teachers indicated that scientific theory and scientific law are compared with the dimension of changeability. Theory is seen as changeable, whereas law is seen as fixed. Such views are naïve, as both theories and laws can be changed.

The SSTs' naïve conceptions are also reflected in the following quote:

*There is a difference [between scientific theory and scientific law]. If a scientific theory is confirmed, it becomes scientific law.* Participant T36

This participant puts scientific law and theory on a hierarchy, that is, scientific law as a higher status knowledge and scientific theory as a lower level. However, both scientific knowledge and scientific theory are not hierarchical. Instead, they represent distinctive aspects of scientific knowledge. This reveals that the participants held naïve conceptions about the distinction between scientific theories and scientific laws.

### 3.2.5. Creativity and Imagination

The research participants were asked to construct answers to the question "... Do you think that scientists use their imaginations and creativity when they do these investigations/experiments? ..." to investigate whether they held informed conceptions about this aspect of NOSK. Their responses revealed that 25% (see Table 2) of the participants demonstrated informed views, with the following being representative:

*Scientists use their imagination and creativity during research. That means although scientific research has its own way of doing it, it uses imagination and creativity during planning, data collection, data analysis, report writing. For example, before researching, it is necessary to have an understanding of the issue.* Participant T36

*They use. Einstein wrote his "Theory of relativity" using the above steps [Planning, data collection, data analysis, report writing].* Participant T48

The above two excerpts from participants' responses indicate that scientists use their creativity and imagination in planning throughout data analysis, and this is a demonstration of their informed conception of the creativity and imagination aspect of NOSK. Nevertheless, a little over half (52.08%) of the participants had naïve conceptions about the creative and imaginative NOSK, as demonstrated by the subsequent three quotations from a male physics teacher T14, as well as male chemistry teachers T28 and T44:

*They use it during report writing.* Participant T14

*They use. They use it during the planning stage as they convert what they hold in their imagination into a plan.* Participant T28

*They are used during planning and data collection.* Participant T44

These respondents believe that scientists use their creativity and imagination at some phases of the investigation process, either during planning, data collection, or both planning and data collection, but not at all phases. As creativity and imagination can be used at all stages of scientific investigation, such views are indications of the naïve conceptions of the participants about the creative and imaginative NOSK.

### 3.2.6. Inference and Nature of Science

The stimulus question used to investigate teachers' conceptions of the inferential NOSK was: "The model of the inside of the Earth shows that the Earth is made up of layers called the crust, upper mantle, mantle, outer core and the inner core. Does the model of the layers of the Earth exactly represent how the inside of the Earth looks? Explain your answer". As can be observed in Table 2, the participants' responses revealed that only a few (10.42%) teachers demonstrated adequate understanding of the distinction between observation and inference. These teachers noted that the layers in the model of the earth (crust, mantle, and core) cannot be directly observed; rather, they are constructed through the analysis of indirect evidence. The following participants' argument supported the idea of uncertainty while discussing the issue of how the model of the layers of the earth is formulated:

*It does not mean that science is done without error. Through the process of vibration on earth, they studied the inner part of the earth and I believe that to some extent they got somehow credible results.* Participant T33

*It is difficult to conclude that it represents them exactly because this is a theory that is not directly observed. Its internal part—the depth, content, diameter, and circumference may not be correct. Participant T42*

