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þÿSecondary School Students A
þÿScience Teachers Conception
Nature Of Scientific Knowledge

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DEPARTMENT OF PSYCHOLOGY

SECONDARY SCHOOL STUDENTS' AND SCIENCE TEACHERS' CONCEPTIONS OF THE NATURE OF SCIENTIFIC KNOWLEDGE

BY

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JULY 2024

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A DISSERTATION SUBMITTED TO THE COLLEGE OF EDUCATION, SCHOOL OF EDUCATIONAL SCIENCES, BAHIR DAR UNIVERSITY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN EDUCATIONAL PSYCHOLOGY

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Declaration

This is to certify that the thesis entitled “Secondary School Students’ and Teachers’ Conceptions of the Nature of Science”, submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Educational Psychology of the Department of Psychology, Bahir Dar University, is a record of original work carried out by me and has never been submitted to this or any other institution to get any other degree or certificates. The assistance and help I received during the course of this investigation have been duly acknowledged.

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Approval of Dissertation defense

We hereby certify that we have supervised, read, and evaluated this dissertation titled "Secondary School Students' and Science Teachers' Conceptions of the Nature of Scientific Knowledge" by Tadele Demelash Teshale prepared under our guidance. We recommend the dissertation be submitted for oral defense (mock-viva and viva voce).

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Approval of Dissertation for defense result

We hereby certify that we have examined this dissertation entitled "Secondary School Students' and Science Teachers' Conceptions of the Nature of Scientific Knowledge" by *Tadele Demelash Teshale*. We recommend that the Dissertation is approved for the degree of "Doctor of Philosophy in Educational Psychology"

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Abstract

This study examined secondary school students and science teachers' conceptions of the nature of scientific knowledge (NOSK). A pragmatic research philosophy was adopted in this study. To address the objectives of the research, a mixed methods approach was employed. Open-ended questionnaires were used to collect data from 134 students, and 48 science teachers. The participants were selected from three schools using a convenient sampling technique. Qualitative analysis involved comparing students' and teachers' responses to experts' views of NOSK. Frequency counts and percentages were also used to describe the NOSK conceptions of the participants. In addition, the Mann-Whitney U test was used to compare students' conceptions of NOSK by grade level and gender. The findings showed that most of the secondary school students had naïve conceptions about NOSK. On a comparative basis, grade 12 students reflected more informed NOSK views than grade 10 students on most of the tenets. Mann-Whitney U test revealed that the mean rank score of grade 12 students is significantly greater than grade 10 students on the subjective (U=3.20, p<.05) and cultural (U=2.42, p<.01) aspects of NOSK. The teachers 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. The findings indicated that there is a need to devise mechanisms to develop secondary school students' and teachers' NOSK understanding to attain its promised benefits. Future research should investigate students' and teachers' NOSK conceptions using large samples across grade levels, from diversified schools, including private and public schools from the different regions of the country to reveal students' and teachers' NOSK conceptions.

Keywords: nature of science, scientific knowledge, secondary school, views of nature of science, students' conceptions, teachers' conceptions

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Acronyms/ Abbreviations

MoE - Ministry of Education (Ethiopian)

NOSK/ NOS - Nature of scientific knowledge (Nature of science)

OECD - Organization for economic cooperation and development

PISA - Programme for International Student Assessment

QUAL - Qualitative

QUAN – Quantitative

S - Student

SS - Secondary school

T- Teacher

UNIT ONE

INTRODUCTION

1.1. Background to the study

Scientific literacy has emerged as a legitimized and central goal of science education in many countries of the world (N. G. Lederman, 2014; McEneaney, 2003; Özdem et al., 2010). The term scientific literacy is used to express the broad and encompassing goal of science education (Bybee et al., 2009). In fact, the core curricular component of science education is scientific literacy (Chaisri & Thathong, 2014). And the most fundamental rationale for providing science education is to develop students' scientific literacy (Glaze, 2018; Seyhan & Türk, 2013; Yalaki et al., 2019).

Scientific literacy is conceptualized by different authors somehow similarly. For example, Abd-El-Khalick et al. (1997, p.417) conceptualized scientific literacy as “one’s understanding of the concepts, principles, theories, and processes of science, and one’s awareness of the complex relationships between science, technology, and society”. More recently the National Academies of Sciences and Engineering (2016) provided a more expanded definition of science literacy beyond basic knowledge of science facts which include “understandings of scientific processes and practices, familiarity with how science and scientists work, a capacity to weigh and evaluate the products of science, and an ability to engage in civic decisions about the value of science.” In general, scientific literacy can be conceptualized as an understanding of scientific concepts and processes, awareness about how science and scientists work, and ability to engage in making decisions related to personal, civic, cultural, and economic issues.

Here, it is important to note that there is a difference between science literacy and scientific literacy, although both phrases are often used synonymously in the literature. After an exhaustive review of the literature on how literacy is conceptualized, Roberts (2010) identified differences between science literacy and scientific literacy. Science literacy focuses on the knowledge, processes, and products of science; whereas, scientific literacy refers to the knowledge of science and the applications of this knowledge to make decisions about personal and societal situations that have both science and non-science components (Roberts, 2010). The individual's ability to make informed decisions about scientifically–based personal or social issues is associated with scientific literacy (N. G. Lederman et al., 2014). Moreover, using the term "scientific literacy" rather than "science literacy" places emphasis on the application of scientific knowledge in the context of life situations than the simple reproduction of traditional school science knowledge (OECD, 2013).

Thus, the focus of this paper is aligned with scientific literacy. This is so because the major purpose of this paper is to investigate the nature of science and it has been widely accepted that understanding the nature of scientific knowledge (NOSK) is a major component of scientific literacy. Science curricula in many countries of the world now explicitly recognize NOSK as an integral component of scientific literacy (Allchin, 2014; Chaisri & Thathong, 2014; Iqbal et al., 2009).

Nature of science refers to the epistemology of science and the values and assumptions embedded in scientific knowledge and the development of scientific knowledge (Aflalo, 2018; N. G. Lederman & Lederman, 2004; Liu & Lederman, 2007; Mesci & Schwartz, 2017). This definition of NOSK demonstrated some consensus among researchers and educators of NOSK. There exists some differences among philosophers of science, educators of science and researchers about the meaning of NOSK (N. G. Lederman et al., 2013; McComas, 2015). However, it is suggested that debating about a "definitive" or universal definition of the construct NOSK is hardly productive (N. G. Lederman et al., 2014). Instead, focusing on developing students' understanding of NOSK which are accepted by the philosophers, educators and researchers of science is more viable. Importantly, there is a high level of consensus among them on the NOSK aspects that are important to students from K-12 (N. G. Lederman et al., 2014; N. G. Lederman & Lederman, 2004; McComas, 2015). This implies that the existing differences about the universal definition of NOSK are not relevant to K-12 learning and teaching. And thus, this study will focus on seven aspects of NOSK which are generally agreed upon to be relevant to all citizens to know to K-12 students (Liu & Lederman, 2007; McComas, 2015). These seven aspects of NOSK are: (1) Empirical nature of science; (2) Observation and Inferential based nature of science; (3) Tentative nature of science; (4) Theory-laden nature of science; (5) Social and Cultural embededdness of scientific knowledge; (6) Creative and Imaginative nature of scientific knowledge; and (7) Distinction between a scientific law and theory.

Scientific literacy can be considered as the main goal for the 21st century science education (Turiman et al., 2012). This is partly because scientific literacy plays a role in fostering education for sustainability, that is, for sustainable human development and sustainable economic growth (Correia et al., 2010; Kostøl et al., 2022). Özdem et al.

(2010, p.6) stated that "In a rapidly changing world, at the very top of the list of educational goals, there is the need to educate young people in order them to know and be able to use new scientific and technological tools." In this 21st century, which is an era of globalization, students need to be equipped with skills involving science and technology to ensure their competitiveness (Rahayu, 2017; Turiman et al., 2012).

Moreover, the goal of students' achieving an in-depth understanding of science subjects is unattainable unless students understand NOSK (N. G. Lederman et al., 2013). For teachers to be able to teach about NOSK to their students, it is necessary to have an adequate understanding of NOSK themselves (Yenice & Saydam, 2010). Teachers need to have informed conceptions of NOSK themselves not only to make informed decisions of everyday demands of their life, but most importantly to enhance their students' understanding of NOSK. Although teachers are required to teach their students to develop appropriate views of NOSK at all grade levels, it is unlikely that those teachers who possess naïve conceptions of the nature of scientific knowledge (NOSK) themselves would be able to help their students develop informed NOSK views (Akerson & Volrich, 2006). This is because developing an understanding of NOSK is a prerequisite, although not a sufficient condition, to teaching science in-depth (N. G. Lederman et al., 2013; Liu & Lederman, 2007).

Different researchers in science education across levels identified gaps in students' conceptions of the nature of science. For example, Glaz (2018) reported that there are students entering and leaving secondary schools with inadequate comprehension of science as a way of knowing and how it is conducted. Khishfe (2012) also assessed grade 9 students' conceptions of NOSK prior to instruction and found that they possessed naïve and intermediary understandings of the studied five aspects. The studied NOSK aspects were the tentative, empirical, inferential, creative and imaginative, and subjective NOSK. Khishfe reported that only a minority of the participants elucidated informed understandings of one or two NOSK aspects.

One of the major concerns in science education involves the under-representation of many groups in science and technology fields, especially by gender (Vincent-Ruz & Schunn, 2018). There are few studies that investigated the relationship between gender and NOSK. Among those few studies, Acar, Büber and Tola (2015) found no score difference between females and males of Grade eight Turkish students NOSK understanding although females surpassed males on physics conceptual knowledge test. A study by Toma et al. (2019), however, found that primary school boys had more naïve conceptions on NOSK (particularly on empirical NOSK), although boys had showed better attitude towards science than girls. Thus, studies of NOSK in relation to gender are very limited and the findings are inconsistent which calls for further investigation.

As the students' grade level increases, their understanding of the nature of science is expected to increase. Although few studies are available with this regard, a study investigated the relationship between grade level (grade 7, grade 8 & grade 9) and NOSK understanding found that students in higher grades showed more sophisticated NOSK conceptions (Kremer et al., 2014). However, a study by Toma et al. (2019) has found opposing findings concerning the relationship between grade level and NOSK understanding, specifically the tentative aspect of NOSK. They reported that as grade levels increased, students' conceptions of the tentative NOSK became more naïve. These inconsistent findings need further investigation on the relationship between students' grade level and nature of science conceptions.

Lack of sufficient understanding of NOSK tenets is also reflected by teachers. For example, a study by Aslan and Taşar (2013) revealed that the participating science teachers held naïve views on many dimensions of the NOSK. For instance, teachers possess a naïve conception that there exists a universal scientific method with certain steps. In a similar way, all teachers in their study held naïve views on the tentative nature of scientific knowledge. In Aslan and Taşar's study, a misconception about the idea that scientific knowledge changes, but scientific laws do not change is also revealed. Other investigators reported that the majority of the teachers in their sample held naïve views of NOSK (Dogan & Abd-El-Khalick, 2008; Yalçinoğlu & Anagün, 2012). These show that misconception about the nature of science exists not only by students but also by the teachers.

In Ethiopia, a study assessed the status of science in primary schools of Addis Ababa, although not directly addressed NOSK tenets, revealed that the textbooks are characterized by the lack of activities that promote the students' process skills of science (Tesfaye et al., 2010). Lack of practical skills is also reported in the secondary schools of Ethiopia (Ayalew, 2017). With regard to the importance of science process skills to NOSK understanding, Krajewski and Schwartz (2014) concluded that emphasizing process–oriented science learning as opposed to product–oriented learning is essential for realizing NOSK teaching. This is because the process skills provide a framework for addressing the nature of science by guiding teachers to recognize where the nature of science fit into the science curriculum (Bell et al., 2012). Therefore, the lack of activities promoting the science process skills might have a hindering consequence of the students NOSK understanding. Thus, it is imperative to examine what understanding do Ethiopian secondary school students have in relation to the nature of science.

Teachers' knowledge and understanding of NOSK is one of the main factors that influence students' knowledge and understanding of NOSK tenets. The importance of teachers' understanding of the nature of science arises from the assumption that to teach content knowledge, including NOSK, teachers must have an adequate understanding of the content (N. G. Lederman et al., 2002). Students gain much of the scientific information from their science teachers (Koksal & Cakiroglu, 2010; Liu & Lederman, 2007). Students' misconceptions of NOSK could have resulted from teachers' instructional planning and practices. Teachers who are not well informed about modern NOSK themselves will not be able to enhance their students achieve the objectives of NOSK. That is, teachers' views of NOSK will translate to their classroom behaviors and practices which in turn affects students' view of NOSK (Abd-El-khalick & Lederman, 2000) directly or indirectly. Therefore, teachers' conceptions of NOSK are worth investigating.

Framed on important premises that scientific literacy has desirable contributions in improving decision-making skills in all aspects of life including health, problem-solving etc. which ultimately contribute to the betterment of a nation, science education is given a secured place in the school curricula of both developed and developing countries(Iqbal et al., 2009). Ethiopia is among those developing countries which offered science subjects to its students from primary to secondary schools. The Ethiopian Ministry of Education (MoE, 2009) in its curriculum framework for education (KG-

Grade 12) document describes science to be offered from primary to general secondary levels to all students, although the structure of science curriculum at the different levels varies. However, the impact of the Ethiopian secondary school science curricula with respect to developing student NOSK conceptions remained unknown.

Literature is not available on the status of Ethiopian secondary school students and teachers with regard to NOSK understanding (Berie et al., 2022). This could be resulted, partly, from the less emphasis given to the NOSK construct in the Ethiopian science education research. Thus, it is necessary to investigate the current status of NOSK understanding of Ethiopian teachers and students. That is, investigating whether Ethiopian secondary school teachers and students held contemporary or uninformed conceptions of NOSK will be the focus of this study.

Identifying areas of NOSK on which teachers and students have an adequate and inadequate conception is a prerequisite to design instruction in accordance with their needs. Research findings help teachers to refine the NOSK objectives and plans to meet the specific gaps (Miller et al., 2010). Accordingly, this study will be devoted to identifying secondary school teachers' and students' conceptions of NOSK aspects.

1.2. Statement of the problem

Developing students' and teachers' conceptions of the nature of science has been a goal of science education for several years (Abd-El-khalick & Lederman, 2000; N. G. Lederman, 1992; Liu & Lederman, 2007; McComas, 2015, 2017). There has been an increasing agreement that students and teachers alike must understand both the traditional science content and the nature of science. Understanding NOSK is important if individuals are going to make responsible personal decisions and become effective local and global citizens (Sangsa-ard & Thathong, 2014). To understand the characteristics of scientific knowledge and how it is obtained, citizens need to be able to appraise claims and apply scientific knowledge that may affect their everyday decisions about things such as health, diet, choosing energy resources and to reach informed views on matters of public policy regarding these areas (Bell & Lederman, 2003). Because of such reasons, helping students to develop sophisticated views of NOSK is a long standing goal of science education (Abd-El-Khalick, 2013; N. G. Lederman et al., 2013; Pleasants, 2017) and its relevance is very critical these days than ever before. McComas (2017) stated its necessity in the present time than ever before as follows:

> This is very timely content. In various nations, it has recently become clear that large numbers of individuals fail to distinguish between news and 'fake news', facts and 'alternative facts'. Understanding how knowledge is generated and validated in science can help. There has never been a more crucial time for students – on their road to becoming reflective citizens– to understand how science functions. This understanding, in turn, will enable our future citizens to evaluate and judge scientific knowledge claims and act appropriately. (p.72)

Literature has also indicated that students' understanding of NOSK has an important role in their science content learning. With this regard, Lederman et al. (N. G. Lederman et al., 2013) stated that those students who do not possess an adequate understanding of NOSK will not develop a deeper understanding of science subjects. The development of students' NOS understanding has been considered an important and vital part of science instruction (Kang et al., 2004; N. G. Lederman et al., 2013). However, NOSK comprehension is affected by different variables, including the cultural context and teachers' levels of NOSK understanding. For example, the learning context in Europe is quite different from that of Asia (Kang et al., 2004), and both learning contexts are different from Africa. Related to this, Leach (2006) stated that different epistemological views are legitimate in different contexts, and that students' epistemological perspectives are likely to be influenced by context. According to Leach, the knowledge generated from studies designed in specific contexts is suitable for informing teaching in those specific contexts. This implies that it is necessary to identify the students' current understanding of NOSK in the Ethiopian context to design effective NOSK instruction.

During classroom interactions teachers' knowledge and values of NOSK are likely to affect students NOSK views either to the informed or naïve conception depending on their current views. With this respect, Sangsa-ard and Thathong (2014) concluded that teachers' conception of NOSK is critical to the implementation of science curricula because they may implement it in a way that reflects their own view of the NOSK. For successful instruction of the NOSK, it is imperative that teachers need to firstly understand NOS concepts before any learning intervention related to the NOSK can take place (Liu & Lederman, 2007; Sangsa-ard & Thathong, 2014). Moreover, efforts should be made to promote science teachers to value NOSK beyond understanding NOSK content and pedagogy (Clough, 2018).

Studies on teachers' NOSK views have mainly focused on pre-service elementary teachers (Firestone et al., 2012). The scant research on secondary school teachers revealed that the teachers held naïve views on many aspects of NOSK. For example, a study by Sangsa-ard and Thathong (2014) investigated junior high school science teachers in Thailand and found that the majority held naïve and intermediate views in all (seven) surveyed aspects of NOSK. A study by Iqbal et al.(2009) also found that the majority of secondary school science teachers in Pakistan fall in the traditional domain of NOSK; they lack a sophisticated understanding of the nature of scientific knowledge.

The literature discussed so far has indicated the need to develop students' NOSK understanding; and to enhance students' NOSK conceptions teachers must have informed views of the NOSK aspects. Therefore, before attempting to design any instruction or curriculum aiming at developing students' NOSK conception, it is necessary to examine what understanding students and teachers possess on the aspects of NOSK. Identifying students' current conceptions of NOSK is a key step to presenting them with experiences that have meaningful links with their existing conceptions. Related to this notion, Kang et al. (2004) asserted that any approach to teaching NOSK aspects without taking into account students existing conceptions of NOSK is difficult. Thus, it becomes necessary to scrutinize on which aspects of NOSK do students have adequate conceptions and on which aspects do they possess intermediate and on which do they have naïve conceptions to design and implement appropriate NOSK instruction. Hence, the main objective of this study was to assess students and teachers current conceptions of NOSK.

Improving students' science achievement is one of the important goals of science education. Thus, enhancing students' understanding of NOSK helps students learning of science (Chaisri & Thathong, 2014; Millar, 2004; Southerland et al., 2012). Related with this, Widowati et al. (2018) found a strong relationship between students understanding of NOSK and their examination results. In the case of Ethiopia, students' science achievement is found to be very low. The national learning assessment (NLA) revealed that secondary school students' science achievement is below adequate. As Desalegn (2013) summarized the report, students' achievement in biology, chemistry and physics, is well below 50%, which is the minimum expected mean score considered adequate. Not only with percentages of marks, the quality of secondary school science education is also found to be low in the country as evaluated by different indicators, including less practical works and less motivated teachers (Ayalew, 2017). With regard to practical work, Millar (2004) argued that it is an important means to develop students' understanding of the nature of science. The most commonly used assessment strategy to assess secondary school students science achievement is characterized by written quizzes and tests (e.g., Ayalew, 2017). It is also important to be cautious that the scores obtained in the EGSECE are based on objective paper–and–pencil tests which might involve guessing and cheating. The internet in the country was shut down to avoid/ reduce cheating through the use of internet services (especially in social media like Facebook, telegram and email) in two consecutive years: 2018 and 2019 during grade 10 and Grade 12 national exams, for example. The cutoff point for university entrance by the year 2019 was decided by using only four subjects; the other subjects do not count because the Ethiopian Ministry of Education together with Regional Education Bureaus decided that there was rampant cheating that affected the exam results to a significant level.

If the examinations were able to reduce the impact of guessing and cheating by including practical and authentic tests, and essays for testing scientific misconceptions, the scores would even be worse than those reported by the EGSECE (Ethiopian General Secondary Education Certificate Examination) and the national learning assessment. According to Clough (2011) teaching the nature of science effectively leads to increased interest in science classes and a better understanding of many science concepts. Similarly, Michel and Neumann (2017, p.951) stated that "an adequate understanding of NOSK is expected to improve science content learning by fostering the ability to interrelate scientific concepts and, thus, coherently acquire scientific content knowledge." Thus, low achievement in science subjects may be related to students' lack of adequate understanding of the nature of scientific knowledge. Hence, examining students' NOSK conception is an essential goal of this study.

This study will also focus on investigating whether there exists a congruence between the NOSK conceptions of teachers and students. We may expect that most teachers have informed conceptions about the nature of science. However, research has indicated that both teachers and students possess misconceptions about many aspects of NOSK. The conception of teachers' may have a relationship with their students' conceptions of NOSK. It is explained that science teachers who are responsible for helping students attain informed conceptions of NOSK must first possess informed views of NOSK (Abd-El-khalick & Lederman, 2000; Buaraphan, 2012; Liu & Lederman, 2007). This study was interested in investigating whether, after many years of NOSK research, secondary school teachers possess misconceptions about the NOSK tenets that are similar to those held by their students. What follows is that in those areas of NOSK teachers are well versed, we fairly expect their students to develop informed conceptions of NOSK; and we should not expect students to possess informed views of NOSK in those areas where their teachers have naïve conceptions.

However, teachers' understanding of NOSK at a theoretical level cannot be directly translated into classroom practice to impact students' conceptions (Waters-

Adams, 2006). It needs other mediating strategies which include teacher's valuing of science education, the ability to include NOSK concepts in the teaching-learning process, student's home and school cultures, and the like. Therefore, there needs an investigation into how congruent are the teachers' and students' conceptions of NOSK. Thus, one of the aims of this study is to investigate patterns in the differences/ similarities between students' and teachers' conceptions of the NOSK aspects.

1.3. Purpose of the study

The purpose of this study was to gain a clearer understanding of the NOSK conceptions of a sample of secondary school students and science teachers. The study was guided by the following research questions:

1. What conception do secondary school students' have about the nature of scientific knowledge? Do students' conceptions about aspects of nature of science align with an informed, a naïve, or a syncretic conception of the NOSK?
2. What conception do secondary school science teachers have about aspects of NOSK? Do science teachers' views about aspects of nature of science align with an informed, a naïve, or a synthetic view of the NOSK?
3. Is there congruence between the teachers and students' conception of NOSK? If so, on which aspects of NOSK do students and teachers have informed views of NOSK in common, on which aspects do they have intermediate views, and on which aspects do they have naïve conceptions?
4. Is there a significant difference in NOSK conception between Grade 10 and grade 12 students?

5. Are the conceptions of male and female students similar or different? In which aspects they are similar and in which ones are they different?

1.4. 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; fail to distinguish between facts and alternative facts (McComas, 2017). It is the understanding of NOSK that will enable individuals to critically evaluate knowledge developed through science and act accordingly (McComas, 2017). Research on the nature of scientific knowledge (NOSK) holds both practical and theoretical significance. Understanding NOS involves comprehending the values, assumptions, and methods underpinning scientific knowledge, which is crucial for both scientific literacy and the advancement of science itself. The following are the practical significance of this finding.

Incorporation of NOSK into science curricula improves students' comprehension of how science works. Understanding of NOSK leads to a deeper understanding of science content (Clough, 2008). In addition, students' understanding of NOSK is associated with their increased interest in science and science classes (Clough, 2008) and science careers (Clough, 2011).

A good grasp of NOSK is critical in evaluating public issues that are related to socio-scientific issues. To this end, NOSK should be accurately and effectively taught in science courses. Rudolph (2007, as cited in Clough, 2011) argued that some business and political groups exploit the public's misunderstanding about how science is done to create doubt about issues like global warming. Moreover, individuals could benefit from understanding NOSK to make informed decisions on personal issues like health and diet.

The findings of this study could help researchers to see the gaps in NOSK understanding of students and science teachers, and find ways that promote students' and teachers' views of NOSK.

The result could be of paramount significance to science instructors in such a way that being aware of the relevance of students' and science teachers’ conceptions of science could trigger them to find ways of developing students' and teachers' understanding of NOSK. The study could also be important to education Bureaus, the Ministry of education and school leaders so that they can create enabling conditions for teachers and students to develop informed views of NOSK. The results could also inform science curriculum designers at both secondary and higher education levels.

This study has the following theoretical significances:

NOSK is important for its various roles include making informed decisions and developing deep understanding of science content, increasing students’ interest in learning science, and pursuing science careers. However, research on NOSK aspects that are appropriate for different educational levels is lacking (Leden & Hansson, 2017). Therefore, this study which investigated the secondary school students and their science teachers could contribute to filling this gap.

This study showed aspects of NOSK on which students and teachers held informed views and on which aspects they subscribed to naïve conceptions. This could provide researchers a basis for future studies to conduct NOSK research across different cultures and to conduct comparative studies across different countries.

The present study could also make an important addition to the literature of NOSK on Ethiopian secondary school students' and teachers' understanding of NOSK. In this regard, this study could serve as pioneering research in Ethiopia as NOSK has not been researched in a local context (Berie et al., 2022).

In general, this research has a theoretical significance that enriches our understanding of science as a dynamic and multifaceted endeavor. It creates connections between scientific research, teaching, and public participation, promoting a society that is more knowledgeable and capable of critical thinking and decision-making.

1.5. Scope of the study

This study aimed to investigate secondary school students and science teachers' conceptions of NOSK. Thus, it is delimited to secondary school students and science teachers. Concerning students, the participants were selected from grade 10 and Grade 12 natural science students. Note that Grade 10 students took both social and natural science subjects. The science teachers teaching grades 9 through 12 were included as participants in this study. Regarding study variables, the study is delimited to seven NOSK consensus aspects that are described under the introduction and theoretical frameworks section. The geographic scope of this study is delimited to three schools that are located in two cities of the Amhara region, Ethiopia.

1.6. Operational definitions

The following are the operational definitions of key terms.

- Informed conception (sophisticated understanding) – Participants’ answers that show a more complete understanding, and there are no contradictory answers present in instrument responses.
- Syncretic/ Intermediate – Participants’ answers that show some understanding of the concept but also show misconceptions
- Naïve conception– participants’ answers that showed a lack of understanding of a concept.