**Table 2.** Secondary school teachers' conceptions of the nature of scientific knowledge (NOSK),  $n = 48$ .

| NOSK Aspect                                      | Conceptions of NOSK |          |                     |       |                  |
|--------------------------------------------------|---------------------|----------|---------------------|-------|------------------|
|                                                  |                     | Informed | Syncretic/Has Merit | Naïve | Not Classifiable |
| Empirical NOSK (Q1 and Q2)                       | Count               | -        | 17                  | 30    | 1                |
|                                                  | Percent             | -        | 35.42               | 62.50 | 2.08             |
| The tentative NOSK (Q3 and Q9)                   | Count               | 28       | 8                   | 12    | -                |
|                                                  | Percent             | 58.33    | 16.67               | 25    | -                |
| Subjective NOSK (Q4 and Q7)                      | Count               | 12       | 10                  | 26    | -                |
|                                                  | Percent             | 25       | 20.83               | 54.17 | -                |
| Distinction of scientific theories and laws (Q5) | Counts              | -        | 15                  | 29    | 4                |
|                                                  | Percent             | -        | 31.25               | 60.42 | 8.33             |
| Creativity and imagination (Q6)                  | Count               | 12       | 7                   | 25    | 4                |
|                                                  | Percent             | 25       | 14.58               | 52.08 | 8.33             |
| Inferential NOSK (Q8)                            | Count               | 5        | 9                   | 7     | 27               |
|                                                  | Percent             | 10.42    | 18.75               | 14.58 | 56.25            |
| Society, culture and science (Q10)               | Count               | 31       | 7                   | 6     | 4                |
|                                                  | Percent             | 64.58    | 14.58               | 12.5  | 8.33             |

The above respondents explained that the representation of the layers of the earth as crust, mantle, and inner core may not be accurate in terms of their size and substances within them, as it is inferred from evidence that is not directly observed. Therefore, the model of the earth in terms of these three dimensions is a result of inferences, as explained by the participants. Thus, the conceptions they held are in line with informed conceptions of the inferential NOSK. However, there were some participants (14.58%) who possessed a naïve conception of the inferential NOSK.

*The lower layer of the earth is correctly represented. This is evident by the capacity of the lower layer to carry load [pressure from the crust and mantle] and by the earth's movement and volcanoes. Participant T27*

*This is scientific and also experimental. The three layers can be observed through electromagnetic waves. Participant T48*

The participants quoted above tended to believe that the model of the layers of the earth is correctly represented, as if it is proven through evidence, including experimentation. Such a conception of participants who perceive science as established knowledge based on evidence or experimentation and observation while ignoring the inferential NOSK is naïve.

What is odd about this aspect of NOSK is that more than half of the participants' (56.25%) (see Table 2) explanations either did not directly relate to the issue or were "I do not know" or left blank. These responses were rated as an unclassified category. One participant responded, "I don't know. If you are able to ask geography teachers, they can give you better information". This indicates that this participant believes the topic is an issue of geography, but not an issue involving science subjects (i.e., biology, chemistry, and physics). This could imply that science teachers, besides lacking an understanding of how scientific theories and models are developed, may not have dealt with topics about the representation of the earth's layers.

### 3.2.7. Social and Cultural Influences of NOSK

The participants' constructed responses to the question presented to investigate their conceptions of the social and cultural NOSK (question number 10) fell into four categories, that is, the informed, syncretic, naïve, and unclassified categories. As can be observed from Table 2, the majority of respondents (64.58%) demonstrated informed NOSK conceptions about the influence of society and culture on the production of scientific knowledge. The following quotes show teachers' informed conceptions.

*They affect scientific research. Because they believe that societal and cultural values passed through generations are right and argue against the scientific results. Whatever truth is told through scientific investigations, they will not accept it. For example, [our] society believed COVID-19 is God's wrath [for our sinful behaviors]. Therefore, they believe God will cure them, but not the washing of hands and wearing masks. Participant T28*

*It has been created before, it is created now, and it will create an effect in the future. For example, before:—The sun revolves around the earth. Now:—The earth revolves around the sun. In religion, such scientists were treated to the extent of receiving capital punishment, but now [the situation is] changed. Evolution is not acceptable by religious people who believe that things that have life are created by God, but its acceptance is increased by people who are cultivated by science. Participant T33*

In the two quotes provided from the descriptions of male physics teachers T28 and T33, it is argued that cultural and societal factors can impact the scientific investigation process and/or the usability of the results. Hence, their conceptions are in line with the informed conceptions of social and cultural NOSK. Nevertheless, few of the respondents (12.50%) held naïve conceptions about the societal and cultural impact on NOSK. The following quoted materials from the respondents were selected to show their naïve conceptions.

*Societal and cultural values are not science, as they are cultures, traditions and habits; I do not believe that they have an effect on scientific research. Participant T11*

*In scientific research, society and culture do not have an effect. Because the individual who undertakes the investigation should make himself/herself part of society [as participant observer]. Participant T18*

*Which type of study??? It has more impact on social studies research. Participant T38*

Participants T11 (a female physics teacher) and T18 (a male physics teacher) argued that societal and cultural values do not have an effect on scientific research, which is contrary to contemporary conceptions of NOSK. Thus, their arguments are naïve regarding the societal and cultural NOSK. The other quoted response from participant T38 shows surprise at the stimulus question; they asked "Which type of study?" By this, the teacher implied that scientific studies cannot be affected by the cultural and societal values. This reflected his/her naïve conceptions of the effect of society and culture on NOSK. Thus, the conceptions of the three participants quoted above showed naïve conceptions regarding the culturally embedded NOSK.

## 4. Discussion

This study explored the conceptions of the nature of scientific knowledge among secondary school science teachers. NOSK is a framework that encompasses seven aspects of scientific inquiry that are considered appropriate for K-12 education. These aspects are: empirical nature, tentative nature, subjective nature, distinction between scientific theory and law, use of imagination and creativity, inferential nature, and impact of culture and society. The results revealed that the teachers had mixed conceptions of NOSK. They demonstrated informed views on the tentative nature and the social and cultural influences of NOSK, but naïve views on the empirical nature, the subjective nature, the distinction between theory and law, and the use of imagination and creativity in NOSK. One aspect, the inferential NOSK, was not clearly classified by the teachers' responses. The follow-

ing sections focused on presenting the current results in the context of other findings in the literature.

#### 4.1. Scientific Theories and Laws

Secondary school teachers did not provide informed views about the distinction between scientific theories and laws. Although some (31.25%) showed syncretic conceptions of NOSK, the majority of participants (60.42%) held naïve conceptions regarding the nature of theories and laws. In this study, theory is seen as changeable whereas law is seen as fixed. Some of the present participants conceive scientific laws and theories as hierarchies, that is, scientific law as a higher status of knowledge and scientific theory as a lower level. Such views are naïve, as not only do both theories and laws change, but they are not hierarchical. Instead, they represent distinctive aspects of scientific knowledge.

A wealth of research evidence has exposed that teachers' conceptions of the nature of theories and laws are naïve. For example, through their work with Bhutanese science teachers, Dorji et al. [26] reported similar findings to those of the present study. In their study, the majority of teachers expressed uninformed conceptions of the distinction between scientific theories and laws. Dorji et al. [26] also revealed that their participants expressed a hierarchical relationship between scientific theories and laws, viewing scientific theories as low-status knowledge that can become laws either in light of evidence or when arguments are supported by logic and reason. Relatedly, Saif [27] reported that the majority of science teachers believed that scientific theories are less secure than laws; and scientific theories are developed to become laws. Another study by Morrison et al. [28] also revealed that teachers did not express informed conceptions of the nature of theories/laws even after intervention. A survey by Sangsa-ard and Thathong [29] also reported that junior high school teachers (i.e., Thailand) held naïve conceptions about the distinction between theories and laws. In sum, teachers' conceptions about scientific theories and laws are naïve across cultures, including in the present study. They view scientific law as high-status and more secure than scientific theory.

#### 4.2. Empirical NOSK

The majority of the science teachers in the present study (60.42%) expressed naïve arguments about the empirical NOSK, and no participant demonstrated an informed conception of empirical NOSK. They conceptualized science as confirmed knowledge and/or truth confirmed by experimentation. Such views of NOSK ignore the aspect of scientific knowledge based on scientists' explanations of the relationships between phenomena. This explanation comes from their imagination and creativity. Nevertheless, there were some participants (37.50%) who showed syncretic conceptions of empirical NOSK. This result is consistent with Saif's [27] findings, which showed that teachers had a naïve understanding of the empirical NOSK. In Saif's study, the majority believed that scientific knowledge resulted from only experiments. However, the present study is not congruent with Dorji et al.'s result [26], which found that the vast majority (80%) of Bhutanese science teachers expressed informed conceptions regarding the empirical NOSK.