UNIT TWO

REVIEW OF RELATED LITERATURE

2.2. Conceptualizing the Nature of Scientific knowledge

The nature of scientific knowledge is a multifaceted concept that includes several key elements, including the empirical foundation of scientific knowledge, the significance of imagination and creativity in science, the theory-laden character of observations, the distinction between laws and theories, the tentative nature of scientific knowledge, and the social and cultural embeddedness of science (N. G. Lederman et al., 2002). Understanding of nature of scientific knowledge is an important topic in science education as well as in science teacher education. The nature of scientific knowledge is conceptualized by many pioneer researchers (Clough, 2008; N. G. Lederman et al., 2014; McComas, 2015; Wolfensberger & Canella, 2015). The works of these researchers has resulted in a consensus view of NOSK, which is agreed important to K-12 school curriculum. The following quoted conceptualization by Clough is a more comprehensive and straightforward for comprehending what nature of science refers:

> The phrase "nature of science" (NOS) is often used in referring to issues such as what science is, how it works, the assumptions underlying the doing of science, how scientists operate as a social group and how society itself both influences and reacts to scientific endeavors. These and many other thoughts regarding the NOS are informed by contributions from several disciplines including, but not limited

to, the history, philosophy, sociology, and psychology of science. (Clough, 2008, p.2).

Researchers in the area of NOSK (N. G. Lederman et al., 2014; Liu & Lederman, 2007; McComas, 2015; Wolfensberger & Canella, 2015) suggested that both teachers and students should know that: (1) scientific knowledge is both reliable (one can have confidence in scientific knowledge) and tentative (subject to change in light of new evidence or re-conceptualization of prior evidence); (2) no single scientific method exists, but there are shared characteristics of scientific approaches to science, such as scientific explanations being supported by empirical evidence, and are testable against the natural world; (3) creativity plays a role in the development of scientific knowledge; (4) theories and laws are distinct but there is a relationship between them; (5) there is a relationship between observations and inferences; (6) though science strives for objectivity, there is an element of subjectivity in the development of scientific knowledge; and (7) social and cultural context also play a role in the development of scientific knowledge.

In line with the conceptualizations of NOSK, it is important to provide the common parameters develop a better understanding of the construct. NOSK seeks to describe the nature of the scientific enterprise and the characteristics of the knowledge it generates (Casey, 2012). Table 2 presented a summary of the parameters which are referred as aspects of the NOSK that are common to researchers to K–12 level education (Bell, 2009; Liu & Lederman, 2007). The Table indicated the most common (seven) aspects of nature of scientific knowledge. In the Table the seven aspects of NOSK are briefly described. It entails us that scientific knowledge is based on empirical evidence and make use of logical reasoning; science uses extensive observations and inferences;

Table 1

Summary of NOSK aspects and their descriptions

NOSK aspects	Descriptions of aspects of NOSK
Empirical nature	Scientific knowledge is derived from data and evidence gathered by 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.
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.
Theories and laws	A law is a succinct description of relationships or patterns in nature based on observation and are 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 shouldn't have confidence in scientific knowledge; rather that it may change in the future.
Creativity and imagination	Creativity and imagination is a source 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.
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.

Theories and laws are two distinct aspects of knowledge, one cannot be changed to the other; scientific knowledge is changeable; creativity and imagination are used in all stages of scientific endeavor; while scientists strive to be objective, their personal beliefs and preferences have a role in the development of scientific knowledge.

As discussed so far, there exists much agreement regarding NOSK ideas worth teaching and learning in science education. Thus, to help students understand NOSK concepts, teachers need to plan and discuss NOSK tenets in the teaching and learning process. This planning and execution is, however, only possible and productive when teachers NOSK understanding is consistent to modern NOSK conceptions. With this regard, Abd-El-Khalik and Lederman (2000) argued that if teachers lack modern conceptions of NOSK, they cannot effectively teach NOSK concepts to students even if the concepts are suitably incorporated in their science curriculum and textbooks. For example, Aslan and Taşar (2013) found that the curriculum promotes many aspects of NOSK including tentativeness of NOSK and the importance of observation and inferences in developing scientific knowledge, however, teachers held naïve views on many dimensions of NOSK which had a hindering effect on the development of students' NOSK understanding. In general, teachers' understanding of NOSK is indispensable, although not sufficient, for effectively translating their understanding into science instruction (J. S. Lederman et al., 2012). To help students learn about the nature of science, teachers must understand the content of NOSK themselves, find out students' misconceptions and implement instructional activities and assessments (Hanuscin & Lee, 2009).

Some authors noted that the knowledge of NOSK is less stable compared to knowledge resulting from concrete evidence in some sciences. Good (2005, p.150) stated that "Unlike knowledge in the natural sciences, social science knowledge is much less stable and coherent, and knowledge about the nature of science and scientists is social science knowledge." However, such a statement of knowledge of science by itself lacked overall consideration of knowledge of science that resulted from scientists' nonuse of experiments, such as hypotheses, and theories which are useful in scientific knowledge. Thus it is important to consider the nature of science as multifaceted with a unifying concept of the nature of science.

2.3. Understanding the nature of NOSK and scientific literacy

Understanding the nature of science (NOSK), which is an essential component of scientific literacy, is important to understand the objects and processes of science, to inform decision making in community issues related to science, and to appreciate cultural values in doing science (Widowati et al., 2018). In a similar vein, Millar (2004) discussed that people in modern society need some understanding of NOSK in order to evaluate claims that may affect their life, such as, health, diet, energy resources, and public policy in order to make informed decisions. Another importance of understanding NOSK is that it can help students to develop interest in science and to better understand scientific content (Chaisri & Thathong, 2014; Widowati et al., 2018).

Scientific literacy is valued because science has played important roles in developing the means of production, communication and transport, protecting countries from enemies and also hoped to play such roles in the future. Related to this, Flammer (2006, p.197) stated that science has played a significant role in various achievements in the past. As Flammer explained, any distortion or weakening of the science education of any country will potentially make that country a weaker nation. Countries whose citizens develop a better understanding of science are likely to lead healthy lives, become competent in knowledge production and consumption, ease of communication and transportation and are in a better position to defend well their country from enemies as compared to nations who lag behind in scientific literacy. The other cause for concern to students' to be scientifically literate is that scientifically literate individuals and society are the beneficiaries through understanding issues such as health and nutrition, the interdependence of biological systems, pollution, soil production, climate, biotechnology, energy use and transportation (Eivers & Kennedy, 2006).

The need for scientific literacy is now clear as it is framed in areas that are vital for human development and survival, as well as harmonious co-existence with the environment with the biomass and material resources. Therefore, understanding science and its important characteristics is a necessity not a choice. Related to this Asimov (as quoted in Wolpert, 1994, p.ix) stated that "A public that does not understand how science works can, all too easily, fall prey to those ignoramuses ...". Populations who do not properly understand the nature of science are prone to make decisions and actions without sufficient considerations which may lead to unintended outcomes.

There is an increasing recognition of the importance of being scientifically literate in developed countries as it plays a significant part in the creation of their wealth (Brito, 2014). The understanding of scientific concepts and applied skills must improve in order to successfully address issues facing society as citizens, policymakers, and scientists. In today's world where technological and social changes are so fast and a bulk of information from different sources like radio, television, social media etc. is available to us understanding science and its nature is even more desirable than ever before (McComas, 2015) to both developed and developing countries. Furthermore, Brito (2014) suggested that developing countries have to give emphasis to develop scientific understanding of their citizens' in order to move from a traditional society to a more modern one so that they can reach the present levels of mass consumption of developed countries.

Many researchers in the field of education have considered proper understanding of the nature of science as a basic component of science instruction (Abd-El-Khalick, 2013; Abd-El-Khalick & Lederman, 2000; Boran & Bağ, 2016; N. G. Lederman & Lederman, 2004; Liu & Lederman, 2007). Development of students' understanding of the nature of scientific knowledge (NOSK) has been considered an important and vital part of science instruction (Kang et al., 2004; Metz, 2006). The aim is not to make students philosophers of science, rather it aims to develop students' ability to critically understand social questions, 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 them (Kötter & Hammann, 2017).

Understanding the nature of scientific knowledge plays a decisive role in the development of scientific literacy (Holbrook & Rannikmae, 2009; N. G. Lederman et al., 2014) and is critical for producing scientifically literate citizens (Kostøl et al., 2022). Without adequate understanding of NOSK, students will not be able to achieve the desired goal of scientific literacy (N. G. Lederman et al., 2013). The critical issue here is that students' ability to make informed decisions about personal and social issues will be compromised if they fail to understand NOSK (N. G. Lederman et al., 2013). In today's world where science and technology are changing very rapidly personal and social decisions like: How big a threat is climate change? Are genetically engineered foods good to eat? Is an electric vehicle worth the price? Require a clear understanding of scientific knowledge and how it is generated (Metz, 2015). Based on such premises some authors argued that developing an understanding about the nature of scientific knowledge is even an end in itself (Lombrozo et al., 2008). Thus, attention should be given to NOSK instruction in order to reach the desired level of scientific literacy and attain the presumed benefits of scientific literacy.

Teachers' and students' understandings of NOSK are objectives in science education and remain a high priority for science education and science education research. With this regard, Tao ((2003) stated that a good grasp of the nature of scientific knowledge is an essential goal of science education. In addition to the importance of NOSK by its own right, developing an understanding of NOSK is also important for a better understanding of science (N. G. Lederman et al., 2013). Krajewski and Schwartz (2014) argued that integrating NOSK and content in daily lessons is key not only to understand the content but also NOSK. An empirical study by Michel and Neumann (2017) confirmed that a positive significant relationship existed between NOSK understanding and science content learning.

Although science subjects are offered in many countries in the world, the goals of the curricula across countries have a wide variety (Iqbal et al., 2009). There are differences concerning the specific content to be included in contemporary science courses and the methods of instruction to be used. Such differences are unavoidable, as the science discipline is rapidly expanding and the curricula present only a small sample of the scientific generalizations and principles. The science curricula in developed countries give an emphasis on developing students' understanding of the nature of science (Iqbal et al., 2009). Brito (2014) argued that developing countries should give emphasis to NOSK learning to gain its benefits like the developed nations. However, developing countries, as Iqbal et al. pointed out, ignored the cultivation of students' understanding of NOSK. As a result, in developing countries, science could be perceived as a fixed set of knowledge, absolute truth and objective knowledge. Perceiving scientific knowledge in such a way that it is fixed and absolute could have undesirable consequences. Iqbal et al.(2009) stated the seriousness of the problem as follows:

> Such views of science have many consequences, both for students as well as teachers. By implication students develop an understanding that there is no room for new discoveries; and that whatever is known about the natural phenomenon is absolute and final. Implication for teaching is that we, as teachers of science have to transmit that fixed body of knowledge to students and students have no other alternative except to learn and memorise what they are told. (p.30)

The quoted text emphasized that if science teachers believed that science knowledge is fixed they are likely to focus on transmitting those fixed body of knowledge presented in textbooks and assess their students' knowledge and comprehension of those predetermined concepts and information. As a result, the role of students becomes mere memorization of what they are told by their teachers with no effort of inquiry. Such conception is, however, not consistent with the contemporary conceptualization of the nature of science. The modern consensus view of NOSK by science educators, philosophers of science and researchers is that NOSK has changing nature (durable but dynamic), subjective nature which is influenced by cultural and societal values rather than fixed and objective (N. G. Lederman et al., 2013; Liu & Lederman, 2007; McComas, 2015). Thus, if educators do not give attention to the development of the students NOSK concept, the education of science could focus on teaching of knowledge that is against the contemporary views of the nature of science. In such instances, science could be viewed as objective, exclusively depended on empirical evidence, free of cultural influences and fixed rather than as a body of knowledge which is dynamic, influenced by subjective interpretations of data and cultural values, make use of inferences and logical reasoning.

Table 2

Structure of Ethiopian science curriculum from grade 1 to 12

Grade level	Subject	Description
1 to 4	Environmental science	Science contents are taught in an integrated form together with social science in a subject called Environmental science
5 to 6	Science	Biology, chemistry, and physics concepts are taught together as integrated science
7 to 10	Biology, Chemistry and Physics	Science contents are presented as separate subjects as biology, chemistry and physics
11 to 12	Biology, Chemistry and Physics	Science subjects are offered to students in the natural science stream as separate subjects as biology, chemistry, and physics. Students who joined the social science stream do not take these science subjects.

MoE identified three important benefits of developing scientific understanding for students from K–12. The benefits enumerated in the MoE document are (1) better understanding of the physical and biological world around them, (2) fuller appreciation of how to lead a healthy lifestyle and (3) good grounding for studying science at higher levels and/or working in scientific and technical careers. These three stipulated benefits of scientific understanding are in line with the objectives of education for K–12 emphasized by science educators.

However, the impacts of these explicitly stated objectives of science education in Ethiopian secondary school curricula with respect to developing student NOSK conceptions remained unknown.

2.3. Students understanding of NOSK

It is the interest of people in the education circle that students develop ‘a more informed understanding of the nature of scientific knowledge. Students understanding of the NOSK is important to make informed decisions about socio scientific issues, to appreciate cultural values in doing science, and to develop interest in science fields (Chaisri & Thathong, 2014; Millar, 2004; Widowati et al., 2018). Development of students NOSK understanding has been considered essential part of science instruction (Abd-El-Khalick, 2013; Metz, 2015). This section is devoted to review empirical research that investigated students' conceptions of the nature of scientific knowledge.

Sangsa-ard, Thathong and Chapoo (2014) conducted a study to examine Thai Grade 9 students understanding of NOSK. These authors addressed their approach as quantitative but as we can see from their results section they entertained both the quantitative and qualitative approaches and therefore their approach was mixed. They collected data using VNOS-C to examine students understanding on seven aspects of NOSK. The VNOS-C consists of ten open-ended questions that help identify understandings of the tentative, empirical, creative, subjective, theoretical, cultural, and social nature of science. Sangsa-ard et al. (2014) reported that they adapted and validated the questionnaire before use. Their finding showed that the examined students possessed inadequate conceptions on all of NOSK aspects. The finding on each NOSK aspect is that 71 students (100%) had demonstrated naïve views on four of the examined seven aspects of NOSK (distinction between scientific theory and law, tentative nature of scientific knowledge, observation based and inferential nature of science & theory laden nature of scientific knowledge). On the other three aspects of NOSK; that is, empirical nature, Creativity and imagination and social and cultural aspects of NOSK students grade 9 students possessed both naïve and intermediate views. On the empirical nature of NOSK, as presented under VNOS-C question number 1, 64.78% and 35.22% showed naïve and intermediate views, respectively. On the creative and imaginative aspect of NOSK the result showed that 47.89% held naïve views, whereas, 52.11% held intermediate views. On the social and cultural aspects of NOSK 56.33% and 43.67% held naïve and intermediate views, respectively. Thus, the result presented by Sangsa-ard et al. (2014) showed that the majority of Thai grade 9 students held naïve conceptions of NOSK while some held intermediate views but none of them possessed informed views of NOSK.

Sormunen and Köksal (2014) studied 39 grade nine advanced science students from five lower secondary schools in Eastern Finland. Their approach was qualitative. Their selection of the advanced science students is reported as follows. First, the 'Motivation toward learning science' questionnaire (SLQ) and 'Attitude toward science' scale (ATSS) was administered. Secondly, science teachers' rankings of the five most successful students in their classrooms were requested. Then, students who's score is 2 or below on the ‘Attitude towards science’ scale (1 = totally agree… 5 = totally disagree), and ‘Motivation toward science learning’ questionnaire (1 = totally agree… 5 = totally disagree), and who were included in the science teachers’ ratings, were being selected for further study.

Sormunen and Köksal (2014) studied the common seven aspects of NOSK; “empirical basis of science”, “observation and inference”, “subjectivity of scientists”, “social and cultural embeddedness”, “creativity in science” “theories and laws” and “tentativeness”. And they discovered that the majority of the students who are included in their study had naïve conceptions in all aspects of NOSK. Sormunen and Köksal further stated that the students’ misunderstandings on two of the seven aspects, namely, “social and cultural embeddedness” and “theories and laws” are the most serious although the qualifier *most series* may lack sufficient clarity because of the fact that the authors already reported that the participants showed naïve views on all of the seven aspects of NOSK. Sormunen and Köksal stated that the misunderstandings observed by the advanced Finish students are not observed in previous studies conducted with ordinary students which makes this result at odds with previous findings. Previous findings indicated that higher achiever students also demonstrate better understanding of NOSK (Sormunen & Köksal, 2014). In addition, Sormunen and Köksal (2014) acknowledged the limitations of their study and suggested future research to use large sample size and multi-method approach.

Dogan and Abd-El-Khalick (2008) conducted a study to assess grade 10 Turkish students’ and science teachers’ conceptions of the nature of scientific knowledge (NOSK) and whether these conceptions were related to selected variables. The variables they studied in relation to NOSK include gender, geographical region, and the socioeconomic status (SES) of their city and region; teacher disciplinary background, years of teaching experience, graduate degree, and type of teacher training program; and student household SES and parents' educational level. They select participants through stratified sampling approach method aiming to represent the country. Their sample comprised of 2,087 students and 378 science teachers. A questionnaire comprising 14 modified ‘‘Views on Science-Technology-Society’’ (VOSTS) items to assess their views of different aspects of NOSK. The NOSK aspects that are targeted by Dogan and Abd-El-Khalick (2008) were the following:

> …the theory-driven nature of scientific observations; tentative nature of scientific knowledge; relationship between scientific constructs (models and classification schemes) and reality; the epistemological status of different types of scientific knowledge (hypotheses, theories, and laws) and their coherence across various scientific disciplines; nature of, and relationship between, scientific theories and laws; myth of a universal and/or stepwise ‘‘Scientific Method’’; the nonlinearity of scientific investigations; and the role of probabilistic reasoning in the development of scientific knowledge. (p.1091)

Participant responses were categorized as ‘‘naïve,’’ ‘‘have merit,’’ or ‘‘informed,’’ and the frequency distributions for these responses were compared for various groupings of participants. The students and teachers views found lacking an overarching and/or consistent framework. That is, the distributions of participants' responses among the three response categories (naïve, have merit, and informed) were varied across items. For instance, all students and teachers believed that when a hypothesis is ‘‘proven’’ correct, it becomes a theory. That is, all students and teachers ascribed to one form or another of the naïve view that the different categories of scientific knowledge (i.e., hypotheses, theories, and laws) are hierarchically interrelated in a connected progression toward achieving some higher status of ‘‘truth’’ or ‘‘correctness’’; this progression was dependent on the accumulation of scientific evidence. The study, on the other hand, with regard to the *tentative* nature of NOSK presented that the majority of students (68.2%) and teachers (72.9%) held informed views. With regard to the scientific method, the vast majority of both students and teachers ascribed to the notion of a procedural, universal, and/ or step-wise *Scientific Method*. However, what needs due attention is that why more teachers (45.8%) than students (44.2%) held naïve views and conversely why more students (17%) than teachers (10%) held informed views of *scientific method*. Dogan and Abd-El-Khalick (2008) argued that this unexpected result could be attributed to the continued and explicit emphasis given to an assumed universal method in both precollege and college education. Nonetheless, it is difficult to agree with their results as well as their arguments are not congruent with the accepted literature which suggests as we learn more science our scientific understanding also increases.

Russell and Aydeniz (2013) conducted a quasi-experimental study to investigate NOSK understanding of 63 high school science students (31 in the intervention group & 32 in the control group). Explicit/ reflective NOSK instruction was embedded within authentic inquiry experiences and supported by online discussions. To measure students conceptualization of various aspects of NOSK they used a Likert type scale NOSK survey (Russell & Aydeniz, 2013) and VNOS-C (N. G. Lederman et al., 2002) which asks students to write essay responses to open-ended questions. The VNOS-C is a widely used instrument.

Russell and Aydeniz's (2013) study revealed that the instructional intervention used in this study which combined explicit/ reflective NOSK instruction with intense inquiry exposure along with ample reflective opportunities in an anonymous online discussion format led to positive learning gains in participants' understanding of the assessed NOSK aspects. That is, in all of the six assessed aspects of NOSK the proportion of students in the experimental group exhibiting acceptable understanding of NOSK after the intervention is much higher than their pre-intervention result. In the pretest the proportion of the experimental group who exhibited acceptable understanding of NOSK tenets, except for tentative NOSK (87%) was very small: creativity 16%, empirical 23%, no single scientific method 13%, social and cultural embeddedness 16% and subjective NOSK 16%. After the intervention, the proportion of high school students in the experimental group who exhibited acceptable understanding of NOSK has increased with a very large proportion: creativity 97%, empirical 100%, no single scientific method 71%, tentative 97%, social and cultural embeddedness 97% and subjective NOSK 90%. As can be noticed by comparing posttest scores with the pretest, the intervention was very successful as the increment is not only very large but also the majority of the high school students exhibited acceptable NOSK after the intervention.

In Russell and Aydeniz's (2013) study posttest results also revealed that the percentage of students exhibiting acceptable understanding of NOSK is higher for the intervention group than the control group in all of the six NOSK tenets. For example, higher proportions of students in the intervention group (90%) have informed conceptions than the control group (62%) in understanding the subjective nature of science. Similarly, larger proportion of students in the intervention group (71%) recognized that there is no single scientific method than the control group (43%). To add just one more example, with regard to the social and culturally embedded nature of science 97% of students in the experimental group showed informed views whereas, 56% of the control group participants held informed views.

To sum up, in Russell and Aydeniz's (2013) study the explicit/ reflective approach was found to be effective in eliciting more advanced understandings of high school students in the NOSK aspects. The posttest results of the intervention group indicated a much larger increment of NOSK understanding as compared to the pretest. Moreover, a larger proportion of students in the experimental group have exhibited informed views as compared to the control group students in all of NOSK aspects assessed.

Huang et al. (2014) investigated how the different discussion approaches in Facebook influenced students' scientific knowledge acquisition and the nature of scientific knowledge views in Northwestern Taiwan. Their purpose was to investigate how synchronous and asynchronous online discussions via Facebook influence student general NOSK views, content-related NOSK and science content knowledge. The participants were two 8th-grade and two 9th-grade science classes in Northwestern Taiwan. There were 49 male and 34 female students who joined the online discussion activities. The study adopted a quasi-experimental design which randomly assigned the four science classes to synchronous or asynchronous groups. One class in each grade level engaged in synchronous discussion, and the other engaged in asynchronous discussion. Each class was divided into five groups, with each group consisting of four to five students. While students in the synchronous groups spent 45 minutes (one class) analyzing a scientific news story on Facebook, students in the asynchronous group had three days to finish their discussion of one news story.

Huang et al. (2014) used a Likert type scale to assess the three features of NOSK (5 items for each), ranging from strongly agree (5 point) to strongly disagree (1 point). Inputs from four science education doctoral students and two scholars reviewed to establish validity of the instruments. The reliability of the three aspects of NOSK are reported to be satisfactory (accumulative = 0.83, creative = 0.69, community = 0.82) and the overall reliability of the scale was 0.86. They analyzed pretests through multivariate analysis technique and reported that pre-intervention results showed no statistically significant difference in the performance of students between the synchronous and asynchronous groups of students in terms of general NOS views, content-related NOSK views, and science knowledge. Moreover, t-test results on three science examinations of first semester indicated no statistically significant difference between the synchronous (N=42) and asynchronous (N=41) groups.

The intervention lasted three weeks which encompassed eight classes, each class period lasting 45 minutes. After administering the pretests, the instructor explained to the students the content of learning activities as well as features of NOSK and the significance of understanding it. To help students understand NOSK, this study posted seven scientific news stories on Facebook which allowed students to analyze the accumulative, creative, and community of NOSK in each designated scientific news story. A paired samples *t* test indicated that after participating in online discussions, students on average achieved significantly better understanding of NOSK, regardless of whether they were assigned to a synchronous or asynchronous group. Additionally, Multivariate analyses of covariance (MANCOVA) revealed that students in the two discussion groups did not have significantly different general NOSK views in the posttest after adjusting the pretest scores (pretest as the covariate in the model). MANCOVA test also revealed that there was no statistically significant difference between synchronous and asynchronous discussion groups on the combined dependent variables of content-related NOSK views, controlling for the pretest. However, MANCOVA indicated students in the synchronous discussion group achieved higher content knowledge than those in the asynchronous discussion group in the posttest when students' prior test was controlled as the covariate.

It was better if grade 8 and 9 students' responses are analyzed separately. Since they have a one year difference in science learning which might have effect on their NOSK understanding. The other issue is related to transferability (generalizability). In this study Facebook is used but it is difficult to Ethiopian context where classrooms are not yet furnished with computers and internet and/ or most high school students do not have smart phones to use Facebook for educational purpose. More NOSK features better include to provide teachers a workable method of teaching/ intervention.

Eastwood et al. (2012) conducted a study to investigate the effects of two learning contexts for explicit-reflective NOSK instruction, socio-scientific issues (SSI) driven and content driven, on student NOSK conceptions. The participants were four classes of grade 11 and 12 students in Florida, USA. Two classes were assigned randomly to the

SSI group (SSI driven-curriculum) and the other two classes to the content group (content-based curriculum). Each class had participants ranging from 27 to 31 students and males and females were equally distributed. Both the SSI and Content groups received explicit instruction. An experienced high school science teacher instructed all of the classes with explicit NOSK activities and demonstrations as well as making explicit connections between NOSK aspects and classroom content for a year.

Eastwood et al. (2012) collected data through VNOS form C prior to instruction and at the end of the instruction to provide pretest and posttest data. VNOS is a well-established instrument in terms of face and content validity, and has been extensively used in research with students and teachers. The researchers conducted inductive analysis of the data set to generate an emergent taxonomy that characterized the range of patterns observed in the data set. Through the inductive data analysis the researchers reported that they identified six distinct NOSK themes to examine within the data sets: the empirical, tentative, creative, social and cultural, distinctions between laws and theories, and the use of scientific models. The researchers established a coding system that included three ordinal categories: 'informed', 'transitional', and 'naïve'; for each NOSK theme an additional 'no relevant response' code was used.

Eastwood et al. (2012) analyzed the pre-instruction VNOS questionnaire data and found that the SSI and Content groups were not significantly different in their levels of NOS understanding. Post instruction analysis revealed that both SSI and Content groups showed significant gains in each aspect of NOSK with the exception of the social/ cultural NOSK for the Content group and the scientific models category for the SSI group. In these two cases, students demonstrated gains, but the gains were not interpreted to be statistically significant. Another interesting result they found is that the post-instruction responses of the two groups showed differences in the ways in which students used specific examples to support their discussion of VNOS questions. However, although greater proportion of students in the SSI group used examples to strengthen their presentation of their perspectives related to how science is socially and culturally influenced, a post hoc chi square analysis indicated that the group differences were not statistically significant. However, the authors believed that these results highlight a potentially important trend that warrants further investigation with large sample.

Kang, Scharmann and Noh (2004) conducted a large-scale survey that examines 6^{th}, 8^{th}, and 10^{th} grade Korean students' views of NOSK. The participants were from randomly selected schools from Seoul, a metropolitan city in Korea. The sample sizes for 6^{th}, 8^{th} and 10^{th} graders were 534, 551 and 617, respectively. These three grade levels correspond to elementary, middle and high school in the Korean 6-3-3 school system. The purposes were to provide a baseline of students understanding to offer meaningful instruction, to gain insight through a cross-age comparison into whether students' views on the NOSK are influenced by their school science experiences, and to characterize potential notable similarities and differences between the respective views on NOSK possessed by Korean students and students of Western countries.

Kang et al. (2004) reported that they used empirically developed multiple-choice format items by adapting with some modifications from Solomon et al.'s (1996) study (i.e., questions 1, 2, 3, and 4) and the VOSTS (i.e., question 5). They conducted cross-tabulations between responses to the different options and to look for significance using chi-square statistics. Students' written responses to the open-ended section of each item were classified according to the rationales students conveyed.

Kang et al. (2004) found that less than 20% of the students possessed informed conception of the purpose of scientific investigation; this contemporarily accepted perspective is "science is investigating natural phenomena and explaining the workings of the world". Furthermore, when considering the rationales that students presented, the percentages of students who showed a sophisticated understanding fell even lower (6th graders: 6.4%, 8th graders: 10.4%, and 10th graders: 9.3%). That is, many of the students who chose the acceptable multiple-choice item did not support their choice with appropriate rationales. The result indicated no statistically significant difference for the distribution of students' responses by grade level ($\chi^2 = 8.596$, $df = 6$, $p = .198$).

Kang et al. (2004) also explored students' views concerning nature of scientific theory and found that the majority of the students possessed a naïve view that "scientific theories are facts which have been proven by many experiments". Only about 25% of students adhered to a contemporarily accepted epistemological viewpoint: "theory is an explanation about the reasons for how things happen". Considering the rationales that students presented, however, the number of students who possessed sophisticated views on scientific theories was substantially lower (6th graders: 13.2%, 8th graders: 13.9%, and 10th graders: 17.6%). A chi-square analysis on the distribution of students' responses detected no statistically significant difference ($\chi^2 = 11.007$, $df = 6$, $p = .088$).

Kang et al. (2004) investigated students' conceptions of a scientific model, which is an important part of a scientific theory, and found that 16% – 40% (sixteen to forty percent) of students across grades demonstrated informed conception; they responded that scientists use models in order to explain the reasons for many phenomena. And a statistically significant difference on the distribution of students' responses was observed (χ 2 = 108.396, *df* = 6, *p* = .001). The number of students who held a perspective that could be regarded as consistent with a contemporary epistemological view, increased with age (6th graders: 15.7%, 8th graders: 33.2%, 10th graders: 39.3%). More 6th graders tended to choose option aligned with naïve conception (i.e., we can see the particles).

Understanding the tentative/ revisionary nature of scientific theories is regarded as one of the important constituents of an individual's appropriate conception of NOSK. However, Kang et al. (2004) found that the majority of the students at all levels possessed traditional views of the tentative NOSK. A chi-square analysis on tentativeness indicated that there was a statistically significant difference on the distribution of students' responses (χ 2 = 78.107, *df* = 6, *p* = .001). More 6th graders tended to choose the option that states "ways of explaining about phenomena have changed", whereas more 8th and 10th graders tended to choose the option "old theories have been proven to be wrong by the development of technology". This result indicated that more 6th graders (15.5%) had views consistent with a contemporary epistemology than 8th (7.7%) and 10th (3.1%) graders had views which are based on traditional epistemology. The authors argued that although school science seemed to distort students' views on the tentativeness of scientific theories at a glance; analyses on students' rationales do not support this interpretation. After considering students' rationales, they found that only a few students possessed a sophisticated understanding of the tentativeness of scientific theories (6th graders: 3.3%, 8th graders: 2.4%, and 10th graders: 1.1%). However, contrary to the authors' contention the result is still showing a declining trend, that is, as grade level increases the proportion of students who held informed views of tentativeness decreases. Thus, in this case as students learn more school science their conceptions of NOSK becomes more naïve. Kang et al.'s (2004) study in relation to the origin of theories revealed that, the vast majority of students held naïve views of NOSK, only a few students were found to possess an appropriate understanding. The students conceived that theories are "out there" to be known by scientists. Thus, the job of Scientists to these students is to discover theories (i.e., facts) that already exist as objects. No statistically significant difference was found for the distribution of students' responses across grades (χ 2 = 7.070, *df* = 6, *p* = .314).

In general, the study conducted by Kang et al. (2004) presented that the majority of students (6th, 8th & 10th graders') held traditional views of the assessed features of NOS regardless of grade level. With regard to the three features of NOSK– purpose of scientific investigation, definition of scientific theory (eg., differentiating scientific theory with scientific fact), and nature of scientific theories (i.e., whether scientific theories are discovered or invented), no statistically significant difference observed as reported by non-significant chi-square test. But on the other two features of NOSK–nature of models and tentativeness, a statistically significant difference on the distribution of students' responses was observed although not in the same way. That is, more 8th and 10th graders held contemporary conceptions of the nature of models than 6^{th} graders, whereas, with regard to tentative NOSK more 6^{th} graders held accepted views of NOSK than 8^{th} and 10^{th} graders. While the result on nature of models seems logical, the result on tentativeness seems to indicate as students are exposed to more school science they become more naïve in understanding the tentative nature of NOSK.

Kiliç et al. (2005) conducted a study to investigate the 9th-grade students' understandings of the nature of scientific knowledge. They also investigated the differences in students' understanding of the nature of scientific knowledge by gender, and school types. A total of 575 ninth grade students (295 girls and 280 boys) from four different school types (General High, Anatolian High, Vocational High and Super Lycee) participated in the study. Kiliç et al. (2005) collected data utilizing an adapted version of the Nature of Scientific Knowledge (NSKS) (developed by Rubba and Andersen in 1978). The NSKS is a 48 item Likert-type scale ranging from strongly agrees to strongly disagree. It covered 6 tenets or postulates of nature of scientific knowledge: 1) amoral i.e., provides people with many capabilities, but does not provide instruction on how to use them; 2) creative i.e., is a product of human intellect; 3) developmental, i.e., is never proven in the absolute and final sense; 4) parsimonious, i.e., tends toward simplicity but not to the exclusion of complexity; 5) testable i.e., is capable of public empirical test; and 6) unified i.e., is born out of an effort to understand the unity of nature. Each of the six tenets includes 8 items.

The NSKS was translated and adapted into Turkish by Kiliç et al. (2005).The reliability of the Turkish version of the scale was found to be 0.74 by using Cronbach alpha. The validation of the scale as reported by the authors was examined by a group of panel judges. Kiliç et al.(2005) analyzed descriptively and found that 9th grade students generally had a moderate (average) understanding of scientific knowledge (Total mean= 26.93). A testable tenet of the NSKS has the highest mean score (M=30.25) and parsimonious tenet has the lowest mean score (M=24.99). Note that a maximum score for each tenet was 40 and a score of 240 points for the total score. A two-way multivariate analysis of variance (MANOVA) was conducted to determine the effect of gender and school types on six tenets of nature of scientific knowledge at 0.05 significance level. Both gender and school types were found to have significant effect on the dependent measures, Wilks' Λ= 0.970, F(6, 562)= 2,919, p= 0.008 and Wilks' Λ= 0.856, F(18,1590)= 5.005, p= 0.000, respectively. No interaction were found between gender and school types Wilks' Λ= 0.951, F(18, 1590)= 1.574, p= 0.059. Concerning gender difference, the univariate ANOVAs for amoral (F (1, 567) = 4.095, p=0.043) and unified tenets (F(1, 567)=7.640, p=0.006) of NSKS were significant in favor of girls while the Univariate ANOVAs for creative, developmental, testable and parsimonious tenets were not significant (p> 0.05). The results indicated that there was significant mean difference between boys and girls with respect to amoral, and unified tenets of the NSKS. The result also revealed that there was significant mean difference among school types on amoral, creative, developmental, testable and unified tenets of NSKS. However, there was no significant mean difference in parsimonious subscale of the NSKS with respect to school types.

Kahana and Tal (2014) conducted a study to investigate high-achieving Israeli high school students enrolled to advanced science courses. Three hundred twenty five (152 male & 173 female) students were selected from 11 urban and countryside high schools to represent different socioeconomic groups. The students included in the study were: 82 biology majors, 81 chemistry majors, 81 physics majors; and a comparison group of 80 students who majored in a non-science (i.e., history, literature, geography, mass communication, fine arts, etc.). The students' background in science in terms of the curriculum they studied was similar prior to beginning the high-level courses in 11th grade. Kahana and Tal also interviewed 16 teachers who taught the science classes. The teachers had advanced degrees in the science disciplines and were highly experienced (24 years on average).

Kahana and Tal (2014) used a mixed methods approach for data collection and analysis. They collected data by preparing an open-ended questionnaire that required the students to understand the NOSK knowledge in the context of the global climate change debate. The questionnaire was administered twice: at the onset of the major program, at the beginning of 11th grade and at the outset of the program, at the end of 12th grade. Students' conceptions relating to the following areas of the nature of science was assessed: (1)Scientific knowledge is interpretive; the same evidence can be differently interpreted; (2) Scientific knowledge is limited; (3) Scientific knowledge is founded on empirical evidence; (4) Scientific knowledge is tentative; (5) Scientific knowledge is subjective and influenced by non-scientific factors like social and economic. Content analysis was performed on students' responses to the five open-ended questions in order to assess students' views about NOSK. Each participant's response was rated as 'informed' (for understanding NOSK) or 'uninformed' (for not understanding NOSK) based on the consensus views about the NOSK described.

Kahana and Tal (2014) compared students' prior to and at the end of their major program in the science and non-science fields. In the interpretive aspect of NOSK they found a significant increase in the informed views of biology students, but in other groups there was a small and non-significant increase. With regard to the limited nature of scientific knowledge and empirical aspect of scientific knowledge, the percentage of students with informed views did not change significantly in any of the groups. In the tentative NOSK aspect, the number of informed conceptions of physics students showed a significant increase; but in the other fields, there was no significant increase. On the fifth aspect of NOSK, social influence on nature of NOSK, all groups showed improvement on NOSK understanding, but the increase was not significant. Kahan and Tal also investigated whether there existed a difference in NOSK views between science students and students who did not major science. They found that, science students showed more informed views than non-science majors in all aspects of NOSK.

Kahana and Tal's (2014) investigation has many merits including their pre-assessment of NOSK and assessment of the teachers. However, there are different schools which may have different facilities, different socio-economic status. In addition, although teachers had informed views of NOSK their skills and attitude to include NOSK teaching may vary. All this issues may lead us to suggest a multilevel modeling data analysis than classifying groups on the basis of major course alone. In addition, the NOSK aspects included are five dimensions, I suggest it was better if they were able to include the other NOSK aspects which are reported to be relevant to K- 12 grade levels by NOSK researchers (e.g., Liu & Lederman, 2007; McComas, 2017).

In general, the students held inadequate views in the majority of the consensus NOSK tenets. For example, the majority of students subscribed to a naïve conception of NOSK aspects including; the subjective (Russell & Aydeniz, 2013; Sangsa-ard et al., 2014; Sormunen & Köksal, 2014), the distinction between theories and laws (Kang et al., 2004; Sangsa-ard et al., 2014; Sormunen & Köksal, 2014), and the influence of society and culture (Eastwood et al., 2012; Russell & Aydeniz, 2013; Sormunen & Köksal, 2014). While the majority of students in some studies demonstrated informed conception of the tentative NOSK (Dogan & Abd-El-Khalick, 2008; Russell & Aydeniz, 2013). These findings led to the conclusion that students understanding of the NOSK is not adequate on one hand and was not similar across the different contexts it has been studied on the other. These situations could lead to further investigations that call for an overarching conclusion about students NOSK conceptions.

2.4. Teachers' NOSK conceptions

Certainly teachers represent the most important variable in the classroom learning equation. Even well-designed NOSK instructional packages that are at odds with the philosophical orientations of teachers may not be effective. Hence, bolstering teachers' understanding of NOSK is clearly a prerequisite for effective science teaching with many adherents (McComas et al., 2002). Teachers who had a good grasp of the nature of science can design more effective science lessons and activities. They can help students appreciate the process of scientific inquiry, understand the provisional nature of scientific knowledge, and engage critically with scientific claims. Moreover, for effective teaching of NOSK teachers should recognize that NOSK is important for their students (Yenice & Saydam, 2010).

A deep understanding of the nature of science informs the development of science curricula. Teachers can ensure that curricular goals align with fostering scientific literacy, promoting inquiry-based learning, and addressing misconceptions about science. Many students hold misconceptions about the nature of science, such as viewing it as a collection of facts or as a linear process with predetermined outcomes. Teachers who are aware of these misconceptions can implement strategies to address them and promote more accurate understandings. Scientific literacy involves not only understanding scientific concepts but also grasping how science works and its impact on society. Teachers who comprehend the nature of science can better equip students with the skills and knowledge needed to navigate the complexities of the modern world.

Teachers who continually deepen their understanding of the nature of science can serve as mentors to their colleagues and contribute to professional development initiatives within their schools or districts. This can help foster a culture of ongoing learning and improvement in science education. In summary, a robust understanding of the nature of scientific knowledge is essential for secondary school teachers to effectively teach science, develop curricula, promote inquiry-based learning, address misconceptions, foster scientific literacy, navigate ethical considerations, and contribute to professional development efforts.

To teach the nature of science, teachers themselves must develop informed conceptions of the nature of science (Mercado et al., 2015). Prior research has indicated a relationship between teachers' conception of NOSK and their teaching of NOSK (Kahana & Tal, 2014). Thus, in this section, the results of some selected articles on teachers' conceptions are summarized in some detail. After the summary there are discussions on each of the articles reviewed.

Akerson, et al. (2000) conducted an intervention study based on a course designed to develop elementary teachers' conceptions of nature of science. The participants were 25 undergraduate students (23 female and 2 male) and 25 graduate students (22 female and 3 male) assigned in two separate sections. Akerson, et al. (2000) selected 40 participants, 20 from each group, for interviewing. Half of these participants, that is, 10 students from each group were randomly chosen for pre-instruction interviews; the other half was interviewed at the conclusion of the study. The first author taught both sections of the elementary science methods course (3 credit hours) in which participants were enrolled. None of the participants, graduate or undergraduate, had formal coursework in history or philosophy of science.

In Akerson et al. (2000) study, during the first week of class, participants were engaged in specially designed activities that were coupled with explicit NOSK instruction. Throughout the remainder of the course, participants were provided with structured opportunities to reflect on their views of the target NOSK aspects. Classes were held weekly in 3hour blocks throughout the semester. During the first 6 hour in the course, the instructor engaged participants in 10 different activities that explicitly addressed the seven target aspects of NOSK. An open-ended NOSK questionnaire coupled with individual interviews was used to assess participants' NOSK views before and at the conclusion of the course. The instructor kept a detailed log of all these reflective opportunities. Akerson et al. (2000) found that the majority of participants held naïve views of the target NOSK aspects at the beginning of the study. Post- instruction assessments indicated that participants made substantial gains in their views of some of the target NOSK aspects. However, less substantial gains were evident in the case of the subjective, and social and cultural NOSK.

Akerson et al. (2000) study showed us how we can use explicit reflective NOSK instruction to develop modern views of NOSK. The data collection techniques, which include both open-ended questionnaire and follow up interview, were advantageous to collect rich data that enables the researchers to identify changes that resulted from the intervention. However, there are some limitations in this study which include (1) the interview was conducted assuming the two halves as equivalent. But as the sample size is small (only 10) in each sub group and not at random, assuming equivalency is very difficult and may lead to unwarranted conclusions, (2) the finding indicated that explicit reflective NOSK instruction was effective to some aspects of NOSK, but not all, and (3) the intervention is part of a course and hence the changes could potentially be influenced by other courses which are offered in parallel to the intervention. All these limitations imply a need for a more controlled research that integrates other intervention techniques in addition to the explicit reflective NOSK instruction that would be more effective to bring the desired changes in all aspects of NOSK.

Chin-Chung Tsai (2006) investigated the effect of science education courses on pre-service and in-service teachers' views of nature of science. All of them had a major in a related science field in a degree program. There were 36 in-service teachers (F=12, M=24) in course I and 32 pre-service teachers (F=13, M=19) in course II. The in-service teachers ranged in age from 28 to 56 years old, and their teaching experiences ranged from 3 to 27 years with an average of 9 years. The pre-service teachers had an age range from 21 to 28 years.

Tsai (2006) administered a Likert-type questionnaire in the first session of each course to assess the participants' initial views about science. One additional open-ended question was also attached to explore the teachers' views about science in the beginning of each course. The open-ended questions were like ''what is your view about science?'' Tsai administered the same questionnaire in the final session of the course. In addition, the end-of-course questionnaire included an open-ended survey, asking the teachers to reflect their contemporary views about science, possible view changes and the sources of changes. In the study, teachers were also asked to retrospect whether his or her views about science had changed, deciding an option among ‘‘no change,’’ ‘‘somewhat change’’ and ‘‘change,’’ and then giving reasons for the selected option. Three pre-service and two in-service teachers who did not express clear ideas in the survey were interviewed for further clarification. The written responses and some interview data were used for content analysis to reveal teachers’ possible view changes and the sources of changes.

Tsai (2006) concluded that science education courses integrating some ideas about the philosophy of science and contemporary learning theories and activities (e.g., student alternative conception and conceptual change) are helpful in changing both pre-service and in-service teachers’ views toward the nature of science. The pre-service teachers initially having empiricist-aligned views about science, tended to possess more constructivist- oriented views about science after the course. The in-service teachers showed more agreement with constructivist views about science in the conclusion of the course, but their position toward the empiricist views about science remained statistically unchanged. This implied that the in-service teachers might have shaped more established beliefs about science, which could not be easily altered.

As this study (Tsai, 2006) involved both in-service and pre-service teachers, although in different courses (with similar content), such a more direct comparison between the views shown by in-service teachers and those by pre-service teachers is informative. Perhaps, due to their prior academic experiences in science and rich practice in teaching science, the in-service teachers might have strongly develop certain (possibly empiricist-oriented) views about science, while these views were resistant to change. Tsai's (2006) finding gives us some insight about the possibility of enhancing pre-service and in-service teachers' views of NOSK. Moreover, changing NOSK views (like empiricist) are relatively easier for pre-service teachers than in-service teachers.

However, Tsai's (2006) study had some limitations. Firstly, the participants are not randomly selected to represent their respective populations, that is, the pre-service and in-service teachers. The study used largely quantitative research design, but the study sample was not selected at random which is not in line with the concept of probability assumption (not representative); moreover, the two groups took different courses that make the comparison even more difficult and the result less generalizable. These call for a need for further study that is carefully designed to control variables that have potential to confound results.

Mansoor Niaz (2008) aimed to facilitate in-service chemistry teachers' understanding of nature of science in order to identify what 'ideas-about-science' can be included in the classroom. The study was based on 17 in-service chemistry teachers who had enrolled in the course, ''Epistemology of Science Teaching,'' as part of a Master's degree program in education, at a major university in Latin America. Nine teachers worked in secondary schools and eight at the university level (male = 6, female 11, age range: 25–45 years), and their teaching experience varied from about 5 to 20 years. In the previous year all teachers had enrolled in the following courses: (a) Methodology of Investigation, in which basic philosophical ideas of Popper, Kuhn and Lakatos were discussed, in order to provide an overview of the controversial nature of progress in science (growth of knowledge) and its implications for research methodology in education. Teachers were familiar that basic ideas like the scientific method, objectivity and inductive nature of science were considered to be controversial and questionable by philosophers of science; (b) Investigation in the Teaching of Chemistry, in which students' alternative conceptions and conceptual change strategies were discussed within a history and philosophy of science perspective, with particular reference to historical controversies.

The participants in Niaz's (2008) study were provided articles. The course, which is offered to the participants, was based on 17 readings and was subdivided in to three sections: 1) *Nature of Science* - seven articles given to six participants one reading material for each participant, except one of the participants who is assigned to two reading materials, 2) *Critical evaluation of nature of science*-five articles one to each participant, and 3) *Critical evaluation of constructivism* -six articles. The researcher used multiple data sources based on the different course activities in the study. These data sources include question–answer sessions after each of the 17 formal presentations, initial and final exams during the final week of the study (separated by 36 hours of class presentations and discussions) and critical essay aimed to present a critique based on epistemological, philosophical, and methodological aspects of NOSK.

Niaz (2008) collected multiple data using different strategies, approaches and methods in such a way that the resulting mixture or combination is likely to result in complementary strengths. This use of multiple methods and approaches is one of the strengths of Niaz's (2008) research. The study is also conducted as part of the course, in such cases the study is more natural (as contrast to artificial) and the students will also have the motivation to take exams. If it were an artificial setting we will not expect enough motivation from students to be well prepared and take exams with their full concentration and make use of their mental (psychic) energy. Having all these strengths, the study by Niaz (2008) has given us some relevant information which will have a meaningful contribution to the practice of science teaching. However, the study also has some limitations that will call for improvement for next researchers. As the study is part of a course there is less control over the extraneous variables that could affect the in-service teachers' conception of NOSK. Thus, establishing a cause and effect relationship, which we expect from intervention studies, is difficult if not impossible from this study. Thus, future researchers should make use of random groups and select intervention techniques and then compare results between different groups that have received different types and/or levels of intervention to establish cause-and-effect relationships.

McDonald (2010) conducted a study to investigate the influence of explicit NOSK and *argumentation instruction* on pre-service primary teachers' views of NOSK. The majority of the pre-service teachers entered the course having studied science to upper secondary levels with varying degrees of success. Sixteen of the 17 pre-service teachers enrolled in the course consented to participate in the study. Five of these 16 pre-service teachers were purposively selected for intensive investigation, and became participants in the present study. The authors used the following four criteria to select the five participants: (1) completion of all data collection task requirements in the study, (2) regular class attendance, (3) freely availed themselves for interviews and informal discussions, and (4) fully participated in all classroom activities.

The course teaches designed basic chemistry concepts with the underlying assumption that pre-service teachers entering the course would generally possess limited conceptual knowledge of chemistry. Classes were held weekly in 3-hour sessions, and covered an 11-week teaching period. Participants were engaged in explicit NOSK instruction, during both inquiry- based classroom sessions and theory-based classroom sessions. According to McDonald (2010), the eight NOSK aspects were introduced, discussed, and reflected upon, at contextually relevant stages throughout the intervention.

McDonald (2010) reported that he utilized four sources of data to provide evidence to address the research questions guiding his study: questionnaires and surveys, interviews, audio- and video-taped class sessions, and written artifacts. Participants completed the VNOS-C, global warming survey, and superconductors survey. The five participants who were selected for the interview took part in both the initial and final interviews.

The findings (Mcdonald, 2010) revealed that all of the participants expressed naïve or limited views on the six or more of the eight NOSK aspects at the commencement of the study. Many positive changes were evident in participants' NOSK views at the end of the study, with four of the five participants' views of NOSK developing from predominantly naïve or limited understandings of NOSK, to predominantly partially informed or informed understandings of NOSK over the duration of the intervention. McDonald revealed that two participants exhibited development in six of the eight examined aspects, and other two participants showed development in five of the eight examined aspects. Participants' views of the subjective and theory-laden NOSK, the social and cultural NOSK, and the creative and imaginative NOSK improved substantially over the duration of the intervention, although little development was evident in participants' views on theories and laws. One participant (David) failed to exhibit substantial development in any of the examined NOSK aspects and continued to express naïve or limited views of all eight examined NOSK aspects at the conclusion of the study.

McDonald (2010) reported that he has concerns with regard to the validity of the study. He stated that he himself conducted all interviews with participants, and was the course lecturer in the classroom intervention phase of the study; marked and graded participants' assessment items in the course. Moreover, the researcher used only one group of participants, small size (16 pre-service teachers) and only five of them were interviewed. These factors all together raise validity issues for the study. Thus, another study design which aimed to control factors that are threats to the study's validity (i.e., designs that help researchers avoid or reduce validity problems) provide findings that will be beneficial to those who have concern to improve teachers NOSK views.

Another NOSK study by Celik and Bayrakceken (2012) investigated the effect of an activity based explicit nature of science (NOSK) instruction undertaken in the context of a "Science, Technology and Society" course on the prospective science teachers' (PSTs') understandings of NOSK. In this course, social science based inquiry activities were used as a context to lead reflection and explicit discussions and project based learning approach (PBL) was used to model an active student centered NOSK teaching and learning- convenient sampling method. The study involved 36 senior PSTs who were seeking a teacher certificate in an elementary science-teaching program in a Turkish college. The course was delivered three credit hours per week, during this study for one semester that spanned 14 weeks. The authors collected data using convenient sampling method at the beginning and end of instruction by an open-ended questionnaire and interview. The authors used Abd-El-Khalick and Lederman's (2000), Views on the Nature of Science Questionnaires (VNOS-B & C) a modified questionnaire to assess the prospective teachers conceptions (PSTs) of NOSK. Three more questions were added to original items from VNOS questionnaires. The analysis focused on generating profiles of PSTs' understandings of NOSK before and after the STS (science, technology and society) course followed the *explicit project based science*. The questionnaire and interview data were analyzed using the analytical inductive model of qualitative data analysis approach. All the questionnaires and interviews were treated separately. The authors also reported that the entire data analysis was repeated two times to increase the reliability of analysis and found about 80 per cent agreement between the two sets of analyses.