The differences in research results could be due to cultural differences, including religious differences, which may influence teachers' conception of NOSK [30]. In addition, Ethiopian education is dominated by teacher-centered methods [14,15], which could imply that scientific knowledge is regarded as an established truth that should be transmitted from the teacher to the student without giving room for student activities. These aspects could contribute to the participants' naïve conception of the empirically based NOSK.

#### 4.3. Creativity and Imagination

With regard to scientists' use of creativity and imagination, a quarter of the respondents expressed informed conceptions of the use of creativity and imagination in scientific knowledge production. They indicated that scientists use their creativity and imagination for planning throughout data analysis. However, more than half (52.08%) of the respon-

dents in this study held naïve conceptions of the creative and imaginative NOSK. These respondents believed that the scientists use their creativity and imagination at some phases of the investigation process during either planning, data collection, or both planning and data collection, but not at all phases. As creativity and imagination are sources of inspiration and innovation, they are used at all stages of scientific investigation [8]. Thus, the views reflected by the present participants are indications of their naïve conceptions. The result of this study is not congruent with the findings of Saif [27] and Dorji et al. [26], who reported that the majority of Saudi Arabian and Bhutanese science teachers recognized the role of imagination and creativity in their respective participants. The participants in the above-mentioned research indicated that scientific knowledge is produced through educated guesses, imagination, and creativity, in addition to experimental results, which is in line with informed conceptions of scientists' use of creativity and imagination. These differences could result from the differences in the science education curricula in Ethiopia (this study's participants), Saudi Arabia, and Bhutan. Saudi Arabia is one of the wealthiest nations in this world. Although being wealthy cannot be translated directly into effecting the best education system, it places the country in a better position to recruit and better train science teachers and to develop and implement science curricula that adopt contemporary views of NOSK. Bhutan, a lower-middle-income country, could have curricular and pedagogical approaches that are in line with contemporary conceptions of NOSK as compared to Ethiopia, which is a low-income country.

The naïve conceptions of Ethiopian science teachers may be a result of the representation of scientific knowledge reflected in curricular materials, as well as teaching and learning practices, as a concrete truth deriving directly from laboratory investigations, as well as the scant representation of the production of scientific knowledge through human endeavor in the sense of creative thinking and innovations that accompany the empirical basis of science. Furthermore, the nature of science in general is not taken as an issue in studies conducted in Ethiopia [20].

#### 4.4. Social and Cultural NOSK

The majority of the teachers (64.58%) in this study expressed informed NOSK conceptions of the influence of society and culture on the production of scientific knowledge. The teachers expressed that cultural and societal factors can impact the scientific investigation process and/or usability of the results. This result is a demonstration of their contemporary views on the social and cultural embeddedness of scientific knowledge. A similar finding was reported by Dorji et al. [26], who reported that Bhutanese science teachers expressed scientific knowledge as a product of either social or cultural values, or both. Similarly, Saif [27] found that science teachers expressed that the development of scientific knowledge is affected by society, politics, and culture.

#### 4.5. Tentativeness

Although scientific knowledge is durable and reliable, it is not absolute and, thus, is subject to change [31]. More than half (58.33%) of the teachers in this study demonstrated informed conceptions of tentative NOSK. They illustrated the changeability of scientific knowledge by presenting examples like geocentric knowledge, which was once accepted as scientific knowledge, being changed to a heliocentric view; the knowledge of the structure of atoms was also changed through the works of different scientists. Their answers indicated that with evidence, a new way of interpreting the existing evidence, or the advancement of scientific tools and methods, scientific knowledge can be totally rejected and replaced by a new concept or modified in some way. This result is similar to the findings of Dorji et al. [26], who found that science teachers have expressed informed conceptions about the tentative NOSK. In a similar vein, Saif [27] reported that science teachers held contemporary conceptions about the changeability of NOSK. On the other hand, Ma [32] reported that Chinese secondary school teachers view scientific knowledge as more certain than tentative.