For the inferential statistic test, each participant's response to each item of the questionnaire was classified under three categories, such as '*informed*', '*mixed*' and '*naïve*'. Based on this classification, the nonparametric Wilcoxon test was used to compare the pre and post instruction results. Celik and Bayrakceken (2012) reported that the majority of PSTs held naïve or mixed views about most aspects of NOSK at the beginning of the instruction, there was substantial development in the participants' conceptions about many aspects of science at the end of the instruction; however, little change took place for either conceptions related to the social and cultural influences on science or creativity and imagination in science.

The findings reported by Celik and Bayrakceken (2012) have the following shortcomings. One of the restrictions is related to the sampling strategy they applied - convenient sample method is that its results cannot be generalized to the expanded population, results are only restricted with its sample (the authors also indicated this limitation). Moreover, the intervention is part of a course – not a specially designed program to develop NOSK; and the outcomes cannot be attributed to this course based intervention alone. Thus, a more, rigorous research design is needed to arrive at conclusive findings that give more confidence to intervene if necessary.

A study by Concannon, Brown and Brown (2013) also investigated prospective teachers' conceptions of science theories before and after instruction. The participants were 35 purposefully selected prospective teachers from four consecutive year students (different groups). All prospective teachers were enrolled in an Elementary and middle school methods of teaching science course or a secondary methods of teaching science course. The instruction focused specifically on prospective teachers' misconceptions that theories are not used to predict, that laws are more important than theories, and that theories are simply hunches. They used an action research design by applying Posner et al.'s (1982) conceptual change model. The authors' reported that the majority of the participants (elementary and middle level prospective teachers) (88%) had only one college science course prior to taking the survey.

Data about prospective teachers' conceptions of science theories before and after instruction was collected for four consecutive years using 10 statements (A to J) which require putting check marks (X's). Descriptive statistics including percentage was used to analyze the data. The primary misconceptions about theories in science prior to instruction discovered by the authors (Concannon et al., 2013) were: 1) a scientific law has been proven and a theory has not; 2) theories do not include observations; 3) theories cannot be used to make predictions; and 4) theories are "hunches" scientists have.

However, Concannon et al. (2013) reported that after receiving explicit instruction these prospective teachers developed more accurate views of NOSK and “scientific theories” while retaining some naïve conceptions. Overall, explicit instruction of science theories decreased the number of incorrect ideas students held. However, the idea that theories are “hunches” persisted, especially for students who had several incorrect ideas about theories in science.

Concannon et al.’s study (2013) gave us some insights on how we can help prospective teachers develop better understanding of NOSK by conducting a study focusing on misconceptions of NOSK through explicit instruction. However, the study has the following limitations that future researchers should be cautious of the results. Firstly, the study was an action research design which is difficult to control variables that affect participants NOSK concepts other than the intervention (the explicit NOSK instruction). Thus, other designs like control-groups pretest- posttest design could provide us a more valid conclusion. Secondly, the data was collected by close-ended questionnaire. Forced choice questionnaire may force participants to provide answers which they may not have any idea about it which may potentially lead to erroneous conclusions. This requires an open ended questionnaire that complements with the closed-ended which is used in this study. The sample size is also small, large samples being other conditions constant can give us a more generalizable data. Even the authors reported that some participants held naïve views of NOSK after intervention. All these shortcomings call for a research design which is more rigorous and able to develop prospective teachers NOSK views.

Seyhan and Türk (2013) conducted a study to determine the problem solving performances of science teachers participating in the problem solving application in the chemistry lab; its relationship with their opinions of the nature of science along with their beliefs about the nature of science and science teaching as variables. Single group Pretest and posttest design was used. The study participants were 40 student- teachers'. Seyhan and Türk designed and implemented problem solving performances application at chemistry lab. This problem solving performance application had five phases (steps) that lasted six weeks. The student-teachers in the chemistry lab were grouped in to four or five members to carry out the PBL activities. They followed five consecutive phases. In the first phase they identified and selected ten (10) problem cases among daily life events. During the second phase (second week of the lab) each group identify a problem. In the third phase, each group has established a hypothesis, and shared responsibilities among group members. They also collected data and present a solution way of choice and present as a form of experiment suggestion. During the fourth phase, they conducted the experiment (Suggested experiment solution), generalize their results and expressed them using their own words. Finally, in the fifth phase, the groups who failed to obtain results according to the hypothesis they established, revised their solution steps.

Student-teachers problem solving skills were scored between 0 and 4 according to the quality of the skill. Content validity- obtained through expert opinion. Opinion survey on the nature of science questionnaire VNOS-C was used. The data was analyzed using paired-sample t-test. The results reported by Seyhan and Türk (2013) following the problem solving application at the chemistry lab, student teachers' knowledge levels about the nature of science increased statistically. As the other studies we have discussed so far the study by Seyhan and Türk (2013), the intervention is part of a course delivery. Only one group is used, there is no randomization is sampling these all raise the issue of validity and generalizability of results. As a result a more rigorous research design that controls the validity threats is necessary to come up with a usable solution.

Boran and Bağ (2016) conducted a study to investigate *The Influence of Argumentation on Understanding Nature of Science*. The participants were 20 pre-service science teachers. Based on pretest and posttest scores of the views of nature of science-C (VNOS-C), three participants were selected for the process of gathering qualitative data with questionnaires and follow-up interviews. The intervention was conducted weekly in 2 hour sessions, and covered a 14-week period. The intervention session of the study was conducted over an 11-week period. They used open-ended questions which were aimed to gather pre-service science teachers views on the following eight aspects of science: the empirical nature of science, the methods of science, theories and laws, the tentative nature of science, the inferential and theoretical nature of science, the subjective and theory-laden nature of science, the social and cultural nature of science, and the creative and imaginative nature of science. After the questionnaires are analyzed Boran and Bağ (2016) selected three participants for interview. During the interviews, the selected participants were provided with a copy of their pre and post VNOS-C questionnaire responses and asked to read, explain, and justify their answers to each of the questions.

Boran and Bağ (2016) found that the argumentation based science instruction has contributed to the positive development of 2 of 3 participants' views of the nature of science from naïve nature of science views to more informed views. After intervention phase, only case 2 showed development from a limited to a partially informed view and the other 2 cases (case 1 and case 3) did not show any change on this aspect. The results on the tentative nature of science aspect showed that before the intervention session, case 2 and case 3 expressed limited, but only case 1 expressed partially informed views of this aspect of the nature of science. Case 2 and case 3 expressed absolutistic views. After intervention phase, only case 2 showed developments from a limited to a partially informed view, case 1 and case 3 did not show any change on this aspect. Only 2 of this 3 cases' (case 1 and case2) views of the theory-laden nature of science improved substantially over the course of the intervention. Case 1 showed a change in his/her view of the theory-laden nature of science from partially informed view to an informed view. Case 2 showed a change in his/her view from a limited view to a partially informed view. Case 3 did not show a significant improvement in this aspect of nature of science.

The aspect of creative and imaginative nature of science – one of the three participants (Case 3) failed to understand the role of creativity and imagination at all stages of scientific research. But all of them showed improvement in their understanding of this aspect, and displayed informed views (case 1 &case2) of this aspect at the conclusion of the study.

Boran and Bağ (2016) reported that all of the participants expressed limited views of the examined nature of science aspects at the beginning of the study. But after the argumentation-based science instruction intervention, pre-service science teachers' views of the nature of science were improved. This study has however some limitations that calls for researchers and users attention. The intervention (argumentation) has failed to promote some aspects of NOSK to some pre-service teachers. These calls for a change in the approach or a need to include additional method(s) that help develop pre-service science teachers NOSK views. In addition, the study is part of a course which is conducted at a specific context, not applied random selection of participants, and used a single group. Such conditions are very loose to control variables that affect results other than the intervention which consequently makes generalization of the result difficult. Thus, future studies designed with the aim of improving participants' nature of science views should apply research designs that better control the influence of extraneous variables that could potentially affect results.

Another NOSK research by Çibik (2016) investigated the effect of project-based history and nature of science practices on pre-service science teachers' views of nature of scientific knowledge. The participants were undergraduate students attending teacher preparation Program of Science Education. The aim of the study was to compare the change of pre-service science teachers' views about the nature of scientific knowledge with PBHNOS training and conventional method. The study was conducted in History and Nature of Science course which is scheduled in the second semester. The experimental group was instructed through PBL, the control group received conventional method.

Çibik (2016) used a *non-equivalent control groups design* out of quasi-experimental designs. Pretest-posttest (one for experimental group, N=41 and the other for control, N= 46 group). The two groups were assigned randomly, but not individuals selected randomly. The experimental group was exposed to practice steps of PBHNOS in addition to the techniques such as discussion, question-answer, and brainstorming. The participants in the control groups were instructed via techniques such as traditional lectures**,** discussion, question-answer and brainstorming. Çibik (2016) used a questionnaire comprised of 24 Likert-scale items (from 1 to 5) and six open-ended questions. The quantitative data was analyzed using independent samples t-test. For the open-ended questions if a response is accordant with the contemporary thought on NOSK, it is found as an *informed views, it is scored 3; transitional views* scored as 2, and those responses including misunderstandings or self-contradictory expressions are evaluated as *naïve views,* scored as 1.Çibik found that the project activities providing attainments at first-hand in acquiring more permanent and detailed knowledge about the nature of scientific knowledge became effective for changing the pre-service teachers' views of scientific knowledge.

The random assignment of the two groups is the strength of Çibik's (2016) quasi-experimental design. Nevertheless, lack of random selection of individuals still poses a problem to its validity, that is, the control and the experimental groups may not be equivalent at the start. And thus, differential experimentation interaction effects are not controlled. This leads us to suggest a more controlled experimental design like pre-test posttest equivalent groups experimental design or better like the Solomon –four group design which can control threats to experimental validity.

Another NOSK study that investigated pre-service science teachers' was conducted by Mesci and Schwartz (2017) to see the effect of reflective/explicit teaching of views of nature of science. These pre-service teachers' were fourteen undergraduates (8 female & 6 male) with an average age of 24. The course was part of a 13 month program for K-12 science teachers. The course was specifically designed to teach about inquiry and NOSK to pre-service teachers over 16-weeks.

Mesci and Schwartz (2017) collected data through questionnaires, interviews, and classroom observations. They reported that NOSK views were assessed in a pre/post course format surveys that are open-ended, they developed a profile for each participant, describing their views on a continuum from naïve to intermediate (mixed) and to increasing levels of understanding. The pre-test (open-ended questionnaires and interviews) indicated that participants' views of NOSK were, in general, not in agreement with some aspects of NOSK, including tentativeness, subjectivity, multiple scientific methods, and distinctions between scientific theories and laws. The authors found that participants' views were mostly mixed on the aspects of creativity, observation and inferences, empirical, and socio-cultural embeddedness.

These two authors reported that at the end of the course, the participants showed positive changes for all aspects of NOSK including scientific methods, tentativeness, and differences between scientific theories and laws, even though some of the participants still struggled with these three aspects. However, in the two aspects of NOSK (i.e., the tentative NOSK and theory/law differences) remain as areas of greatest struggle. The participants who did not show change continued to report a hierarchical view of scientific theories transitioning to laws, which are absolute and unchanging.

In the study of Mesci and Schwartz (2017) there were positive changes in some aspects of NOSK as a result of the course that designed to enhance pre-service teachers NOSK views. They collected data using different methods including questionnaire, interview and observation which may help to get more comprehensive data that could contribute to its validity. Moreover, as the study is part of a course students will have the necessary motivation to learn and take the tests and interviews. However, as the intervention is part of a course (although it has merits as I already mentioned before), we cannot be sure whether the result is purely from this course based intervention alone or influenced by other courses offered in parallel. Moreover, the participants were pre-existing classes (i.e., they are not randomly selected and assigned), thus they cannot be taken as representatives of pre-service science teachers in their state or country, which makes the generalizability (or transferability) of findings untenable. Furthermore, after the completion of the course the finding revealed that there were still some pre-service teachers who struggle at three aspects of NOSK, namely scientific method, tentativeness of NOSK and understanding differences between theory and law, especially the last two aspects are reported to be areas of greatest struggle. All these limitations, which include lack of representativeness in terms of the study population, lack of control (results potential interference with other courses. Further research is necessary to determine the extent to which the results of this study may be generalized.

2.5. Summary and conclusion

Modern conceptions of nature of science (NOSK) need to be cultivated to both the teachers and students. However, there are gaps in the NOSK understanding of students and teachers. All of the interventions were course based which are parts of an in-service or pre-service science teacher education program. The program levels range from Kindergarten to secondary schools teacher education programs. The researchers used different types of research approaches (designs) that include explicit and reflective instruction, conceptual change model, project based instruction, and argumentation based instruction, problem solving approach. More than half of the studies used a single group study (Mcdonald, 2010; Mesci & Schwartz, 2017; Seyhan & Türk, 2013) and some others applied group comparisons (e.g., Çıbık, 2016). The groups are non-equivalent quasi-experimental type. Most of the interventions were conducted throughout the whole semester, except for two studies. The length of the studies reported in the papers ranged from 11 to 16 weeks. One of these studies lasted six weeks (Seyhan & Türk, 2013) and the other for four years (Concannon et al., 2013).

The instruments of data collection used in the reviewed articles can be classified in to three - questionnaire, interview and observation, although most of the studies used questionnaires and follow-up interviews. With regard to data analysis some of the studies applied qualitative approach (eg., Mcdonald, 2010), some use mixed (e.g., Niaz, 2008; Tsai, 2006), and some others used quantitative analysis (Concannon et al., 2013; Seyhan & Türk, 2013).

The pre-intervention assessment results of all (except one paper which made the assessment after some intervention) of the reviewed papers revealed that participants held naïve views of NOSK, at least on some aspects. The post-intervention assessments of participants NOSK views in all papers indicated some positive changes. Participants developed modern views on the NOSK aspects that they initially (i.e., before intervention) had naïve conceptions as a result of the intervention. But on some aspects of NOSK little progress is reported.

Intervention based studies reviewed in this paper were part of a course work for either in-service teachers or pre-service teachers or both. The research approaches were largely qualitative, except some which adopted a quantitative research approach. For example, Celik and Bayrakceken (2012) used a mixed research by applying both qualitative and qualitative designs and Seyhan and Türk (2013) used quantitative analysis technique. Most of the researchers applied the intervention study on a single group, while few of the studies used two groups. All of the studies reported that they were able to develop modern views of the in-service and pre-service teachers NOSK views, at least in some aspects of NOSK and to some participants.

The intervention studies were successful in giving us insights on how to change pre-service and in-service teachers' views of NOSK. However, there are limitations in the studies some inherent to the research designs they used. For example, all of the studies were part of courses and most of the intervention time last for a semester. Hence, the changes in the pre-service and in-service teachers cannot be fully attributed to the intervention alone. The changes could be also attributed to other related courses offered in parallel. The sample sizes they used are not selected at random and are also small, the findings based on such sample lacks generalizability to other populations. And thus, future research should use a research design that enables to control threats to validity (eg., pretest-posttest equivalent groups design) and sufficiently large sample which will give us a more confidence on the results to apply in similar contexts.

Others studies also found that teachers had inadequate understanding of most of the NOSK aspects (Govender & Zulu, 2017). However, the aspects of NOSK tenets that are exhibited uninformed differ. Some studies reported that teachers showed naïve views on many or all of the examined NOSK aspects while others reported or one or few of the NOSK aspects. The science teachers who subscribed naïve conceptions of NOSK appears that they are ill-prepared to evaluate how well informed an analysis a student may produce in such circumstances in a conventional manner or on a large scale (see discussion by Allchin, 2011).

This calls for further investigation to reach at a conclusive generalization. Thus, this study investigated to fill this gap by identifying on which aspect/ aspects did the teachers and their students reflected informed conceptions and on which aspects did they held naïve views.

2.1. Theoretical framework

This study aims to look at the nature of scientific knowledge views of secondary school teachers and students. The study is based on a theoretical model adopted from McComas (2015, 2017) regarding the nature of scientific knowledge.

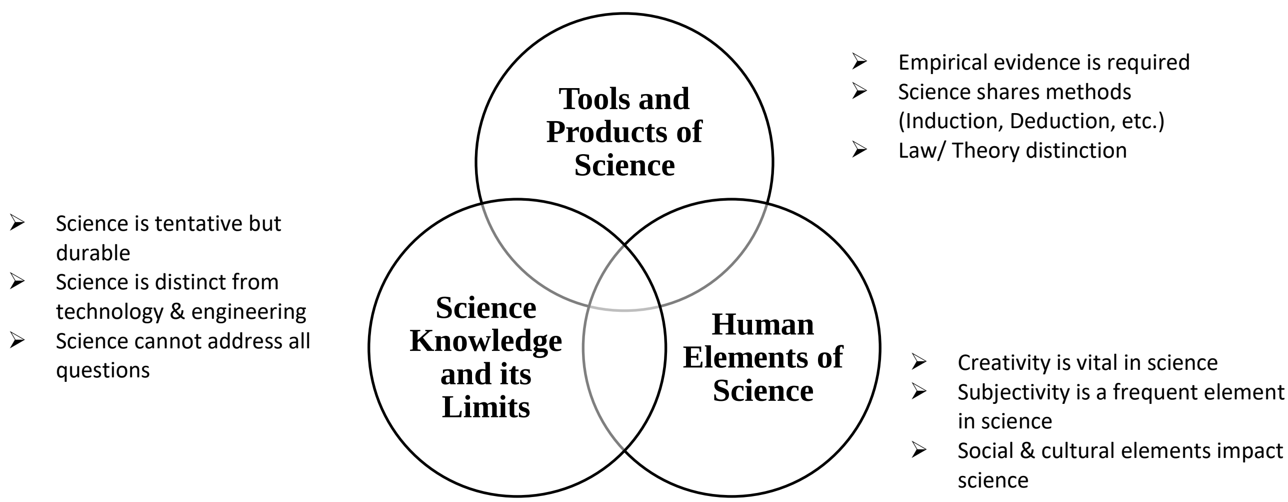

Figure 1

Major aspects of NOSK arranged in three clusters

The model shows the common elements of NOSK that will provide guidance regarding the elements of NOSK that might be integrated to science teaching. In the model, as can be seen from Figure 1, NOSK elements are arranged in three clusters with related sub-elements. McComas (2017, p.75) stated that "…we have strong rationales for the inclusion of NOS in the classroom and equally robust and thoughtful suggestions for what must be taught in this domain". It is based on the premise that students should learn about the purpose of science, how scientific knowledge is obtained, and the values and beliefs that influence the advancement of scientific knowledge (Abd-El-Khalick & Lederman, 2000; Urhahne et al., 2011). This is guided by the questions about which NOSK concepts students should be informed at the secondary school grade level. The theoretical model used for this study is based on Lederman's (1992) conceptualization of NOSK. This theoretical model is supported by many leading researchers in the area of NOSK (Abd-El-Khalick, 2012; N. G. Lederman et al., 2002; Liu & Lederman, 2007; McComas, 2017). The approach of examining sets of recommendations for providing guidance regarding the element of NOSK that might be integrated into science teaching is called the NOS consensus approach. Several researchers in the area of NOSK have concluded that there exists a considerable consensus about the foundational aspects of the NOSK (N. G. Lederman et al., 2014; Liu & Lederman, 2007; McComas, 2015).

Based on the consensus view, N. G. Lederman et al. (2002) suggested seven aspects of NOSK that are relevant and accessible to K-12 students. These aspects are the following:

> …scientific knowledge is tentative; empirical; theory-laden; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the lack of a universal recipelike method for doing

science, and the functions of and relationships between scientific theories and laws. (p. 499)

The theoretical model depicted in Figure 1 gives readers on how the nature of science is conceptualized. However, in order to examine secondary school teachers' and students' conceptions of NOSK, it is necessary to focus on the dimensions of NOSK that are well recognized to be useful to K- 12 class level. The specific tenets of NOSK that will serve as a framework are those which describe the nature of scientific knowledge as tentative, empirically based, subjective, involves human imagination and creativity, and socially and culturally embedded, distinctions between observations and inferences, and understanding the relationships between scientific theories and laws.

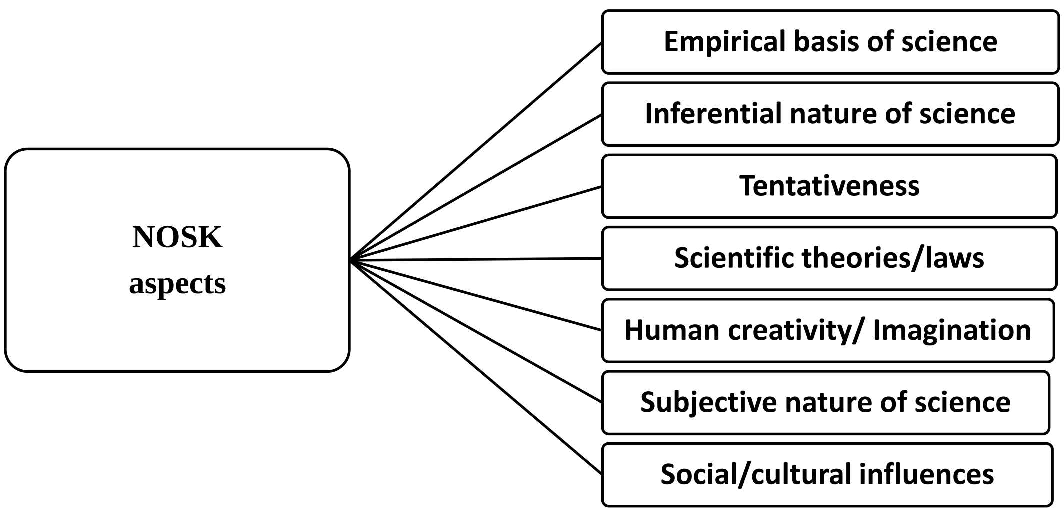

Figure 2

Theoretical framework of NOSK

Figure 2 shows the theoretical framework used in this study to examine secondary school teachers and students NOSK conceptions. This research uses these seven aspects of NOSK to examine secondary school students and teachers' conceptions of NOSK.

These seven aspects are well recognized by different researchers in the area of NOSK and used as a reference to assess secondary school students and teachers conceptualizations of the NOSK (N. G. Lederman et al., 2002; Liu & Lederman, 2007; Sangsa-ard & Thathong, 2014).

The seven dimensions presented in Figure 2 are distinct, each providing information on a unique aspect of the NOSK; however, all of them are epistemologically interrelated by the overarching construct of NOSK. That is, epistemological views developed by students in one domain of the NOSK can inform or impact their ideas within the other domains (Smith et al., 2000). For example, scientists perform their work in an interpretive explanatory framework which cultivates the notion that scientific knowledge is subjective and often tentative (N. G. Lederman et al., 2002). Therefore, it is important to remember that they are interrelated and, as a result, to understand the underpinnings of each domain will require reference to the other domains within the NOSK construct.

It appears that students' conceptions of NOSK have been placed within the constructivist epistemology (N. G. Lederman, 1992). Constructivists base their approach to learning on grand theorists of Jean Piaget's and Lev Vygotsky's learning theories. Although Piaget and Vygotsky are within the constructivist learning framework, they have followed different lines; cognitive constructivist and social constructivist, respectively. However, this paper did not focus on the differences in their emphasis and as a result did not discuss them separately. This is because the intention here is to give a brief account where the NOSK learning is situated among the major learning theories, but not to present the details of the two specific theories.

Both Piaget and Vygotsky asserted that the learner actively interacts with his/ her physical or social environment and constructs his/ her own understanding. Constructivism postulates an epistemological view that the learner is an active agent who makes meaning out of the interaction. In this regard, Applefield et al. (2001) stated that constructivism is an epistemological view of knowledge acquisition that emphasizes learner as the one who constructs his/her own knowledge rather than receiving knowledge from others.

Constructivists learning is conceived as a set of constructive processes in which the individual student alone or socially builds, activates, elaborates, and organizes knowledge structures (Seidel & Shavelson, 2007). That is, the learner builds and transforms knowledge based on present interactions and previous experiences (Applefield et al., 2001). The learners based on their existing experience and new information can build their own understanding at times different from that of the teacher or responsible adult (Knapp, 2000). Based on constructivists perspective, teaching should be geared towards maximizing opportunities for learners to partake in tasks that facilitate higher order learning (Seidel & Shavelson, 2007).

Moreover, students enter to the classroom with misconceptions about science content and process as well as the nature of science that originate from their prior experiences (Rudge & Howe, 2009). According to constructivists, students must be challenged so that they can realize the insufficiency of their own prior conceptions (i.e., misconceptions). It is through facilitating this reconstruction process that teachers have a chance to overcome those previously held misconceptions by students and develop students' modern views of the nature of science (Rudge & Howe, 2009).

In order to assess higher order level thinking it is not sufficient to rely on closed ended paper-and-pencil items. Research findings revealed that constructivist assessments help students to develop higher-order thinking and become independent, autonomous learners (Abulnour, 2016). The qualitative approaches provided more in depth assessments of teachers and students' conceptions of NOSK while not contradicting with results from quantitative approaches (N. G. Lederman, 1992).

UNIT THREE

RESEARCH METHODOLOGY

3.1. Introduction

This unit dealt with the research philosophy that this study related to, the study population, the ways how participants were selected, the nature of data collection instruments, procedure of data collection, and data analysis techniques as well as ethical measures considered in this study.

3.2. Research Philosophy

The purpose of this study was to examine secondary school students and science teachers' conceptions of the NOSK. To address the research objectives, this research adopted pragmatic philosophical assumptions. The pragmatic paradigm rejects the discourse that the qualitative and quantitative methods are mutually exclusive. In fact, researchers have increasingly come to believe that these two research methods can coexist in a dialectical relationship and the findings from the two methods, either convergent or divergent, enrich our understanding of the phenomenon under investigation (Hashemi & Babaii, 2013). Quantitative researchers assume a single reality, whereas, qualitative researchers believe in multiple truths. However, pragmatists' conception of reality shares from both stances. For pragmatists, although there exists a single "real world", individuals could conceptualize it differently. As Morgan (2007) nicely put it:

> In a pragmatic approach, there is no problem with asserting both that there is a single “real world” and that all individuals have their own unique interpretations of that world. Rather than treating incommensurability as an all-or-nothing barrier between mutual understanding, pragmatists treat issues of intersubjectivity as a key element of social life. (p.72)

This intersubjectivity represents the pragmatic solution to the incommensurability issues (Morgan, 2007). Since the practical value of using mixed approaches is evident, the problem of incommensurable philosophical assumptions behind the qualitative and quantitative approaches need not be a hindrance (Hashemi & Babaii, 2013). Thus the present study adopting this pragmatic philosophy makes use of both quantitative and qualitative data which provided us a rich understanding of the teachers and students conceptions of the NOSK.

3.3. Research Method

3.3.1. Research approach

This study used a mixed methods research design. The formal distinction between quantitative and qualitative study is no longer significant because the pragmatic tradition provides us with a more accurate and facilitating perspective on thought, inquiry, and philosophical thinking in education (Giarelli, 2005). This means that the difficulty with rigorous thought is no longer useful (Giarelli, 2005). These philosophical underpinnings of pragmatism allow researchers to use mixed methods to answer research questions that can be addressed using a variety of methods. As a methodology, it involves the collection and analysis of data and the mixture of qualitative and quantitative data in a single study (Creswell, 2009; Fraenkel et al., 2012; Teddlie & Tashakkori, 2009). Thus, a researcher is able to analyze data, integrate the findings and draws inferences using both qualitative and quantitative approaches in a single study.

The advantage of using a mix of qualitative and quantitative methods have complementary strengths and non-overlapping weaknesses (Fraenkel et al., 2012). Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone. In this regard, Almalki (2016) explained that using a mixed methods research approach is convenient for any given project and besides has the potential to provide greater depth and breadth of data which cannot be achieved through one method. In a similar vein, Hashemi and Babaii (2013) explained that research informed by both the QUAL and the QUANT approaches will yield more detailed evidence, whereas, absent one or the other meant many questions remain only partially answered.

In this study, both quantitative and qualitative research approaches are used to investigate students' and teachers' understanding of NOSK. The results from both the qualitative and the quantitative data were integrated to form general conclusions or meta-inferences. "A meta-inference is a conclusion generated through an integration of the inferences that have been obtained from the results of the QUAL and QUAN strands of an MM study" (Teddlie & Tashakkori, 2009 ,p.136). In the recent decade, NOSK research has used both QUAL and QUAN approaches (Ssempala, 2019).

This research used a mix of approaches (Qualitative & Quantitative) and participants (students and teachers). The QUAL and QUANT phases are mixed to answer related aspects of the same overarching research questions in a parallel, either simultaneously or with some time lapse (Teddlie & Tashakkori, 2009). The present study adapted an embedded mixed methods design to examine students and science teachers' conceptions of the nature of science.

3.3.2. Population, sample and sampling techniques

Data for examining students' and teachers' understanding of NOSK was collected from three secondary schools. The schools were selected from two cities in the Amhara region of Ethiopia, namely, Bahir Dar and Debre Markos cities. The two cities were accessible to the researcher as the one is located at his home University (working site) and the other is at his host University (learning site).

The three schools were selected because of their seniority; these schools are the senior (old) ones in their respective cities. They are also among the senior schools in the region. Senior schools are selected as samples primarily related to the depth and richness of data they can provide. Long-serving staff members can offer perspectives and insights that newer institutions may lack. Studies in established schools can be more easily generalized to other similar institutions. This helps in creating benchmarks and setting standards for other schools to follow. Selecting older schools as samples allows researchers to tap into a rich vein of historical data, stable institutional practices, and broader social and cultural contexts, providing a deeper and more comprehensive understanding of educational phenomena.

The other issue to be noted here is that from Debre Markos city two schools were selected because Nigus Tekile Haymanot School had no grade 12 students; and Debre Markos secondary school had no grade 10 students (see Table 3) during the time of data collection. To select secondary school students' strata was formed based on gender and grade level to ensure a fair representation of the subgroups. Then the participants were selected using systematic random sampling technique.

The student population in the selected schools by grade level and gender, and the total population is presented in Table 3.

Table 3

Student population in the selected secondary schools

Name of secondary school	Grade 10			Grade 12			Total
	Male	Female	Total	Male	Female	Total	
Nigus Tekile Haymanot	580	684	1264	-	-	-	
Debre Markos	-	-	-	272	177	449	
Tana Haik	554	453	1016	338	354	692	
Total	1134	1137	2280	610	531	1141	3421

Grade 10 students were considered as samples because of the fact that about half of the students terminate learning science subjects at this grade level. That is, after completing Grade 10, some of the students would join technical and vocational colleges; the world of work; or some would join to social science streams if promoted to grade 11. In such cases, there is less likely to get science education in a formally organized way. Grade 12 students were included aiming to investigate at the completion of secondary schooling, to what extent natural science students were informed about the nature of scientific knowledge. In addition, including grade 10 and 12 students as a study population enabled the researcher to examine whether the science subjects offered after grade 10 had a developmental role on students NOSK conception by comparing the two Grade levels.

Although the sample for this study was selected from only three high schools; from two cities in the Amhara region, the researcher did not believe it to be a likely threat to the representativeness of the population. This assumption is based on the fact that the schools in Ethiopia follow the national curriculum, which could result in homogeneous learning and teaching in terms of quantity as well as quality. Moreover, these schools are among the most senior schools that accommodate broader social and cultural contexts, providing a deeper and more comprehensive understanding of educational phenomena.

3.3.2.1. Demographic characteristics of selected students

Table 4 presented the characteristics of the students who participated in this study. Grade 10 students were 66 (M= 31, F= 35), and grade 12 students were 68 (M= 39, F= 29) who completed the questionnaire. The age of grade 10 students ranged from 15 to 23 with a mean of 17.46 and an SD of 1.47. The age of grade 12 students ranged from 16 to 23 with a mean of 18.66 and an SD of 1.35.

Table 4

Demographic characteristics of selected students

			Secondary school name			
Sex		Grade level	Tekile Haymanot	Debre Markos	Tana Haik	Total
Male		Grade 10	14	0	17	31
		Grade 12	0	18	21	39
	Total		14	18	38	70
Female		Grade 10	22	0	13	35
		Grade 12	0	13	16	29
	Total		22	13	29	64
Total		Grade 10	36	0	30	66
		Grade 12	0	31	37	68
	Total		36	31	67	134

All of the selected students returned the questionnaire as it was administered face to face. However, due to incomplete data 5 questionnaires (5.71%) from grade 10, and 1 questionnaire (1.45%) from grade 12 were excluded from data analysis.

3.3.2.2. Demographic characteristics of science teachers

Table 5

Population of science teachers in the sample schools

Name of secondary school	Field of Study						Total
	Biology		Chemistry		Physics		
	Male	Female	Male	Female	Male	Female	
Nigus Tekile Haymanot	6	3	3	6	9	0	27
Debre Markos	5	2	6	2	5	2	22
Tana Haik	7	4	6	5	11	1	34
Total	18	9	15	13	25	3	83

Table 5 presented the population of science teachers of the selected schools by field of study and gender. The researcher attempted to access all of the teachers. However, some of the teachers who were assigned to teach grade 9 science subjects were not available because of the delay of grade 8 students' national examination results, grade 9 students were not registered during the time of data collection. This resulted in a substantial cut from the potential science teacher participants.

Table 6 displayed the actual sample of teachers who took part in the study. The Table shows the demographic characteristics of the secondary school science teachers who completed the questionnaire in terms of their sex, school and field of study. As displayed in Table 6, the science teachers who completed the open-ended questionnaire were 48. The majority (79.17%) were males (M=38, F=10). Regarding their field of specialization; 13 biology, 16 chemistry and 19 physics teachers. All participants had a minimum of a Bachelor's degree (BSc/ BEd). The age of participants 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 6

Demographic characteristics of participant science teachers

School Name	Field of Study						Total
	Biology		Chemistry		Physics		
	Male	Female	Male	Female	Male	Female	
Tekile Haimanot secondary school	3	0	1	3	6	0	13
Debre Markos secondary 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

The three schools, as mentioned above, 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. The Ethiopian Orthodox Tewahedo Church, for example, was the primary paradigm for understanding Ethiopia (Ancel & Ficquet, 2016). 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 selected schools had modern buildings, laboratories, libraries, and sports fields. However, the number of classrooms was limited, and to overcome the problem, about half of the students were attending classes in the morning while others were learning 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' and students' proficiency in the language might 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 reality could impact student learning by guiding the learning-teaching process to meet the demands of passing exams by cramming and regurgitating rather than understanding concepts in depth. This could also have effects on teachers' levels of understanding of scientific concepts as they could also focus on the coverage of the subject they teach. Therefore, the students' and teachers' conceptions of the NOSK could be explained at least partly as a function of these socio-cultural forces that need to be addressed.

3.3.3. Data collection instruments

In this research open-ended questionnaire that elicited both qualitative and quantitative data was used. Open-ended questions have the advantage of probing students' explicit statements about NOSK contextualized in students' choice of words (Leach, 2006). When respondents are able to explain answers in their own words, it helps to ensure that the data accurately reflects their true thoughts and experiences, thereby increasing the reliability of the findings (Sangsa-ard et al., 2014).

Students' conceptions of NOSK can be elicited by various methods. Interviews are among the methods frequently used because it is a good way to learn the narratives underlying the participants' experiences. However, the goal of this study was to explore beyond the level of individual representations of school science. Moreover, the generalizability of the interview method is called into question, which results from a controversy about the applicability of the findings from small samples (Bihu, 2020). Therefore, the present study used a writing-based survey that invited more participants. These surveys provided a more coherent means of representing participants' views of the NOSK than oral interviews.

In contrast, close-ended items can help minimize interpretation bias on the part of the researcher and are advantageous in providing large amounts of data from a wider population at a relatively low cost. However, they fail to detect either the participants' perceptions or interpretations of the test items or their underlying reasons for making choices (Chen, 2006; Liu & Lederman, 2007). The assumption that the participants and the developers agree or disagree with statements for the same reasons further threatens the validity. Chen argued that in conditions where the underlying reasons cannot be assessed, the data analysis will be too superficial to reveal the participants' conceptions of NOSK. As a result, the present study used an open-ended NOSK questionnaire.

Open-ended questions allow participants to elaborate on their understanding of NOSK, and overlapping of target aspects among the questions allowed researchers to generate profiles of students' and teachers' understanding of each NOSK aspect (Eastwood et al., 2012; Liu & Lederman, 2007). The most widely used open-ended pencil and paper tool is the Views of the Nature of Science VNOS-C Questionnaire developed by Lederman et al. (2002). It was primarily constructed with the justification that earlier convergent instruments were all designed around forced-choice items, including Likert scales, agreement/disagreement, or multiple choice. This 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. Liu and Lederman (2007) used seven of the VNOS-C items to assess prospective elementary science teachers in Taiwan. These seven items together with VNOS-D^+ items were adapted and used in the present open-ended questionnaire. The VNOS-C instrument was used to elicit both quantitative and qualitative data in many NOSK researchers (e.g., Mercado et al., 2015; Sangsa-ard et al., 2014).

3.3.4. Translation procedure

The questionnaire was prepared in English and translated into Amharic by the present researcher. The translation was reviewed in terms of meaning and word selection according to the original text by three peers who were PhD candidates in the field of educational psychology. Then, two language experts who were competent in both Amharic and English reviewed and validated the translation. Finally, the principal supervisor of this research, who had rich experiences in educational and psychological research, provided comments for improvement on the meaningfulness of the questionnaire. The suggestions provided by peers, language experts and the supervisor helped to improve the quality data collection instruments.

3.3.5. Validity of the instrument

The items used in this study were developed by adapting from previous studies which were validated and widely used that provided a basis to construct validity. The validity of the instrument was established with undergraduate and graduate college students, pre-service elementary teachers, and pre-service and in-service secondary teachers by Lederman et al. (2002). The validity of the items had been also tested in previous studies (Govender & Zulu, 2017; Liu & Lederman, 2007).The present researcher also translated and used the questionnaire items for research with biology postgraduate diploma (pre-service teachers) students at Bahir Dar University during a PhD course work.

Although the items were adapted from previous studies that were translated and used in different cultures, mainly in Asia and Western countries, the present researcher tested whether they serve a similar purpose in Ethiopian culture to which these instruments were not used before. The validity of the present NOSK instruments were established through the following means. First, three educational psychology PhD candidates provided their comments on the relevance of each item on the instruments. Then, the instruments were pilot tested. The purpose of the pilot testing was finding out if the questionnaire will work in the "real world" by trying it out first on few samples. To this end, the open-ended instruments were administered to three science teachers and six students (3 from grade 10 & 12, each). The teachers and students were asked to provide comments for improvement. The objective was to make sure that participants in the sample understand the questions and to see if any question makes respondents feel uncomfortable. During the administration of the questionnaire, the participants in the pilot study were reminded twice (i.e., at the beginning & middle) to make a note of any word, phrase, or sentence that they had to read more than once, that they felt uncomfortable about answering, or about which they were unsure of the meaning. The pilot study was also important to determine how long it could take to complete the questionnaire in real time.

3.3.6. Reliability of instruments

The reliability of data collection instruments is computed by Kendall's tau. As the data was collected using open-ended questionnaire and rated by ordinal level of measurement Kendall's tau (τ) was used to determine the level of agreement between the two scorers. Tau is a rank order correlation statistic used to gain useful descriptive and inferential insights about the data.Brossart, Laird and Armstrong (2018). The inter rater coefficient for empirical NOSK was .84, tentative NOSK .85, subjective NOSK .84, Theory/ Law .73, creativity .92, Inferential NOSK .90, and society .76. These seven coefficients showed that the tau is statistically significantly ($p<.001$) different from zero. Moreover, the τ coefficients revealed a very high correlation between the two raters as it ranges from .73 to .92, and are positive. Thus, it can be concluded that the data collection instrument was reliable to elicit data from the study participants.

3.3.7. Data collection procedure

The instruments were administered to secondary school science teachers and secondary school students from the three selected schools. The participants in the selected institutions were given the necessary information about the study and were invited and encouraged to participate in the study voluntarily. The questionnaires were administered to participants who were willing to participate in the study. It is recommended to administer the VNOS Form-C questionnaire under a controlled condition (Mercado et al., 2015). Accordingly, the present students completed the questionnaire in the classrooms in a face-to-face manner. On average, it took 35 minutes to complete the background data and the open-ended items of the questionnaire. Science teachers completed the questionnaire in their own time (e.g., in their office or home) due to practical reasons. For the teachers, on average, it was expected to take about 45 minutes to complete. During data collection, the administrator/s reminded the participants that there was no right or wrong answers, but accurately presenting their views is important to the study; this concern was also addressed in the instruction part of the questionnaire.

3.3.8. Data analysis procedures

In order to analyze the open-ended questionnaires analytical categories were used based on the seven NOSK aspects, which were targeted in this study, to create meaning. Pre-specified categories, as the case in this study, to which the researcher is looking for the seven NOSK aspects, are useful if the researcher knows what he/ she is looking for (Griffee, 2005). Such analytic induction method of analysis was also used by Liu and Lederman (2007).

A scoring guide (Appendix E) was prepared for the analysis of the students' and teachers' responses to the open-ended questions. If a response was in accordance with the contemporary views of NOSK, it was rated as an *informed view* (score = 3). Syncretic/*Intermediate views* (score=2) represented the responses that are partially informed understanding or fail to provide reasons for justification. Responses including misunderstandings or self-contradictory expressions are evaluated as *naïve views* (score =1). Finally, the following situations were rated as *not classifiable (unclassified),* (NC) if 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 were used by different researchers (e.g., Çıbık, 2016; Liang et al., 2008; Miller et al., 2010).

Table 7

Sample scoring rubric

NOS aspect	Naïve conception, score = 1	Syncretic/Intermediate conception, score = 2	Informed conception, score = 3
Empirical NOSK	Focuses responses on only empirical evidence and has a particular focus on being able to see all aspects of what is being studied.	Understands that a model cannot be seen but still overly focused on empirical data.	Knows that inferences have to be made to create knowledge, particularly about things that cannot be seen.

Note: Table 7 presents a sample scoring guide used in this study. The complete guide is presented in Appendix E.

During a study related to coursework, the current researcher became acquainted with the NOSK grading guide. In addition, the researcher carefully reviewed the scoring rubric to understand the meanings given for every NOSK aspect. Then, using the rubric as a guide, the researcher scored the surveys as 1) uniformed, 2) syncretic, and 3) informed (Appendix E). To be as objective as possible, the questionnaire responses were scored across the participants. A month later, the scoring was done once more to find any inconsistencies, reflect on challenges encountered, and adjust the scoring as needed. Then, participants' conceptions of each tenet were substantiated with written quotes and were reviewed by a colleague who was proficient in both Amharic and English languages. The percentages of naïve, syncretic/ intermediate, and informed views were described based on the analysis of the participants' responses to each category.

The results of grade 10 and grade 12 students were compared to determine if there were differences between them in their NOSK conceptions; on which aspects did they relatively hold more informed conceptions and on which aspects did they hold naïve conceptions. For this purpose, the Mann-Whitney U test was used. IBM SPSS 23 was used to compute the U test. Mann Whitney U test was also used to compare the NOSK conceptions of male and female students.

Finally, discussions were made based on the finding of the study vis-à-vis the extant literature of NOSK.

3.3.9. Ethical considerations

Issues related to informed consent, confidentiality and the right to withdraw from the research were addressed in this study to make this research ethical, to provide benefits and to do no harm on the participants. With regard to informed consent, the researcher provided sufficient information to the study participants about the nature of the study. Informed consent is related to the research participants' right to be fully informed about all aspects of a research project that might influence their decision to participate (Ruane, 2005). The researcher asked permission from school principals to obtain the consent necessary to contact teachers and students in their schools. A letter written by department of psychology, Bahir Dar University College of education and behavioral sciences, which described the purpose of the study and requested the cooperation of concerned secondary schools was provided to Tana Haik secondary school principal. Another letter written by Debre Markos University college of education and behavioral sciences research vice dean which requested cooperation from secondary schools was given to Nigus Tekile Haymanot and Debre Markos Secondary school principals. Permission and cooperation was obtained from the three schools.

After securing permission from the principals, the purpose of the study was explained to the potential participants, that is, to secondary school science teachers and selected students, to participate voluntarily without any coercion. The purpose and the expected time to complete the study was explained to the participants. They were also informed that they can ask questions or raise concerns at any time about the nature of the study or the methods that will be used.

Other important ethical issues include treating research participants with respect and protecting the participants from both physical and psychological harm (Fraenkel et al., 2012). Accordingly, this study treated participants with respect and protect their physical and psychological wellbeing. Written informed consent is necessary if participants are exposed to more than minimal risk (Shaughnessy et al., 2012). Minimal risk is described as any harm or discomfort participants may experience is not greater than what they might experience in their daily lives or during routine physical or psychological tests (Shaughnessy et al., 2012). Shaughnessy et al. argued that many psychological laboratory studies that involve lengthy paper-and-pencil tests are likely no greater than minimal risk. This study, which involved students to participate in an educational classroom situation, and teachers in completing questionnaires in their own time is, therefore, expected to be no more than minimal risk. Thus, only oral consent was obtained in this study.

The right of participants to withdraw from the study at any time without compelled to give reason was addressed to the participants. The participants were informed that data gathered from them would be used in writing a research report and direct quotes from them may be used in the paper but their names and other identifying information would be kept confidential. Informing participants that the information they provide will be kept confidential has also other advantages. If participants know that their responses will be kept confidential, they are less likely to lie or withhold information (Shaughnessy et al., 2012).

In order to protect research participants from social injury, the researcher removed any identifying information in writing the research report and used code numbers that have no relation to the participants' privacy. If participants' identifiers such as IDs exist, they should be kept in secure settings (Fraenkel et al., 2012; Ruane, 2005). Accordingly, this study restricted participants' response sheets to only the researcher and to those who participated in the analysis of the study. For example, those who proofread the translation accuracy of written quotes had access to data in a way that will not breach confidentiality.

UNIT FOUR

RESULTS

4.1. Introduction

This section presents the participants' data, and the research results as well as the discussions made based on the results. Open-ended questionnaires were used to collect data about secondary school students and science teachers' NOSK conceptions. The questionnaires were analyzed based on the seven consensus aspects of the NOSK. The results are presented under these seven examined NOSK sub-headings: (1) empirical basis of science, (2) tentativeness, (3) subjectivity of scientists, (4) distinction between scientific theories and laws, (5) creativity and imagination in science, (6) observation and inference, and (7) social and cultural embeddedness of the nature of scientific knowledge. Mann-Whitney U test was also used to compare the NOSK conceptions between grade 10 and grade 12 students, and between male and female students.

4.2. Students' conceptions of NOSK

This section deals with grade 10 and grade 12 students conceptions of NOSK. Their conceptions are categorized as informed, uninformed, syncretic (intermediate) and unclassified based on their responses to questions that address each NOSK aspect.

4.2.1. Students' conception of the empirical NOSK

Students' conception of empirical NOSK is examined by their definitions of science and their explanations or descriptions of science by comparing it with other sources of knowledge: Q#1) What is science? And Q#2) What makes science (or a scientific discipline such as physics, biology, etc.) different from other subjects/ disciplines (religion, philosophy, etc.)?

Table 8

Frequency counts and percentage of grade 10 students' conceptions of NOSK

NOSK aspect	Response category	Frequency counts	Percent %
Empirical NOSK (Q1 &Q2)	Informed	0	0.00
	Syncretic (Has merit)	9	13.64
	Naïve	57	86.36
	Unclassified	0	0.00
Tentative NOSK (Q3&Q9)	Informed	26	39.39
	Syncretic (Has merit)	15	22.73
	Naïve	24	36.36
	Unclassified	1	1.52
Subjective NOSK (Q4&Q7)	Informed	24	36.36
	Syncretic (Has merit)	22	33.33
	Naïve	15	22.73
	Unclassified	5	7.58
Distinction between scientific theories and laws (Q5)	Informed	0	0.00
	Syncretic (Has merit)	4	6.06
	Naïve	51	77.27
	Unclassified	11	16.67
Creativity and imagination (Q6)	Informed	7	10.61
	Syncretic	18	27.27
	Naïve	34	51.52
	Unclassified	7	10.61
Inferential NOSK (Q8)	Informed	3	4.55
	Syncretic	12	18.18
	Naïve	29	43.94
	Unclassified	22	33.33
Society, culture and science (Q10)	Informed	16	24.24
	Syncretic	16	24.24
	Naïve	28	42.42
	Unclassified	6	9.09

Table 8 illustrates that the vast majority (86.36%) of grade 10 students showed naïve conceptions of the empirical NOSK. Only about 14% expressed syncretic conceptions but no student reflected informed conceptions on this aspect. The following quotations are exemplars of their naïve conceptions of empirical NOSK:

> Science refers to investigations that resulted in confirmed truth. Science in my opinion is a result of manmade technology. By doing research that gives answers that hold truth to those issues which are unanswered is called science. (S16)
>
> It differed [scientific study differed from religion & philosophy] as they focus on practical research; is based on truth, focused on confirmed work. (S42)

These grade 10 students expressed scientific knowledge as confirmed truth. In addition, S16, a female student, explained science as similar to technology while S42, a male student, described it as practical work. These responses are naïve in the sense that all scientific knowledge is not confirmed truth; science and technology are not the same; and all scientific knowledge is not practical it could give only theoretical explanations about natural phenomena.

The conception of grade 12 students on empirical NOSK is also inadequate as the vast majority of students (76.47%) held naïve conceptions. Only about 22% elucidated syncretic understanding. There was no student among grade 12 participants who exhibited informed views of empirical NOSK. A grade 12 student (S124, a male student) described science as "Science refers to a product which is confirmed for not causing harm." This student conceived science as a material product disregarding the process of conducting science and the generation of knowledge. In answering the question, "What is science?" one participant (SS124) went on to define science as: "Science changes a person's life. For example, if a woman who used to bake injera [Ethiopian thin bread] using traditional mitad [injera baking stove] if she can bake it with electric mitad that means there is science.'' This student defined and described science aligned to practical applications while disregarding the part of science that has been explored and exploring natural phenomena and has produced and is producing knowledge for its own sake. Thus, the participants' conception of empirical NOSK is classified as naïve.

Both grade 10 and grade 12 students expressed scientific knowledge as confirmed truth and its focus is on practical works. The participants regardless of their grade level expressed that scientific knowledge resulted exclusively from empirical evidence and laboratory investigations ignoring the explanatory purpose of scientific knowledge that resulted from scientists' subjective interpretation and imagination. In addition, some of the students view science as similar to technology. These responses are naïve in the sense that all scientific knowledge is not confirmed truth; science and technology are not the same; and all scientific knowledge is not practical or empirical as it could develop only theoretical explanations about natural phenomena.

4.2.2. Students conceptions of tentative NOSK

Students' understanding of the tentative NOSK was explored using two questions: Q#3. Knowledge in science is produced by scientists. Do you believe that in the future this knowledge may change? Describe your response and provide an example. And Question #9. Does a scientific theory (such as atomic theory, or evolution theory) ever change after it has been produced by scientists? Describe and provide an example.

A sizable proportion of grade 10 (39.39%), and grade 12 (47.06%) students, as presented in Table 8, expressed informed conceptions of the tentative NOSK. Note that grade 12 students demonstrated just shy of 50% in the tentative NOSK. The following excerpts from grade 10 (S03, S37) and grade 12 (S109, S118) students presented to illustrate their informed conceptions of the tentative NOSK.

> It can be changed. For example, in chemistry, it was believed that organic compounds are found in nature. But the compound named urea was created from non-natural chemicals artificially in a laboratory. (S03)
>
> Yes. Perhaps, we could find something different from research results. For example, first scientists believed that rotten meat was a source of living things. After that, Louis Pasteur disproved spontaneous generation by experimenting with mutton soup and concluded that living things come from microorganisms that are in the air. [i.e., Living things come from living things]. (S109)

In the quoted excerpts above, the students' views are consistent with the informed nature of the tentative NOSK. For example, the first participant (S03) who was a grade 10 student, demonstrated his/her understanding of the tentative NOSK by giving an example from the history of knowledge change in chemistry. The other student (S109), who was a grade 12 student, provided an example on the changeable nature of NOSK by providing experimental explanation of how spontaneous generation was disproved. Another student (S131, a grade 12 female student) also described that “Yes, as they do detailed research, they can investigate new things about the issue. Hence, there knowledge can get wide and can be changed.” These students (S03, S109 & S131) demonstrated an informed view that although scientific knowledge is durable, it is subject to change either in light of new evidence or by reinterpretation of existing knowledge.