#### 4.6. Subjective NOSK

More than half (54.17%) of the teachers in this study aligned with the naïve conception of subjective NOSK. Only 25% of participants showed informed conceptions about subjective NOSK. The remaining (20.83%) held syncretic conceptions. This clearly shows that the majority of Ethiopian science teachers who participated in this study expressed naïve conceptions of subjective NOSK, believing that scientists are objective and are not influenced by their background knowledge when carrying out scientific investigations. This result is consistent with the findings of Iqbal et al. [9]. Iqbal et al. reported that secondary school teachers in Pakistan held naïve conceptions about the subjective NOSK; they believed that scientists are objective and open-minded, and use empirical evidence and report exact data truthfully following a step-by-step scientific method. A similar naïve conception held by teachers was reported by Saif [27], which consisted of the idea that scientists are open-minded about investigating scientific issues objectively without any subjective bias.

#### 4.7. Inferential NOSK

The analysis of teachers' responses on inferential NOSK revealed that the majority of the teachers do not demonstrate informed conceptions of NOSK. Only few (10.42%) participants demonstrated an informed understanding of the distinction between observation and inference. They noted that the layers in the model of the earth (crust, mantle, and core) are not directly observed; rather, they are constructed through the analysis of indirect evidence. However, more than half of the participants' (56.25%) explanations either did not directly relate to the issue, responded "I do not know", or were left blank. These responses were rated as an unclassified category. And some of the participants believed that the model of the layers of the earth is correctly represented through evidence including experimentation. Such a conception of participants who perceive science as established knowledge based on evidence or experimentation and observation while ignoring the inferential NOSK is naïve.

Iqbal et al. [9] also found similar results in that the Pakistani teachers reflected naïve conceptions about the inferential NOSK. These teachers believed that scientists report the exact data as they are. Saif [27] also reported that the majority of science teachers believe that a scientific model (e.g., the atomic model) is a copy of reality. Relatedly, findings reported by Morrison et al. [28] revealed that science teachers did not demonstrate informed conceptions of the inferential NOSK.

### 5. Conclusions and Implications

The overall results of this study showed that secondary school teachers' conceptions of the NOSK are aligned with uninformed conceptions. It was only in two of the seven NOSK aspects examined in this study, namely, the tentative NOSK and the influence of culture and society on NOSK, that the majority of the teachers reflected informed conceptions. On the five aspects—empirical, subjective, distinction between scientific theories and laws, creativity and imagination, and inferential NOSK—the teachers held uninformed conceptions of contemporary NOSK.

Developing an understanding of contemporary and constructive notions of the NOSK is an essential goal of science education in many countries. This is due to the belief that understanding NOSK is critical to developing an understanding of scientific literacy and to achieve an in-depth understanding of the subject matter of science [6,19,33]. Without being scientifically literate, students' ability to make informed decisions will be compromised [19]. Furthermore, from the psychological point of view, students having informed conceptions of NOSK are independent and confident and play an active role in their own learning [9].

It is necessary for teachers to engage students in a teaching–learning process on how scientific knowledge is developed and accepted. However, the teachers in this study who are expected to help students develop NOSK understanding do not themselves demonstrate adequate understanding of NOSK. It is reasonable to assume that inadequate views of NOSK held by teachers may prevent them from teaching about NOSK [19,34]. Teachers

with informed conceptions about the NOSK tenets are a prerequisite to incorporating NOSK into classroom teaching and learning [35].

Therefore, professional development programs and short-term training should be organized by the Ministry of Education, Regional Education Bureaus, Education colleges, and universities of the country to enhance teachers' understanding of NOSK.

## 6. Limitations of the Study and Implications for Future Research

This study has some limitations. The study sample focused on three schools from two cities in one of the regions (i.e., Amhara region) of Ethiopia. The impacts of cultural differences on teachers' NOSK conceptions in varied regions remain undiscovered. In addition, suburban schools in the studied region were not included in this study. Moreover, the information gained in this study is limited to secondary school teachers. Regarding research methods, this research used descriptive analysis and frequency counts and percentages. Future research is required in order to study the NOSK conceptions of primary school and higher education teachers, as well as students from primary through tertiary levels across different regions in the country, to gain better insight into teachers' NOSK conceptions at different educational levels. Larger samples might lead to some generalizable results. Comparative studies are also needed to shed light on the NOSK conceptions of Ethiopian students and teachers in relation to other developing and developed nations.

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