However, there are about 36% of grade 10 and 31% of grade 12 students who harbored a naïve conception of the changeable nature of scientific knowledge. These students demonstrated that once scientific knowledge is produced it is everlasting. The following excerpts show the students uninformed conceptions of the tentative NOSK.

> I think it cannot be changed. Because the knowledge resulting from research is based on their field of study, they philosophize on it, and capacitate themselves; thus, how this knowledge can be changed? Because they philosophize on the reality/ concrete truth and therefore it cannot be changed. (S37)
>
> It [scientific knowledge] cannot be changed. For example, scientists produced knowledge by researching something; that knowledge will never change. Participant (118)

These students both are females, S37 a grade 10, and S118 a grade 12, argued that knowledge produced by scientists is concrete truth (S37) and that knowledge cannot be changed (S37 & S118). Such conceptualization of the NOSK is clearly to the opposite of contemporary NOSK conception. Therefore, their conceptions are naïve.

There are some proportion of students who have demonstrated intermediate (syncretic) conceptions of tentative NOSK. There were 23% of grade 10 students and 17% of grade 12 students had syncretic views on tentative NOSK. These students simply expressed that scientific knowledge is changeable without providing any further explanation.

In general, the students showed mixed views of the changing nature of scientific knowledge.

4.2.3. Subjective NOSK

Two questions were presented to investigate students' conceptions of subjective NOSK: *Q#4 If different scientists use the same data, do you think their conclusions are the same or different? Illustrate with examples. Q#7. It is estimated that the dinosaurs went extinct 65 million years ago. --- one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago --- that caused the extinction. ---another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different results possible if scientists in both groups have access to and utilize the same set of data to reach their conclusions?*

Analysis of data based on these two questions revealed that more than one-third (36.36%) of grade 10 students and the majority of grade 12 students (64.71%) reflected informed conceptions of subjective NOSK (see Table 8 & 9). These students acknowledged the influence of scientists' backgrounds on scientific knowledge construction beyond empirical evidence. The following quotations from grade 10 (S30, female) and grade 12 (S91, male & S95, male) students showed their informed views of subjective NOSK:

> It could not be similar. This is because human beings' thoughts and understandings are different. For example, if we ask the same question to different people their responses could be different because they understand it differently. Their understanding and attitude influence their conclusions. (S30)

It can be different. Although the data are similar, scientists may see it from a different perspective, their interpretation can be different and consequently, their conclusions can also be different. (S91)

As they used their idea or imagination and creativity, and the subject of the scientific study [dinosaurs] had extinct from the face of the earth, there could not be an absolute conclusion. In addition, as our world has passed through ups and downs, they [scientists] might guess based on the different natural phenomena. All these are the result of the power of imagination or thinking. (S95)

However, about 23% of grade 10 and 19% of grade 12 students held naïve conceptions of subjective NOSK. These participants indicated that if scientists use the same method and the same data and if correctly done scientific results are the same disregarding the possibility of producing different scientific knowledge that resulted from scientists' backgrounds. The following quoted texts from grade 10 (S57, male) and grade 12 (S86, female) represent the students' naïve views of subjective NOSK:

It can be similar. If they use the same data their conclusion could be similar. (S57)

It is not. It is because if their understanding and way of doing science and using data is different they cannot reach to similar conclusion. For example, if two scientists combine 2H with 1O, we can get H_2O. That scientist who does it correctly gets water. The other if do it wrongly, cannot get water instead may get a different molecule. (S86)

Table 9

Frequency counts and percentage of grade 12 students' NOSK conceptions

NOSK aspect	Response category	Frequency counts	Percent (%)
Empirical nature of scientific knowledge (Q1 &Q2)	Informed	-	-
	Syncretic (Has merit)	15	22.06
	Naïve	52	76.47
	Unclassified	1	1.47
The tentative nature of science (Q3&Q9)	Informed	32	47.06
	Syncretic (Has merit)	11	16.18
	Naïve	21	30.88
	Unclassified	4	5.88
Subjective nature of scientific knowledge (Q4&Q7)	Informed	44	64.71
	Syncretic (Has merit)	10	14.71
	Naïve	13	19.12
	Unclassified	1	1.47
Distinction of scientific theories and laws (Q5)	Informed	-	-
	Syncretic (Has merit)	5	7.35
	Naïve	52	76.47
	Unclassified	11	16.18
Creativity and Imagination (Q6)	Informed	15	22.06
	Syncretic	12	17.65
	Naïve	34	50
	Unclassified	7	10.29
Inferential nature of scientific knowledge (Q8)	Informed	9	13.24
	Syncretic	5	7.35
	Naïve	13	19.12
	Unclassified	41	60.29
Society, culture and Science (Q10)	Informed	35	51.47
	Syncretic	15	22.06
	Naïve	10	14.71
	Unclassified	8	11.76

The excerpts from participants', S57 and S86, conceptions of the subjective NOSK were naïve as they indicated that if correctly done scientific results are the same ignoring the possibility of producing different scientific knowledge that resulted from scientists' personal backgrounds. These students argued that scientists as far as they did their studies correctly, could come up with correct/ similar conclusions regardless of their personal knowledge and values. This study also revealed that some of the students elucidated syncretic views of subjective NOSK; about 33% and 15% of grade 10 and grade 12 students, respectively.

In general, grade 12 students demonstrated an informed view of the subjective nature of NOSK. This revealed that grade 12 students have informed views about the influence of the scientists' personal beliefs, judgments, and social values when doing scientific research and making conclusions. Whereas, grade 10 students showed a mixed view of the subjective NOSK; some were informed while others were naïve.

4.2.4. Students' conception of scientific theories and laws

Question #5 of the present questionnaire inquires: Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example. The analyses of the students' answers showed that most of them, irrespective of grade level, had naïve conceptions about the nature of scientific laws and theories. Regarding the nature of scientific theories and laws, about 77% of grade 10 students (see Table 8) and 76% of grade 12 students (see Table 9) expressed naïve views. Students portrayed scientific law as correct and permanent, and high-status knowledge. Some of the participants lacked the notion of law in the context of scientific endeavour. The following quotations are selected to represent the students' naïve views of the nature of theories and laws.

> There is a difference because theory refers to practice. But law refers to guidelines. For example, assume someone investigates some new theory and other

researcher follow the law during the investigation, this shows their differences. (S18)

Scientific theory can be changed from time to time but scientific law is always the same thing through time; it cannot be changed. (S112)

Yes, there is a difference. A scientific theory whether it is correct or not, it is a must to verify it or approve it in scientific law. In scientific law, the knowledge or invention unless it is correct it cannot be accepted by society and has undesirable consequences. (S132)

The excerpts described scientific theory and law on two different dimensions. For example, participant S112 (a male student), explained them about changeability and participant S132 relative to correctness. In both cases, scientific theory was seen as low-status knowledge as changeable and not yet proved correct. On the other hand, scientific law was portrayed as permanent and correct. In both explanations, the students' views were aligned with a naïve conception of the distinctions between scientific theories and laws. Since both scientific theories and laws can be changed and hence cannot be described in terms of correctness.

Although no participant in either grade level reflected informed views of the nature of scientific theories and laws, there are about 6% of grade 10 students and 7% of grade 12 students who showed syncretic understanding. This study, in general, exposed that the secondary school students participated in this study possessed naïve conceptions of the nature of scientific theories and laws.

4.2.5. Creativity and imagination

In this study, stimulus question #6 was posed: ---.Do you think that scientists use their imaginations and creativity when they do scientific investigations or experiments? a) If NO, explain why. b) If YES, in what part(s) of their investigations …? Give examples if you can.

The analysis of the data indicated that scientists' use of their creativity and imagination (CI) in scientific endeavours is neglected by a large proportion of the present participants. About 52% of grade 10 students and 50% of grade 12 students exhibited naïve conceptions of scientists' use of CI. They indicated that scientists use CI in some phases of the investigation process but not in all phases or do not use it at all. The following excerpts are presented to exemplify students' naïve conceptions of creativity and imaginative NOSK of grade 10 (S11, female) and grade 12 (S88, female) students:

> They do not use. They do not relate it to their own ideas. But after research, when they present their results or during reporting they can present using their own creative ability. (S11)
>
> They do not use. It is because when they do experiments, it is very necessary to have knowledge and skill beginning from how to use equipment to how to record results. Researchers at the starting point before doing an experiment, they can use their imagination but during experimentation, I think they do not use their imagination. (S88)

Participants S11 and S88 explanation fits with the naïve view of CI NOSK. They argued that scientists follow procedures that are devoid of their imagination and creativity although at some phases like during the planning before the beginning of experimentation or at the end of the research during reporting. Therefore, these students views are classified us uninformed because scientists use their CI at all phases of the investigation.

There are few proportion of participants from both grades 10 (10.61%) and 12 (22.06%) who demonstrated informed conceptions of CI NOSK. These students thought that scientists use their creativity and imagination when doing scientific research. The following quoted excerpts are examples of their informed conceptions: The following quoted excerpts are examples of their informed conceptions:

> They use [creativity & imagination]. For example, in space science although there is no tangible evidence about black hole different explanations are given through imagination. (S76)
>
> They must use because when they try to get a finding, for example, to find a vaccine for Corona [COVID-19] they guess (hypothesize] a possible solution and prepare plan for practical work. Therefore, I think scientists use their imagination and creativity. (S84)

The arguments of students, S76 and S84 (both males), showed that scientists use their imagination and creativity during scientific investigation and this conception is in line with the contemporary view of NOSK.

About 27% of grade 10 students and 18% of grade 12 students had syncretic opinions about how scientists employ creativity and imagination in their study. These students did not, however, elaborate on their reasons for not utilizing CI.

In general, the secondary school students who participated in this study exhibited naïve conceptions of contemporary NOSK.

4.2.6. Inferential NOSK

Question #8 was presented to trigger responses of participants' understanding of the inferential NOSK: ---. Does the model of the layers of the Earth exactly represent how the inside of the Earth looks? Justify your response.

Participants' responses indicated that a substantial proportion of grade 10 students held naïve conceptions of the inferential NOSK (43.94%). However, only about 19% of grade 12 students possessed naïve conceptions of this tenet. The following quotations represent the students' naïve conceptions of inferential NOSK. The students' responses to the stimulus question about the representation of the layers of the earth were:

> It represents because the model is a result of their [scientists] in-depth thinking and research. (S18)
>
> It can represent. They use an instrument named Seismograph. (S35)
>
> As it is resulted from scientific studies, it can represent correctly. (S43)

The above quoted texts indicated that the students believed that the model is a correct representation of the three layers of the earth because they are results of either scientists' in-depth thinking or measured by a scientific instrument. Such responses are indicators of students' uninformed conceptions about the inferential nature of scientific knowledge; scientific models are produced by scientists to explain what they represent but are not exact copies of what they stand for.

Few students elucidated informed views of inferential NOSK; about 5% of grade 10 and 13% of grade 12 students. These students explicated that the model of the earth resulted partly from scientists' imagination and hence can be changed in the future if scientists come up with an improved idea and/ or with the advancement of technology that enables researchers to refine their existing understanding. The following quoted excerpts are presented to show students' informed conceptions:

> They can be true by existing knowledge, but in the future, they may not be correct because as the technology develops and expands there could be a better idea. (S08)
>
> It cannot be exactly known at this time. It cannot be known correctly, it could be a result of hypothetical measurement. (S19)

What is noticeable in this inferential aspect of NOSK is that the responses of a large proportion of students fall under the not-classifiable category. That is, more than 33% of grade 10 students and the majority of grade 12 students (60.29%) responses are either not directly referring to the inferential NOSK or responded "I do not know" or did not give any response. One of the reasons for this could be related to the stimulus question that addresses this NOSK aspect which is seen as a topic of geography by the respondents but not a topic of science subjects. Consider the following quoted excerpts:

> I think this question can be better answered by social [science] students because they learn about it in geography subject better than natural [science] students. The layer of the earth known as the core has many natural minerals, for example, it has a mineral named Nickel. (S87)

There is also a similar response by another respondent (S134): "I don't know, I am a natural [science] student". These students' responses implied that the topic of the layers of the earth is not dealt with in high school science subjects (i.e., biology, chemistry & physics) in the Ethiopian secondary school curriculum.

4.2.7. Students' conceptions of relations between society, culture, and science

To elicit students' understanding of the cultural NOSK Q#10 was paused: ---. Is there a relationship between science, society, and cultural values? If so, how? If not, why not? Explain and provide examples.

Students' answers revealed that about a quarter (24.24%) of grade 10 students (see Table 8) and more than half (51.47%) of grade 12 students (see Table 9) had informed views about how society and culture affect scientific endeavours were evident. The following quotations showed their informed conceptions.

> They create impact. For example, scientific studies promote to elimination of female genital mutilation. But the society believes that if girls are not mutilated, they will flee from their parents' home by agreeing to be kidnapped. (S23)
>
> They create. People believe that they descend from Adam and Eve but science explains people are evolved from monkeys. Although people are silent to science no individual believed human beings were descended from monkeys. They ask why today's monkeys are not changing. (S76)

These students (S23, male & S76, male) expressed informed views about the influence of culture on the acceptance of scientific knowledge. According to these quoted excerpts, cultural knowledge and values greatly influence the understanding of scientific knowledge and its acceptance. Similarly, another student (S82, female) demonstrated an informed view of the influence of society and culture on scientific endeavor. She stated that: "They create. …because studies are results of individuals' work, individuals, in turn, are products of societies' culture and their own thinking."

As presented in Table 8 and 9, large proportion of grade 10 students (42.42%) and about 15% of grade 12 students exhibited naïve conceptions of cultural NOSK. The students contended that since scientific knowledge is founded on reliable data, it is not influenced by society and cultural norms. The following quoted materials revealed their naïve views.

> Societal and cultural values do not have effect on scientific research because scientific investigations are based on accurate evidence. (S117)
>
> They do not have effect. There is no connection between societal and cultural values, and scientific research. (S127)

Participants' S117 (a female student) and S127 (a male student) stated that scientific knowledge is free from the influence of society and culture. Their contention is that societal and cultural values cannot affect scientific research because scientific investigations are based on accurate and objective evidence. Thus their conception is naïve as societal and cultural values affect scientific investigations.

In general, in the cultural and societal NOSK, a clear difference between grade 10 and grade 12 students was observed. The grade 12 students demonstrated more informed conceptions while 10^{th} graders showed more naïve views.

4.3. Comparison of students' NOSK conceptions by grade level and gender

4.3.1. Comparison of grade 10 and grade 12 students NOSK conceptions

Grade 10 and grade 12 students conceptions of NOSK are compared based on their response categories on the target aspects. Generally grade 12 students displayed more informed conception of NOSK than grade 12 students.

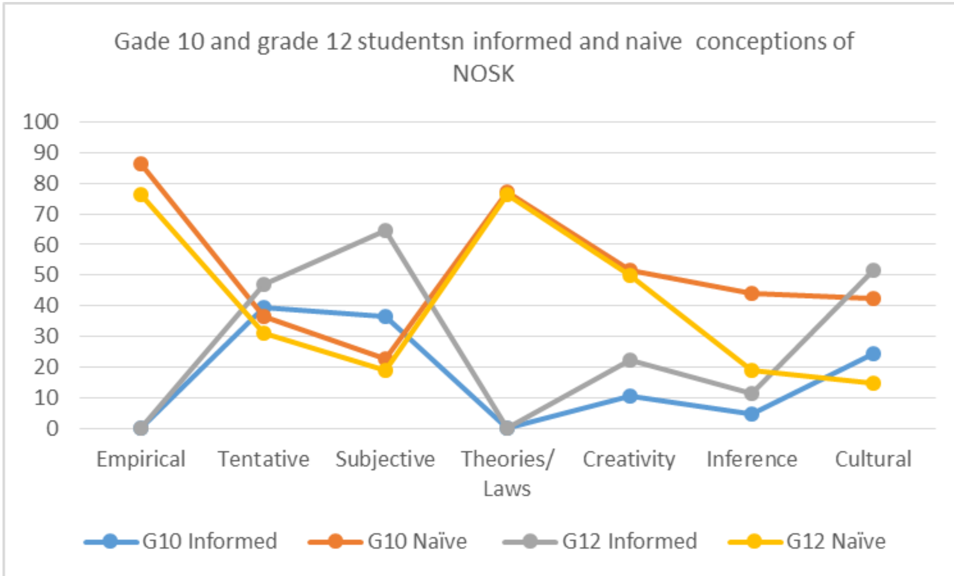

Figure 3

Graphical depiction of students' NOSK conceptions by grade level

The graph is aimed at providing a simplified representation of students' NOSK conceptions by grade level based on the data in Table 8 and Table 9 by extracting the informed and naïve views while leaving the intermediate and not classifiable categories. As shown in the Figure, the trend of NOSK views to both grade levels is similar. A substantial proportion of students showed informed views on the subjective, cultural, and tentative aspects, and low on the creativity aspect. Figure 3 also depicted that a very high proportion of students from both grade levels exhibited naïve NOSK views of the empirical and the nature of theories and laws; and no student demonstrated informed views on these two aspects.

When we look at closely the differences between the two grade levels, grade 10 students showed more naïve views than grade 12 students. Stated in another way, grade

12 students showed more desirable conceptions on the majority of the NOSK tenets than grade 10 students.

Table 10

Mean rank scores of grade 10 and grade 12 students of the NOSK aspects

NOSK aspect	Grade	N	Mean Rank	Sum of Ranks
Empirical	Grade 10	66	67.74	4471.00
	Grade 12	68	67.26	4574.00
	Total	134		
Tentative	Grade 10	65	60.27	3917.50
	Grade 12	64	69.80	4467.50
	Total	129		
Subjective	Grade 10	61	56.93	3472.50
	Grade 12	67	71.40	4783.50
	Total	128		
Theory/ Law	Grade 10	55	56.07	3084.00
	Grade 12	57	56.91	3244.00
	Total	112		
Imagination and Creativity	Grade 10	59	60.29	3557.00
	Grade 12	62	61.68	3824.00
	Total	121		
Inferential NOSK	Grade 10	42	33.27	1397.50
	Grade 12	27	37.69	1017.50
	Total	69		
Cultural and society	Grade 10	61	51.54	3144.00
	Grade 12	60	70.62	4237.00
	Total	121		

As Table 10 presents the mean rank score of grade 12 students is higher than those of grade 10 students, except for empirical NOSK. These differences are subject to statistical tests to see whether the observed differences are significant or not. To this effect, the Mann-Whitney U test was conducted to determine whether there is a statistically significant difference between grade 10 and grade 12 students' conceptions of the NOSK tenets.

Table 11

U test between grade 10 and grade 12 students NOSK conceptions

Test Statistics[a]							
	Empirical	Tentative	Subjective	Theory/ Law	Imagination/ Creativity	Inferential	Cultural
Mann-Whitney U	2228.00	1772.50	1581.50	1544.00	1787.00	494.50	1253.00
Wilcoxon W	4574.00	3917.50	3472.50	3084.00	3557.00	1397.50	3144.00
Z	-.096	-1.56	-2.415	-.290	-.241	-1.01	-3.20
Asymp. Sig. (2-tailed)	.923	.119	.016	.771	.810	.314	.001

a. Grouping Variable: Grade

The U test result, as can be seen from Table 11, indicated that a significant difference was observed in two of the five aspects. They are 1) Grade 12 students scored significantly higher mean rank (71.40) than grade 10 students (56.93) on the subjective NOSK, U (N_{G10}=61, N_{G12}=67) = 1581.5, z = -2.42, p<.05. 2) Grade 12 students also showed a significantly higher mean rank score (70.62) on the social/ cultural NOSK than grade 10 students' mean rank score (51.54); U (N_{G10}=61, N_{G12}=60) =1253, z = -3.20, p <.05. Thus, the null hypothesis that states that there is no difference between grade 12 and grade 10 students in their conceptions of NOSK is rejected as their conceptions are significantly on the subjective and cultural NOSK. This indicated that as grade level increases the students' NOSK understanding also increases.

Table 12

Hypothesis test summary using U test between the grade levels

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Empirical is the same across categories of Grade.	Independent-Samples Mann-Whitney U Test	.923	Retain the null hypothesis.
2	The distribution of Tentative is the same across categories of Grade.	Independent-Samples Mann-Whitney U Test	.119	Retain the null hypothesis.
3	The distribution of Subjective is the same across categories of Grade.	Independent-Samples Mann-Whitney U Test	.016	Reject the null hypothesis.
4	The distribution of TheoryLaw is the same across categories of Grade.	Independent-Samples Mann-Whitney U Test	.771	Retain the null hypothesis.
5	The distribution of ImaginatonCreativity is the same across categories of Grade.	Independent-Samples Mann-Whitney U Test	.810	Retain the null hypothesis.
6	The distribution of Inferential is the same across categories of Grade.	Independent-Samples Mann-Whitney U Test	.314	Retain the null hypothesis.
7	The distribution of Cultural is the same across categories of Grade.	Independent-Samples Mann-Whitney U Test	.001	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

On four of the seven aspects of NOSK Mann-Whitney U test reveals no significant difference between the mean rank score of grade 10 and grade 12 students. Thus, the null hypothesis that assumes that there is no difference between the two groups is not rejected.

Therefore, we can conclude that there is no significant difference between grade 10 and grade 12 students in their conceptions on the four aspects of NOSK – the empirical, tentativeness, theory/ law, creativity and imagination NOSK. On these four aspects, as presented in the qualitative data analysis, both groups held naïve conceptions. One aspect of NOSK–the inferential NOSK the majority of the respondents' responses fail into the not classifiable (NC) category.

4.3.2. Comparison between male and female students NOSK understanding

Table 13

Mean rank scores between male and female students

Ranks

	Gender	N	Mean Rank	Sum of Ranks
Empirical	Male	70	69.69	4878.00
	Female	64	65.11	4167.00
	Total	134		
Tentative	Male	65	65.88	4282.00
	Female	64	64.11	4103.00
	Total	129		
Subjective	Male	67	58.53	3921.50
	Female	61	71.06	4334.50
	Total	128		
Theory/ Law	Male	59	55.80	3292.00
	Female	53	57.28	3036.00
	Total	112		
Imagination/ Creativity	Male	65	63.54	4130.00
	Female	56	58.05	3251.00
	Total	121		
Inferential	Male	29	30.00	870.00
	Female	40	38.63	1545.00
	Total	69		
Cultural	Male	64	55.44	3548.00
	Female	57	67.25	3833.00
	Total	121		

As displayed in Table 13 the descriptive statistics indicated that male students score higher on the empirical, tentative, creativity and imagination NOSK aspects.

Female students on the other hand score higher on the subjective, inferential and cultural NOSK aspects. To test these apparent differences Mann–Whitney test was used and presented in Table 14.

Table 14

Mann–Whitney significance test between male and female students

Test Statistics[a]

	Empirical	Tentative	Subjective	Theory/ Law	Imagination/ Creativity	Inferential	Cultural
Mann-Whitney U	2087.000	2023.000	1643.500	1522.000	1655.000	435.000	1468.000
Wilcoxon W	4167.000	4103.000	3921.500	3292.000	3251.000	870.000	3548.000
Z	-.923	-.289	-2.091	-.514	-.948	-1.991	-1.979
Asymp. Sig. (2-tailed)	.356	.772	.037	.608	.343	.046	.048

a. Grouping Variable: Gender

The Mann–Whitney U test revealed that there is a significant difference between male and female students in three of the seven examined NOSK aspects (Table 14&15). It is in the subjective NOSK the mean rank score of female students (71.06) is larger than the rank mean score of male students (58.53). This difference as confirmed by the U test is statistically significant, U (N_{Male}=67, N_{Female} = 61) = 1643.5, z = -2.09, p <.05. The mean rank score (30) of males is lower than that of females (38.63) in the inferential aspect of the NOSK. U test revealed that this difference is statistically significant, U (N_{Male}= 29, N_{Female} = 40) = 435, z = -1.99, p<.05. The third NOSK tenet that showed a significant difference between male and female students was the social/ cultural NOSK.

Table 15

Hypothesis test summary between conceptions of the two genders

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Empirical is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.356	Retain the null hypothesis.
2	The distribution of Tentative is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.772	Retain the null hypothesis.
3	The distribution of Subjective is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.037	Reject the null hypothesis.
4	The distribution of TheoryLaw is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.608	Retain the null hypothesis.
5	The distribution of ImaginatonCreativity is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.343	Retain the null hypothesis.
6	The distribution of Inferential is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.046	Reject the null hypothesis.
7	The distribution of Cultural is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.048	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

The male students mean rank score (55.44) is significantly lower than the mean rank score of female students (67.25), U (N_{Male}= 64, N_{Female}=57) = 1468, z = -1.98, p<.

05. Therefore, the null hypothesis that assumes that there is no difference between the NOSK conceptions of male and female students is rejected since there existed a difference in three of the seven NOSK aspects in this study. We can deduce that female students score significantly higher mean rank than their male counterparts on their conception of subjective, inferential and cultural NOSK. This indicated that regarding the view that scientists' knowledge and beliefs influence their scientific endeavors, the female students' conceptions are more informed than those of males. The study also showed that more female students as compared to males conceived that the models presented by scientists resulted through inference rather than direct copies of reality. Female students also view more favorably that the cultural and societal values affect the production of scientific knowledge and its acceptance than males. In both cases, female students' conceptions of NOSK are closer to the more desirable conception of NOSK than their male counterparts. On the other NOSK aspects, the Mann-Whitney U test revealed no significant difference between male and female secondary school students (see Tables 14 & 15).

4.4. Science Teachers' NOSK Conceptions

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 as informed, syncretic (has merit), naïve, and unclassified 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.

4.4.1. 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 of 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. (T02)
>
> Science is a field of study based on concrete knowledge. (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 an 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 (for example, religion & philosophy) are based on belief which we cannot prove but continue believing in it. (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 a 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. (T32)
>
> Science is based on confirmed findings but religion and philosophy are processes based on an individual's thinking and level of belief. (T33)
>
> It is a branch of knowledge confirmed by concrete evidence and through experimentation. It is a 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, secondary school teachers who participated in this study generally held naïve conceptions, and no teacher demonstrated an informed conception of empirical NOSK.

4.4.2. 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.

Table 16

Secondary school science teachers' conception of NOSK

Nature of scientific knowledge aspect		Teachers' conceptions of the NOSK			
		Informed	Syncretic/ has merit	Naïve	Unclassified
Empirical nature of scientific knowledge (Q1 &Q2)	*Count*	0	17	30	1
	%	0	35.42	62.50	2.08
The tentative nature of science (Q3&Q9)	*Count*	28	8	12	0
	%	58.33	16.67	25	0
Subjective Nature of scientific Knowledge (Q4 & Q7)	*Count*	12	10	26	0
	%	25	20.83	54.17	0
Distinction of scientific theories and laws (Q5)	*Counts*	0	15	29	4
	%	0	31.25	60.42	8.33
Creativity and Imagination (Q6)	*Count*	12	7	25	4
	%	25	14.58	52.08	8.33
Inferential nature of scientific knowledge (Q8)	*Count*	5	9	7	27
	%	10.42	18.75	14.58	56.25
Society, culture and science (Q10)	*Count*	31	7	6	4
	%	64.58	14.58	12.5	8.33

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 have also changed; everyday inventions are changing the world; and the truth we hold is also changing. (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]. (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 reach the conclusion that they cannot be changed. (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. For example, the starting point of life is the cell. (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.

4.4.3. 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. (T37)
>
> It can be different because they may interpret the data in different ways. (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 16, 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. (T02)

> It can be similar because a right (correct) study is valid, reliable and accurate. However, a reliable study may not be valid. A false result may be reliable although we use wrong information (data). (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.

4.4.4. Distinction between 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 16, 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, and Third laws; the law of segregation & independent assessment (Mendel's 1st & 2nd laws). (T39)

> Theory can be changed or improved but law cannot be changed. (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. (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.

4.4.5. 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 16) 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. (T36)

They use. Einstein wrote his “Theory of relativity” using the above steps [Planning, data collection, data analysis, report writing]. (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. (T14)

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

They are used during planning and data collection. (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.

4.4.6. Inferential NOSK

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 16, 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. (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. (T42)

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 mantel] and by the earth's movement and volcanoes. (T27)
>
> This is scientific and also experimental. The three layers can be observed through electromagnetic waves. (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 16) 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, & 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.

4.4.7. Social and cultural 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 16, 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. (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. (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. (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]. (T18)
>
> Which type of study??? It has more impact on social studies research. (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.

4.5. Congruence between students and teachers NOSK conceptions

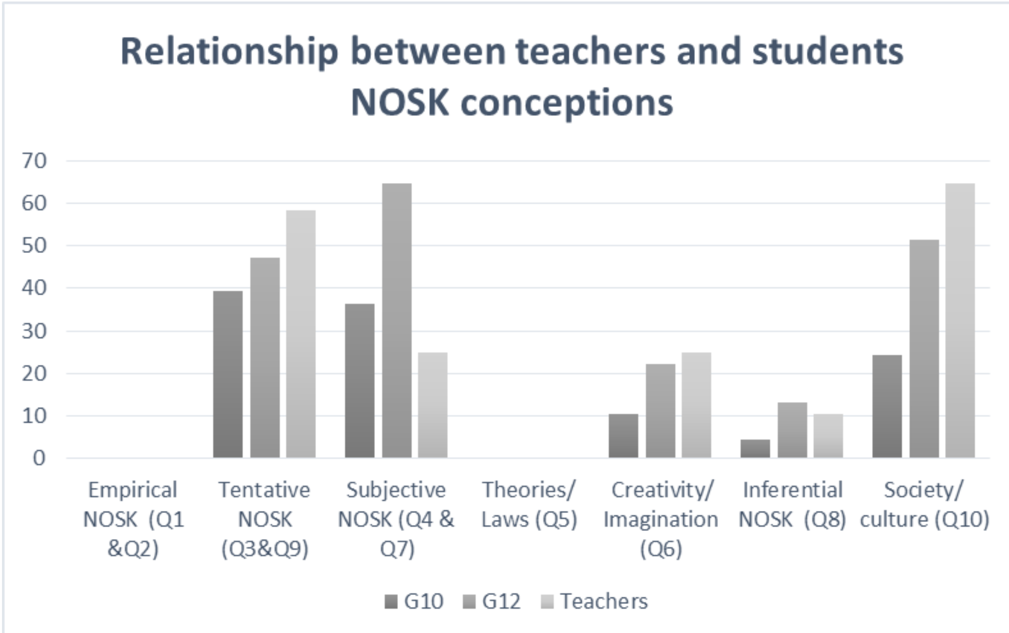

Figure 4

Relationship between teachers and students NOSK conceptions

Figure 4 depicts the proportion of science teachers who demonstrated more informed conceptions on three of the seven aspects of the assessed NOSK aspects. However, in the subjective NOSK, the students demonstrated a more desirable NOSK conception than their science teachers. On the empirical and the distinction between scientific theories both the teachers and the students showed naïve views, that is, no participant demonstrated an informed conception of this tenet of NOSK. A meaningful relationship was displayed by the inferential NOSK between the students and the teachers. In general, this finding indicated that teachers showed more informed views than their students as they demonstrated more sophisticated conceptions on three of the examined NOSK tenets.

UNIT FIVE

DISCUSSION

5.1. Introduction

This study explored the conceptions of the nature of scientific knowledge among secondary school students and 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 grade 10 students showed naïve views in all the studied aspects of NOSK. Grade 12 students relatively showed more informed conceptions of the NOSK. The teachers exhibited 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 remaining aspects of NOSK except, on inferential NOSK to which a substantial proportion of teachers' responses or nonresponses fall under the unclassified category. The following sections focused on presenting the current results in the context of other findings in the literature.

5.2. Students' and science teachers' conceptions of NOSK

5.2.1. Empirical nature of scientific knowledge

Scientific knowledge is a result of human endeavor but viewing it as a pursuit of truth or equating it with technology and exclusively resulted from observation and experimentation is naïve (Liu & Lederman, 2007). In this study, the overwhelming majority of students and science teachers found harbored naïve conception of empirical NOSK. It is in this empirical aspect of NOSK that the largest proportion of grade 10 students (86.36%) showed naïve conceptions. Similarly, the majority of grade 12 students (76.47%) showed naïve conceptions on the empirical NOSK. Although grade 10 students displayed more naïve conceptions than grade 12 students, both groups in the present study regardless of grade level harbored naïve views of the empirical NOSK. Similar finding were reported by different countries. For example, Bektas and Geban (2010) found that only a small proportion (19%) of Turkish secondary school students demonstrated informed conceptions of empirical NOSK the majority of them held either syncretic or naïve views of this NOSK tenet. In the same vein, Kang et al. (2004) found that the majority of Korean students possessed absolutist/ empiricist view of NOSK. The present participants', like that of the Korean counter parts, lack of informed conception of the empirical nature of NOSK indicated that they conceptualize scientific knowledge as confirmed knowledge and/or truth through experimentation.

This study also exposed that the majority of the science teachers (60.42%), like the students, 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 (2016) 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 (2022) result, 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 (Aflalo, 2018). In addition, Ethiopian education is dominated by teacher-centered methods (Fekede & Tynjälä, 2015; Shishigu, 2018), 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.

Although all groups of participants' showed naïve conceptions of NOSK, this study portrayed an important trend of the developmental nature of NOSK. As year of science learning increases from grade 10 to grade 12 through teachers, the proportion of participants possessing naïve conceptions decrease. This gives insight on the relevance of teaching science to improve their NOSK understanding. But this did not imply that learning more content of science is adequate to bring about the desired level of NOSK conception of this empirical aspect because the changes are not enough as the majority of the participants held uniformed views on this aspect of the NOSK.

5.2.2. The Tentative NOSK

Although scientific knowledge is durable and reliable, it is not absolute and thus subject to change (Abd-El-Khalick, 2012). Grade 10 and grade 12 students in this study reflected mixed views of the tentative nature of NOSK as 39.39% and 47.06% reflected informed conceptions and 36.36% and 30.88% showed naïve conceptions, respectively. This finding is not consistent with the findings of Dogan and Abd-El-Khalick (2008) which revealed the majority of grade 10 Turkish students (68.20%) demonstrated informed conceptions of tentative NOSK. Kiliç et al. (2005) also found that majority of ninth grade Turkish students acknowledged the changeable nature of scientific knowlegde. The diffierences could be attributtted to many factoors including cultural differences, curricular emphasis, and teachers knowledge of the NOSK construct.

This study revealed that 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. (2022), who found that science teachers have expressed informed conceptions about the tentative NOSK. In a similar vein, , Dogan and Abd-El-Khalick (2008) and Saif (2016) reported that science teachers held contemporary conceptions about the changeability of NOSK. On the other hand, Ma

(2009) reported that Chinese secondary school teachers view scientific knowledge as more certain than tentative. These differences between the Chinese teachers and those in Turkey could be attributed to the nature of their curriculum in portraying scientific knowledge could be different. That is, the Chinese culture and curriculum could tend to see scientific knowledge as fixed, where as in Turkey, which is a western nation could see scientific knowledge as changeable in light of new evidence or new ways of interpretation of old data. However, it needs an investigation for the real reasons for the observed differences.

A significant percentage (roughly 40%) of the science teachers in this study had either naïve or syncretic views of this NOSK tenet, indicating that it still needs to be addressed. Nevertheless, more than half of the teachers reflected informed NOSK views, suggesting that teachers' tentative NOSK views still need to be developed.

5.2.3. Subjective NOSK

The advancement of scientific knowledge greatly influenced by scientists' expectations, prior background, individual opinions, and intuition (Abd-El-Khalick, 2012; Bell, 2009). The problems that scientists choose to study, their methods of investigation, their observations (both of what is and is not observed), and their interpretation of these data are all influenced by these background influences (Abd-El-Khalick, 2012). Science rarely begins with neutral observations, despite popular opinion; research questions are inspired by and given context from particular theoretical vantage points (Abd-El-Khalick, 2012).

However, the majority of science teachers (54.17%) in the present study harbored naïve conceptions of the subjective NOSK. Only 25% of these teachers showed informed conceptions about subjective NOSK. The remaining (20.83%) held syncretic conceptions. This indicated that the majority of science teachers who participated in this study believed that scientists are objective and are not influenced by their background knowledge when carrying out scientific investigations. This finding is consistent with the findings of Iqbal et al.(Iqbal et al., 2009). 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 (2016), which consisted of the idea that scientists are open-minded about investigating scientific issues objectively without any subjective bias.

The science teachers across different cultural contexts, including the present participants, did not understand the role of scientists' personal views and biases in the process of developing scientific knowledge (Iqbal et al., 2009; Saif, 2016; Sangsa-ard & Thathong, 2014).

This study revealed that the majority of grade 12 students (64.17%) and a substantial proportion of grade 10 students (36.36%) reflected informed views of NOSK. However, the majority of science teachers (54.17%) showed naïve views on this subjective NOSK. Only 25% of the teachers demonstrated informed conception of the subjective NOSK. This result clearly showed that there existed a difference between students and teachers subjective NOSK views; students showing more informed conceptions than their teachers in this NOSK category. A related finding was forwarded by Dogan and Abd-El-Khalick (2008), who discovered that among the participating teachers, those with PhD degrees in the sciences held the most naïve opinions regarding a number of NOSK features, and those with MS degrees held more naïve views than those with BSc degrees.

The discrepancy between teachers' and students' understanding of the NOSK is a complex issue influenced by various factors, including teacher preparation, professional development, curricular constraints, and evolving educational practices. One critical reason that could be attributed to such results is that teachers had studied the scientific method which follows a prescribed step-by-step approach and has done much laboratory work compared to students which could lead them to believe that scientific knowledge is objective. With this regard, Windschitl (2004) argues that when labs are conducted in traditional lab settings with a focus on achieving predetermined results, they can reinforce the perception of science as a straightforward, objective process where correct answers are discovered through prescribed methods.

5.2.4. Distinctions between scientific theories and laws

Secondary school students and teachers who participated in this study did not provide informed arguments about the nature of scientific theories and laws. The majority of grade 10 (77.27%) and grade 12 students (76.47%), and science teachers (60.42) failed to demonstrate informed conceptions of the nature of scientific theories and laws. Although there is no participant who demonstrated informed views on this aspect, there are small proportion of grade 10 (6%) and grade 12 (7%) students who showed syncretic/

intermediate views; and a sizable proportion (31.25%) of science teachers who showed intermediate views. This indicated that relatively teachers showed more desirable NOSK views (intermediate) on this tenet than the students. A similar finding was reported by Bektas and Geban (2010) who revealed the majority of secondary school students in their study possessed naïve views; it was only a negligible proportion (2.08) of students who reflected informed conceptions.

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. (2022) 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. 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 (2016) 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. (2009) 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 (2014) also reported that Thai junior high school teachers held naïve conceptions about the distinction between theories and laws; they view scientific theories as less secure than law. 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 knowledge and more stable than scientific theory.

In the present study, there is no significant difference between grade 10 and grade 12 students' conceptions of the nature of scientific laws and theories. In both cases, the majority of the students showed naïve conceptions of the nature of scientific theories and laws. This finding corroborated to the finding reported by Al-Bouti (2018) who revealed no significant difference between students' conceptions of scientific theory by grade levels.

In this study, theory is seen as changeable whereas law is seen as fixed. Some of the present participants conceived scientific laws and theories as hierarchies, that is, scientific law as a higher status knowledge and scientific theory as a lower level. Those who held naïve views of the nature of theories and laws showed a common misconception that portray scientific theory and law as hierarchical. With sufficient evidence and verification, scientific theories can be developed into scientific laws. A hierarchical view of theories and laws was also discovered by other studies (Bektas & Geban, 2010; Dogan & Abd-El-Khalick, 2008; Kiliç et al., 2005). Such views are naïve as both theories and laws are not only changed but also not hierarchical. Instead, they represent distinctive aspects of scientific knowledge. The students in this study also view scientific theory as guess and law as social order, not in the context of the concepts in science fields. In this regard, Reiners et al. (2017) stated that students' conceptions of theories and laws differ from the ones in chemistry. Thus, they asserted that it is important to distinguish between the scientific meanings of law and theory and their colloquial meanings.

5.2.5. Creativity and imagination

Creativity and imagination are essential elements for scientific knowledge production. Scientists often speak as though they are explaining how nature is while explaining ideas, models, and other constructs that come from human imagination (Taber, 2017).

Regarding the present respondents, more than half of the students and the science teachers exhibited a naïve conception of the CI NOSK. Among the students, 51.52% of grade 10 and 50% of grade 12 students' revealed naïve conceptions. The majority of science teachers (52.08%) also showed naïve conceptions of the creative and imaginative NOSK. These respondents argued that scientists do not use their creativity and imagination or use it at some phases of the investigation process either during planning, data collection or during both planning and data collection, but not at all phases. Scientific knowledge production involves human imagination and creativity. It should be noted that as creativity and imagination are sources of inspiration and innovation, they are used at all stages of scientific investigation (Liu & Lederman, 2007). It is only a quarter of the science teachers (25%), 22% of grade 12 students, and 11% of grade 10 students reflected informed conceptions. These figures indicated that science teachers and grade 12 students exhibited a more desirable conception of CI NOSK than grade 10 students.

The present study corroborated the findings of Dogan and Abd-El-Khalick (2008) who revealed the majority of students and science teachers did not appreciate the role of creativity in producing scientific knowledge through their responses. Similarly, Thai Junior secondary teachers did not demonstrate an informed conception of the creative and imaginative NOSK (Sangsa-ard & Thathong, 2014). Bektas and Geban (2010) who used the VNOS-C instrument to collect information from their participants revealed that no student demonstrated informed views of NOSK.

On the other hand, the present study is not congruent with the findings of Kiliç et al. (2005), who employed a close-ended questionnaire for data collection, and found that the majority of the students reflected informed conceptions about the use of human creativity and imagination in scientific knowledge creation. These inconsistent findings could be partly attributed to the difference in the nature of the questionnaires. As close-ended items require students' agreement/ disagreement on written statements while open-ended items require students to generate their own original ideas. This could lead students not to address NOSK-related responses for those exposed to open-ended items as the case in the present study. On the other hand, students exposed to a close-ended questionnaire may easily select among written alternatives which could lead to a higher level of agreement with contemporary NOSK views. These inconsistencies, nevertheless, need further investigation.

The majority of the teachers' reflection on naïve conceptions in the present study is not congruent with the findings of Saif (2016) and Dorji et al. (2022), 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 (Berie et al., 2022). This disregard for NOSK could be a reason for teachers' and students' ignorance of the concept, not just for this tenet but also for the tenets.

The present study observed no significant gender difference between students in their conceptions of creative and imaginative NOSK. In the same vein, Kiliç et al. (2005) found no significant gender difference in this aspect of NOSK.

5.2.6. Inferential nature of NOSK

In this study, only three (4.55%) grade 10 students and 13 (13.24%) of grade 12 students demonstrated informed conception of inferential NOSK. This finding is similar to Bektas and Geba's (2010) finding which reported a negligible proportion (2.03%) of students who held informed conceptions of the inferential NOSK. Somehow a related finding was also reported by Dogan and Abd-El-Khalick (2008). They found a small proportion of participant students believed that models help to explain reality but are not true copies of reality and are liable to change. Few students in the present study noted that the layers in the model of the earth (crust, mantel & core) are not directly observed, rather they are constructed through the analysis of indirect evidence. The students who held naïve conceptions of inferential NOSK contend that scientific knowledge is concrete truth, and a direct copy of reality without involving the human imagination and creation of theories, principles and models representing different aspects of scientific knowledge.

The analysis of teachers' responses on inferential NOSK also 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 science teachers (56.25%) explanations either did not directly relate to the issue or responded "I do not know" or left blank. These responses are rated as not classified (NC) category. And some of the participants believed that the model of the layers of the earth is correctly represented through evidence including experimentation. Such conception of participants who perceive science as established knowledge based on evidence or on experimentation and observation while ignoring the inferential nature of the NOSK is naïve.

Iqbal et al. (2009) also found similar results in that the Pakistani teachers reflected naïve conceptions about the inferential nature of NOSK. These teachers believed that scientists report the exact data as they are. Saif (2016) also reported that the majority of science teachers believed that scientific models (e.g., the atomic model) are copies of reality. Relatedly, findings reported by Morrison et al. (2009) revealed that science teachers did not demonstrate informed conceptions of the inferential nature of NOSK. Dogan & Abd-El-Khalick (2008) found that only a small proportion of teachers (34%) acknowledged that models serve explanatory functions but are not true copies of reality.

In general, this study revealed that both teachers' and students' conceptions of the tentative NOSK were naïve. It is also important to note that as the participants advance in their science learning, as they move from grade 10 to 12 through becoming science teachers, the proportion of participants who held informed conceptions has increased. This shows that learning more science content could lead to more desirable learning outcomes regarding inferential NOSK.

5.2.7. Social and cultural NOSK

The concept of scientific knowledge should embrace the different legitimate ways of arriving at legitimate knowledge (Snively & Corsiglia, 2001), 2001). Additionally, they contended that science education ought to place a strong emphasis on the connections between science and technology and the norms, values, and procedures of the society in which we live. Regarding the present participants, about half of grade 12 students (51.47%) and 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. Among the grade 10 students about a quarter reflected informed conceptions of the cultural and societal influence on scientific endeavor. These students and teachers expressed that cultural and societal factors can impact the scientific investigation process and/or the usability of the results. These contentions demonstrate their contemporary views of the social and cultural embeddedness of scientific knowledge. Nevertheless, a substantial proportion (42.42%) of grade 10 students, and about 15 % of grade 12 students, and about 13% of science teachers exhibited naïve conceptions. These participants believed that scientific investigations are independent of societal and cultural influences.

A significant percentage of junior high school students (44%) were found to have intermediate views on the cultural aspect of NOSK, according to a study by Rahmah and Siahaan (2018). It is approximately twofold as compared to the proportion in the present study. In addition, the percentage of students possessing naïve conceptions on this aspect is 28% in their study, which is substantially lower than the percentage of students who held naïve views in this study. Thus, the present study shares some similarity as the participants in their study aligned with an intermediate view of the cultural NOSK than the grade 10 student participants in this study.

Regarding science teachers a similar finding was reported by Dorji et al. (2022), who reported that Bhutanese science teachers expressed scientific knowledge as a product of either social or cultural values or both. Similarly, Saif (2016) found that science teachers expressed that the development of scientific knowledge is affected by society, politics, and culture.

The scientists' societal values and cultural backgrounds influence the way scientific knowledge is created and accepted. Lichtenberg's aphorism (cited in Reiners et al., 2017, p.606) stated that “He who understands nothing but chemistry does not truly understand chemistry either.” Thus, to understand the subject matter it is necessary to have a good grasp of how the knowledge of that subject was developed and is developing. Simply put, science teachers need to develop an understanding of the nature of the scientific enterprise to understand science subjects.

This finding suggested that in addition to the advantages of knowing NOSK, which include critical thinking and well-informed decision making, increasing teachers' and students' awareness of the social and cultural aspects of NOSK is essential for improving scientific content understanding.

5.3. Comparison of students NOSK conceptions by grade level and gender

5.3.1. Comparison of grade 10 and grade 12 students NOSK conceptions

Grade 10 and grade 12 students conceptions of NOSK are compared on the seven target aspects. On most of the aspects no significant difference was observed. But on two NOSK aspects, grade 12 students showed more desirable NOSK conceptions than grade 10 students in this study. The Mann-Whitney U test revealed that the mean rank scores of grade 12 students was significantly higher than grade 10 students on the subjective and cultural NOSK aspects. This indicated that there is a relationship between grade level and NOSK understanding. This result is congruent with Kremer et al.’s (2014) finding who revealed that as grade level increased, students NOSK conceptions get more sophisticated. Kremer et al investigate the NOSK conceptions of grade 7 through 9 and found that students in higher grades showed more sophisticated NOSK conceptions.

However, the results of this investigation do not agree with those of Toma et al.'s (2019) findings about the relationship between primary school students' NOSK comprehension and grade level. Lower pupils reportedly held better informed opinions about the tentative nature of science. This indicates that pupils' NOSK comprehension declines as grade level increases. These contradictory results suggest that more research is necessary to determine how kids' grade level and their ideas of science relate to one another.

5.3.2. Comparison of students' NOSK conception by Gender

The present study revealed that female students conceptions is more informed than that of male students. Specifically, the female students score significantly higher mean rank than their male counterparts on their conception of the subjective, inferential and cultural NOSK. There are few studies in the literature that investigated the relationship between gender and NOSK. Among these, Acar et al. (2015) found no score difference between females and males of Grade eight Turkish students NOSK understanding and although females surpassed males on physics conceptual knowledge test. A study by Toma et al. (2019), however, found that primary school boys had more naïve conceptions on NOSK (particularly on empirical NOSK), although boys had showed better attitude towards science than girls. Toma et al.'s finding is thus, somehow corroborate with the present research. However, as studies of NOSK in relation to gender are very limited and the findings are inconsistent more research is needed to substantiate the current finding.

UNIT SIX

CONCLUSION, RECOMMENDATIONS AND IMPLICATIONS

6.1. Conclusion

The greater majority of secondary school students and their science teachers who participated in this study subscribed to naïve conceptions of most of the consensus aspects of NOSK, which are critical for developing scientific literacy. The majority of grade 10 students' responses to all of the seven NOSK tenets did not align with informed NOSK views had showed naïve conceptions of all of the seven studied NOSK tenets. Regarding Grade 12 students, their conceptions of two of the seven aspects, namely the subjective and cultural NOSK, aligned with experts' views of NOSK. The score of grade 12 students on these two aspects was significantly higher than that of grade 10 students. Then we can conclude that grade 12 students’ NOSK conception was better than that of grade 10 students. Nonetheless, on most of the tenets, grade 12 students exhibited naïve conceptions. The science teachers in this study demonstrated informed conceptions of two of the seven aspects– the tentative and cultural NOSK. On the remaining majority of the tenets, they harbored naïve conceptions.

This study revealed differences in students' and teachers' NOSK comprehension. The science teachers and grade 12 students showed critical differences in their views of the subjective NOSK. Grade 12 students revealed informed conceptions of the subjective NOSK, while their teachers showed naïve views on this aspect. However, this is not an overarching conclusion in that on the other NOSK tenets the science teachers generally showed more desirable NOSK conceptions than their students. Hence, we can conclude that as individuals are exposed to more science lessons, their conceptions of the NOSK is enhanced. However, some research needs to be conducted to come up with a more conclusive argument. The other important finding of this research was that female students showed more favorable views than male students at least in some aspects of NOSK. Nevertheless, the reasons behind these differences remained undiscovered.

Although the generalizability of this investigation might be limited by the sample size and student background (i.e., participants were sampled from three schools in two cities of the Amhara region), these results should be potentially useful to a wide range of science teachers/educators in that the data revealed conceptions embraced by Ethiopian secondary school students as well as their science teachers. Because secondary schools follow the national curriculum, teachers are educated in similar higher education institutions which could result in more or less similar student learning in terms of quantity and quality. Therefore, the findings of this study can provide baseline data for the designs of science lessons, units, and/or curricula.

6.2. Recommendations

The results of this study showed that most NOSK components, such as the distinction between scientific theories and laws and inferential and empirical NOSK, are poorly understood by both science teachers and students. Nonetheless, there is some optimism in the study's conclusions; because a large number of students held either informed or intermediate conceptions of some of the target NOSK aspects. More specifically, the majority of students showed informed/or syncretic views of the NOSK on three of the seven tenets: the tentative, subjective, and cultural components of the NOSK. This finding implies that some students were capable of developing some informed views of the NOSK on their own although their teachers showed uninformed views of some of the NOSK aspects. Therefore, students need to be provided with opportunities that facilitate their NOSK understanding.

Many science curricula prioritize factual knowledge and technical skills over understanding the processes and philosophies underpinning scientific inquiry. This narrow focus can prevent students from appreciating the broader context and nature of scientific knowledge. Thus curricular amendments that entertain inquiry-based learning, process skills, and critical thinking skills that encourage students to analyze and question scientific claims that enhance students' NOSK understanding, developing assessment tools that measure students' understanding of NOSK alongside traditional science content knowledge are imperative. To this effect, national and regional education authorities should encourage the explicit inclusion of NOSK in secondary school science curricula and instruction.

The teachers in this study who were expected to help students develop NOSK understanding did not themselves demonstrate adequate understanding of the NOSK. Hence, we cannot assume that teachers with inadequate conceptions of NOSK could teach the NOSK tenets effectively. It is reasonable to assume that inadequate views of NOSK held by teachers may prevent them from teaching about NOSK. Teachers having informed conceptions about the NOSK tenets is a prerequisite to incorporating NOSK into classroom teaching and learning. Thus, on-the-job professional development programs and short-term training should be organized by the Ministry of Education, regional education bureaus, and Education colleges of the country to enhance teachers' understanding of NOSK.

Students will benefit from the teachers' implementation of the NOSK in the classroom. Not only did teachers lack sufficient understanding of the subject NOSK, but even in the aspects where they did have informed conceptions, they found it difficult to apply them in the classroom. This made the implementation of NOSK instruction challenging. Therefore, it is argued that in the context of teaching-learning scenarios, on-site interventions and scaffoldings are essential (Abd-El-Khalick, 2013). Stated differently, when educators are provided with effective ways to teach NOSK, they stand to gain and can subsequently facilitate students' NOSK understanding. The teachers should be supported by projects that equip them with skills to implement NOSK in the classroom. The projects could involve a concerted effort of the MoE, education bureaus, teacher education colleges and Woreda education offices.

6.3. Implications and future research directions

The following are the implications and future research directions that can be drawn from the present study.

This research is limited in terms of sample size and geographical location as well as it uses frequency counts and percentages and qualitative descriptions, the researcher recommends that future research on teachers' and students understanding of NOSK is needed using a larger sample from diverse geographic areas using quantitative approaches to reach at more conclusive generalizations.

This research indicated that both teachers and students have inadequate conceptions of NOSK. This lack of an overarching framework for teachers' and students' conceptions suggests that these perspectives are more flexible than fixed in some complex, well-established framework. As a result, it appears that students' conceptions can change in response to targeted educational interventions. In addition, this research is survey type. Thus, intervention-based investigations are required for future research. Future research should be done to identify effective methods to teach it. The research could include experimental/ longitudinal studies to monitor how NOSK instruction affects students' attitudes toward science and understanding.

Future research could focus on investigating curriculum materials and textbooks from primary to secondary levels as well as science teachers' education curriculum on how well the NOSK concepts are presented in the Ethiopian secondary school science curricula including the textbooks. In addition, the curriculum materials could be scrutinized for the process skills and the teaching-learning methods associated with the development of NOSK (e.g., Inquiry-based learning, argumentation-based).

The present research focuses on the students and their science teachers' conceptions of NOSK. Future research could focus on the correlates of NOSK understanding. These could include investigating the relationships between NOSK conceptions with science content understanding, attitude towards science, and science-related career choice.

REFERENCES

Abd-El-Khalick, F. (2012). Examining the sources for our understandings about science: Enduring conflations and critical issues in research on nature of science in science education. *International Journal of Science Education*, *34*(3), 353–374. https://doi.org/10.1080/09500693.2011.629013

Abd-El-Khalick, F. (2013). Teaching with and about nature of science, and science teacher knowledge domains. *Science and Education*, *22*(9), 2087–2107. https://doi.org/10.1007/s11191-012-9520-2

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1997). The nature of science and instructional practice : Making the unnatural natural. *John Wiley & Sons, Inc*, 417–436.

Abd-El-khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665–701. https://doi.org/10.1080/095006900050044044

Abd-El-Khalick, F., & Lederman, N. G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching*, *37*(10), 1057–1095. https://doi.org/10.1002/1098-2736(200012)37:10<1057::aid-tea3>3.3.co;2-3

Abulnour, R. (2016). *Constructivist assessment and evaluation in secondary science: How do Ontario secondary school science teachers who have demonstrated leadership and expertise in the area of constructivist learning theory enact assessment and evaluation?* [University of Toronto]. https://tspace.library.utoronto.ca/bitstream/1807/72140/1/Abulnour_Raghda_A_201606_MT_MTRP.pdf

Acar, Ö., Büber, A., & Tola, Z. (2015). The effect of gender and socio-economic status of students on their physics conceptual knowledge , scientific reasoning , and nature of science understanding. *Procedia - Social and Behavioral Sciences*, *174*, 2753–2756. https://doi.org/10.1016/j.sbspro.2015.01.962

Aflalo, E. (2018). Changes in the perceptions of the nature of science and religious belief. *Issues in Educational Research*, *28*(2), 237–253. http://www.iier.org.au/iier28/aflalo.pdf

Agustian, H. Y. (2020). Students' understanding of the nature of science in the context of an undergraduate chemistry laboratory. *Electronic Journal for Research in Science & Mathematics Education*, *24*(2), 56–85.

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Elementary Science Teaching*, *37*(4), 295–317.

Akerson, V. L., & Volrich, M. L. (2006). Teaching nature of science explicitly in a first-grade internship setting. *Journal of Research in Science Teaching*, *43*(4), 377–394. https://doi.org/10.1002/tea.20132

Al-Bouti, E. (2018). The UAE high school students' conceptions of the nature of science (NOS).

Journal for Researching Education Practice and Theory (JREPT), *1*(2), 55–76. https://bspace.buid.ac.ae/buid_server/api/core/bitstreams/ada646cb-e475-49c4-be78-a9b150ecd3c0/content

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. *Science Education*, *95*(3), 518–542. https://doi.org/10.1002/sce.20432

Allchin, D. (2014). From science studies to scientific literacy : A view from the classroom. *Science and Education*, *23*, 1911-1932. https://doi.org/10.1007/s11191-013-9672-8

Almalki, S. (2016). Integrating quantitative and qualitative data in mixed methods research - Challenges and benefits. *Journal of Education and Learning*, *5*(3), 288–296. https://doi.org/10.5539/jel.v5n3p288

Ancel, S., & Ficquet, É. (2016). the Ethiopian Orthodox Tewahedo Church (EOTC) and the challenges of modernity. *Understanding Contemporary Ethiopia: Monarchy, Revolution, and the Legacy of Meles Zenawi.*, 65–91. https://www.academia.edu/download/54268021/ANCEL_FICQUET-2015-EOTC.pdf

Applefield, J. M., Huber, R., & Moallem, M. (2001). Constructivism in theory and practice: Toward a better understanding. *The High School Journal*, *84*(2), 35–53. https://www.jstor.org/stable/40364404

Aslan, O., & Taşar, M. F. (2013). How do science teachers view and teach the nature of science? A classroom investigation. In *Education and Science* (Vol. 38, Issue 167, pp. 65–80).

Ayalew, H. R. (2017). Quality of science teaching in secondary schools of North Gondar zone in Ethiopia. *International Journal of Educational Sciences*, *16*(1–3), 21–35. https://doi.org/10.1080/09751122.2017.1311592

Bektas, O., & Geban, O. (2010). Turkish high school students' conceptions of the nature of science. *Procedia - Social and Behavioral Sciences*, *2*(2), 1982–1986. https://doi.org/10.1016/j.sbspro.2010.03.268

Bell, R. L. (2009). Teaching the nature of science : Three critical questions. In *Best practices in science education*. http://www.ngspscience.com/profdev/monographs/scl22-0449a_sci_am_bell_lores.pdf

Bell, R. L., & Lederman, N. G. (2003). Understandings of the nature of science and decision making on science and technology based issues. *Wiley Perdicals, Inc*, *87*(3), 352–377. https://doi.org/10.1002/sce.10063

Bell, R. L., Mulvey, B. K., & Maeng, J. L. (2012). Beyond understanding: Process skills as a context for nature of science instruction. *Advances in Nature of Science Research*, 225–245. https://doi.org/10.1007/978-94-007-2457-0

Berie, Z., Damtie, D., & Bogale, Y. N. (2022). Inquiry-based learning in science education: a content analysis of research papers in Ethiopia (2010–2021). *Education Research International*, *2022*. https://doi.org/doi.org/10.1155/2022/6329643

Bihu, R. (2020). Using unstructured interviews in educational and social science research: The process, opportunity and difficulty. *Global Scientific Journal*, *8*(10), 1241–1252. www.globalscientificjournal.com

Boran, G. H., & Bağ, H. (2016). The Influence of argumentation on understanding nature of science. *Intererrnational Journal of Environmental and Science Education*, *11*(6), 1423–1431. https://doi.org/10.12973/ijese.2016.410a

Brito, L. (2014). The role of science, technology and innovation policies and instruments for a paradigm shift towards sustainable development. In et al. Bolay (Ed.), *Technology for sustainable development* (pp. 13–20). Springer international pub. https://doi.org/10.1007/978-3-319-00639-0

Brossart, D. F., Laird, V. C., & Armstrong, T. W. (2018). Interpreting Kendall's Tau and Tau-U for single-case experimental designs. Cogent Psychology, 5(1), 1518687. DOI: 10.1080/23311908.2018.1518687

Buaraphan, K. (2012). Embedding nature of science in teaching about astronomy and space. *Journal of Science Education and Technology*, *21*(3), 353–369. https://doi.org/10.1007/S10956-01

Bybee, R., Mccrae, B., & Laurie, R. (2009). PISA 2006 : An assessment of scientific literacy. *Journal of Research in Scientific Teaching*, *46*(8), 865–883. https://doi.org/10.1002/tea.20333

Casey, D. (2012). *The Nature of Science*. Virginia science standards.

Celik, S., & Bayrakcekenp, S. (2012). The influence of an activity-based explicit approach on the Turkish prospective science teachers' conceptions of the nature of science. *Australian Journal of Teacher Education*, *37*(4). https://doi.org/10.14221/ajte.2012v37n4.3

Chaisri, A., & Thathong, K. (2014). The nature of science represented in Thai biology textbooks under the topic of evolution. *Procedia - Social and Behavioral Sciences*, *116*, 621–626. https://doi.org/10.1016/j.sbspro.2014.01.268

Chen, S. (2006). Development of an instrument to assess views on nature of science and attitudes. *Wiley Periodicals, Inc.*, 803–819. https://doi.org/10.1002/sce.20147

Çıbık, A. S. (2016). The effect of project-based history and nature of science practices on the change of nature of scientific knowledge. *Intererrnational Journal of Environmental and Science Education*, *11*(4), 453–472. https://doi.org/10.12973/ijese.2016.331a

Clough, M. P. (2008). We all teach the nature of science–Whether accurately or not. *Iowa Science Teachers Journal*, *35*(2), 2–3.

Clough, M. P. (2011). Teaching and assessing the nature of science: How to effectively incorporate the nature of science in your classroom. *The Science Teacher*, *78*(6), 56–60. https://www.jstor.org/stable/24148368?seq=1&cid=pdf

Clough, M. P. (2018). Teaching and learning about the nature of science. *Science and Education*, *27*, 1–5. https://doi.org/10.1007/s11191-018-9964-0 EDITORIAL Teaching

Concannon, J. P., Brown, P. L., & Brown, E. (2013). Prospective teachers' perceptions of science theories: An action research study. *Creative Education*, *4*(1), 82–88. https://doi.org/10.4236/ce.2013.41011

Correia, P. R. M., Xavier do Valle, B., Dazzani, M., & Infante-Malachias, M. E. (2010). The importance of scientific literacy in fostering education for sustainability: Theoretical considerations and preliminary findings from a Brazilian experience. *Journal of Cleaner Production*, *18*(7), 678–685. https://doi.org/10.1016/j.jclepro.2009.09.011

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Sage pubs, Inc.

Desalegn, C. J. (2013). *Trends in National Learning Assessment in Ethiopia*. *July*.

Dogan, N., & Abd-El-Khalick, F. (2008). Turkish grade 10 students' and science teachers' conceptions of nature of science : A national study. *Journal of Research in Science Teaching*, *45*(10), 1083–1112. https://doi.org/10.1002/tea.20243

Dorji, K., Jatsho, S., Choden, P., & Tshering, P. (2022). Bhutanese science teachers' perceptions of the nature of science: a cross-sectional study. *Disciplinary and Interdisciplinary Science Education Research*, *4*(1), 1–18. https://doi.org/10.1186/s43031-021-00044-9

Eastwood, J. L., Sadler, T. D., Zeidler, D. L., Lewis, A., Amiri, L., & Applebaum, S. (2012). Contextualizing nature of science instruction in socioscientific issues. *International Journal of Science Education*. https://doi.org/10.1080/09500693.2012.667582

Eivers, E., & Kennedy, D. (2006). The PISA assessment of scienntific literacy. *Education Research Center*, *37*, 101–119. https://www.jstor.org/stable/30077514

Fekede, T. G., & Tynjälä, P. (2015). Professional learning of teachers in Ethiopia: Challenges and implications for reform. *Australian Journal of Teacher Education*, *40*(5), 1–26. https://doi.org/10.14221/ajte.2015v40n5.1

Firestone, J., Wong, S., Luft, J. A., & Fay, D. (2012). The nature of science or the nature of teachers: Beginning science teachers' understanding of NOS. In *Advances in nature of science research: Concepts and methodologies* (Khine, M.S, pp. 189–206). Springer. https://doi.org/10.1007/978-94-007-2457-0

Flammer, L. (2006). The importance of teaching the nature of science. *The American Biology Teacher*, *68*(4), 197–198. https://www.jstor.org/stable/4451964

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). McGraw-Hill companies, Inc.

Giarelli, J. M. (2005). Qualitative inquiry in philosophy and education: Notes on the pragmatic tradition. In R. R.Sherman & R. B.Webb (Eds.), *Qualitative Research in Education: Focus and Methods* (Vol. 6, Issue 1, pp. 22–27). Routledge.

Glaze, A. . (2018). Teaching and learning science in the 21st century: Challenging critical assumptions in post-secondary science. *Education Sciences*, *8*, 1–8. https://doi.org/10.3390/educsci8010012

Good, R. G. (2005). Cautionary notes on assessment of understanding science concepts and nature of science. In J. D. Mintzes, J. J., Wandersee, J. H., & Novak (Ed.), *Assessing science understanding: a human constructivist view* (Vol. 38, Issue 07, pp. 343–354). https://doi.org/10.5860/choice.38-4010

Govender, N., & Zulu, D. (2017). Natural sciences junior high school teachers' understanding of the nature of science and its impact on their planning of lessons. *Journal of Baltic Science Education*, *16*(3), 366–378.

https://www.proquest.com/openview/4313ed8bcbe4529b384398f7f6168901/1?pq-origsite=gscholar&cbl=4477238

Griffee, D. T. (2005). Research tips: Interview data collection. *Journal of Developmental Education*, *28*(3), 36–37. https://files.eric.ed.gov/fulltext/EJ718580.pdf

Hanuscin, D. L., & Lee, E. J. (2009). Perspectives: Helping students understand the nature of Science. *National Science Teachers Association*, *46*(7), 64–65.

Hashemi, M. R., & Babaii, E. (2013). Mixed methods research: Toward new research designs in applied linguistics. *Modern Language Journal*, *97*(4), 828–852. https://doi.org/10.1111/j.1540-4781.2013.12049.x

Holbrook, J., & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental & Science Education*, *4*(3), 275–288. https://eric.ed.gov/?id=EJ884397

Huang, H., Wu, H., She, H., & Lin, Y. (2014). International forum of educational technology and society enhancing students' NOS views and science knowledge using facebook based scientific news. *Journal of Educational Technology & Society*, *17*(4), 289–301.

Iqbal, H. M., Azam, S., & Rana, R. A. (2009). Secondary school science teachers' views about the 'nature of science'. *Bulletin of Education and Research*, *31*(2), 29–44. https://pu.edu.pk/images/journal/ier/PDF-FILES/2_Secondary School Science Teachers' Views.pdf

Kahana, O., & Tal, T. (2014). Understanding of high-achieving science students on the nature of science. *International Journal of STEM Education*, *1*, 1–13.

Kang, S., Scharmann, L. C., & Noh, T. (2004). Examining students' views on the nature of science : Results from korean 6th , 8th , and 10th graders. *Wiley Periodicals, Inc.*, 314–334. https://doi.org/10.1002/sce.20053

Khishfe, R. (2012). Nature of science and decision-making. *International Journal of Science Education*, *34*(1), 67–100. https://doi.org/10.1080/09500693.2011.559490

Kiliç, K., Sungur, S., Çakiroğlu, J., & Tekkaya, C. (2005). Ninth grade students' understanding of the nature of scientific knowledge. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *28*(28), 127–133.

Knapp, N. F. (2000). Constructivist assessment: Trying to practice what I teach in educational psychology. *Action in Teacher Education*, *21*(4), 9–26. https://doi.org/10.1080/01626620.2000.10462977

Koksal, S., & Cakiroglu, M. J. (2010). Examining science teacher's understandings of the NOS aspects through the use of knowledge test and open-ended questions. *Science Education International*, *21*(3), 197–211.

Kostøl, K. B., Bøe, M. V., & Skår, A. R. (2022). Nature of science in Norway's recent curricula reform: Analysis of the biology, chemistry, and physics curricula. *Science and Education*, 1–21. https://doi.org/10.1007/s11191-022-00399-z

Kötter, M., & Hammann, M. (2017). Controversy as a blind spot in teaching nature of science should be an issue in the science classroom. *Science and Education*. https://doi.org/10.1007/s11191-017-9913-3

Krajewski, S. J., & Schwartz, R. (2014). A community college instructor's reflective journey toward developing pedagogical content knowledge for nature of science in a non-majors undergraduate Biology course. *Journal of Science Teacher Education*, *25*(5), 543–566. https://doi.org/10.1007/s10972-014-9390-3

Kremer, K., Specht, C., Urhahne, D., & Mayer, J. (2014). The relationship in biology between the nature of science and scientific inquiry. *Journal of Biological Education*, *48*(1), 1–8. https://doi.org/10.1080/00219266.2013.788541

Leach, J. (2006). Epistemological perspectives in research on teaching and learning science and learning science. *Research on Epistemology: Bridging Disciplinary Boundaries and Theoretical Perspectives, American Educational Research Association, San Fransisco April 2006*, 1–27. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=da04075faae3fd504c664c92be35a008b90fac2e

Leden, L., & Hansson, L. (2017). Nature of science progression in school year 1–9: A case study of teachers' suggestions and rationales. *Research in Science Education*, *49*(2), 591–611. https://doi.org/10.1007/s11165-017-9628-0

Lederman, J. S., Lederman, N. G., Kim, B. S., & Ko, E. K. (2012). Teaching and learning of nature of science and scientific inquiry: Building capacity through systematic research-based professional development. In M. S. Khine (Ed.), *Advances in Nature of Science Research: Concepts and methodologies* (pp. 125–152).

Lederman, N. G. (1992). Students ' and teachers ' conceptions of the nature of science : A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331–359.

Lederman, N. G. (2014). Guest editorial: Nature of science and its fundamental importance to the vision of the next generation science standards. *Science and Children*, *52*(1), 8–10.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L. &, & Schwartz, R. S. (2002). Views of nature of science questionnaire: toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497–521. https://doi.org/10.1002/tea.10034

Lederman, N. G., Antink, A., & Bartos, S. (2014). Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry. *Science and Education*, *28*, 285–302. https://doi.org/10.1007/s11191-012-9503-3

Lederman, N. G., & Lederman, J. S. (2004). Revising instruction to teach nature of science: Modifying activities to enhance student understanding of science. *The Science Teacher*, *71*(9), 36–39.

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology*, *1*(3), 138–147. www.ijemst.com

Liang, L. L., Chen, S., Chen, X., Kaya, O. N., Adams, A. D., Macklin, M., & Ebenezer, J. (2008). Assessing preservice elementary teachers' views on the nature of scientific knowledge: A dual-response instrument. *Asia-Pacific Forum on Science Learning and Teaching*, *9*(1), 1–

20.

Liu, S. Y., & Lederman, N. G. (2007). Exploring prospective teachers ' worldviews and conceptions of nature of Science. *International Journal of Science Education*, *29*(10), 1281–1307. https://doi.org/10.1080/09500690601140019

Lombrozo, T., Thanukos, A., & Weisberg, M. (2008). The importance of understanding the nature of science for accepting evolution. *Evolutionary Education Outreach*, *1*, 290–298. https://doi.org/10.1007/s12052-008-0061-8

Ma, H. (2009). Chinese secondary school science teachers' understanding of the nature of science - Emerging from their views of nature. *Research in Science Education*, *39*(5), 701–724. https://doi.org/10.1007/s11165-008-9100-2

McComas, W. F. (2015). The nature of science and the next generation of biology education. *The American Biology Teacher*, *77*(7), 485–491. https://doi.org/10.1525/abt.2015.77.7.2.

McComas, W. F. (2017). Understanding how science works : The nature of science as the foundation for science teaching and learning. *The School Science Review*, *98*(365), 71–76. https://www.ase.org.uk/journals/school-science-review/2017/06/365

McComas, W. F., Clough, M. P., & Almazroa, H. (2002). The role and character of the nature of science in science education. In W. F. Mccomas (Ed.), *The Nature of Science in Science Education: Rationales and Strategies* (pp. 3–39). Kluwer Academic Pub.

Mcdonald, C. V. (2010). The influence of explicit nature of science and argumentation instruction on preservice primary teachers' views of nature of science. *Journal of Research in Science Teaching*, *47*(9), 1137–1164. https://doi.org/10.1002/tea.20377

McEneaney, E. H. (2003). The worldwide cachet of scientific literacy international education society the worldwide cachet of scientific literacy. *Comparative Education Review*, *47*(2), 217–237. https://www.jstor.org/stable/10.1086/376539

Mercado, C. T., Macayana, F. B., & Urbiztondo, L. G. (2015). Examining education students' nature of science (NOS) views. *Asia Pacific Journal of Multidisciplinary Research*, *3*(5), 101–110.

Mesci, G., & Schwartz, R. S. (2017). Changing preservice science teachers' views of nature of science: Why some conceptions may be more easily altered than others. *Research in Sciennce Education*, *47*, 329–351. https://doi.org/10.1007/s11165-015-9503-9

Metz, S. (2006). Editor's Corner: Problem-based learning. *The Science Teacher*, *73*(8), 8.

Metz, S. (2015). Editor 's corner: The nature of science. *National Science Teachers Association*, *82*(7), 6. https://www.jstor.org/stable/43683302

Michel, H., & Neumann, I. (2017). Nature of science and science content learning and their learning about the concept of energy. *Science and Education*, 951–975. https://doi.org/10.1007/s11191-016-9860-4

Millar, R. (2004). *The role of practical work in the teaching and learning of science. Commissioned paper-Committee on High School Science Laboratories: Role and Vision*.

Miller, M. C. D., Montplaisir, L. M., Offerdahl, E. G., Cheng, F., & Ketterling, G. L. (2010). Comparison of views of the nature of science between natural science and nonscience majors. *CBE-Life Science Education*, *9*, 45–54. https://doi.org/10.1187/cbe.09–05–0029

MoE. (2009). *Curriculum framework for Ethiopian education (KG – Grade 12). Federal democratic republic of Ethiopia, Ministry of education*. https://moe.gov.et/storage/Books/Curriculum Framework for Ethiopian Education (KG – Grade 12).pdf

Morgan, D. L. (2007). Paradigms lost and pragmatism regained: Methodological implications of combining qualitative and quantitative methods. *Journal of Mixed Methods Research*, *1*(1), 48–76. https://doi.org/10.1177/2345678906292462

Morrison, J. A., Raab, F., & Ingram, D. (2009). Factors influencing elementary and secondary teachers' views on the nature of science. *Journal of Research in Science Teaching*, *46*(4), 384–403. https://doi.org/10.1002/tea.20252

National Academies of Sciences, Engineering, and M. (2016). *Science literacy: Concepts, contexts, and consequences. Washington, DC: The National Academies Press*. The National Academies Press. https://doi.org/10.17226/23595

Niaz, M. (2008). *What 'ideas-about-science' should be taught in school science? A chemistry teachers' perspective*. 233–249. https://doi.org/10.1007/s11251-007-9031-8

OECD. (2013). *PISA 2012 Assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy*. OECD Publishing. https://doi.org/10.1787/9789264190511-en

Özdem, Y., Çavaş, P., Çavaş, B., Çakıroğlu, J., & Ertepınar, H. (2010). An investigation of elementary students'scientific literacy levels. *Journal of Baltic Science Education*, *9*(1), 6–19. http://oaji.net/articles/2014/987-1404740965.pdf

Pleasants, J. (2017). Connecting science and technology: Exploring the nature of science using historical short stories. In *Natonal teachers association* (Vol. 84, Issue 9).

Rahayu, S. (2017). Promoting the 21st century scientific literacy skills through innovative chemistry instruction. *AIP Conference Proceedings*, *1911*, 020025. https://doi.org/10.1063/1.5016018

Reiners, C. S., Bliersbach, M., & Marniok, K. (2017). The cultural argument for understanding nature of science: A chance to reflect on similarities and differences between science and humanities. *Science & Education*, 583–610. https://doi.org/10.1007/s11191-017-9912-4

Roberts, D. A. (2010). Scientific literacy/ science literacy. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 729–780). Routledge: Taylor & Francis Group.

Ruane, J. M. (2005). *Essentials of research methods: A guide to social science research*. Blackwell pub.

Rudge, D. W., & Howe, E. M. (2009). An explicit and reflective approach to the use of history to promote understanding of the nature of science. *Science and Education*, *18*(5), 561–580. https://doi.org/10.1007/s11191-007-9088-4

Russell, T., & Aydeniz, M. (2013). Traversing the divide between high school science students and sophisticated nature of science understandings: A multi-pronged approach. *Journal of*

Science and Technology, *22*(4), 529–547. https://doi.org/10.1007/s 10956-012-9412-x

Saif, A. D. A. (2016). The nature of science as viewed by science teachers in Najran district, Saudi Arabia. *Journal of Education and Practice*, *7*(12), 147–153. https://core.ac.uk/download/pdf/234638936.pdf

Sangsa-ard, R., & Thathong, K. (2014). Examining junior high school science teachers ' understanding of the nature of science in Chaiyaphum province , Thailand. *Procedia - Social and Behavioral Sciences*, *116*, 4785–4797. https://doi.org/10.1016/j.sbspro.2014.01.1026

Sangsa-ard, R., Thathong, K., & Chapoo, S. (2014). Examining grade 9 students ' conceptions of the nature of science. *Procedia - Social and Behavioral Sciences*, *116*, 382–388. https://doi.org/10.1016/j.sbspro.2014.01.226

Seidel, T., & Shavelson, R. J. (2007). Teaching effectiveness research in the past decade: the role of theory and research design in disentangling meta-analysis results. *Review of Educational Research*, *77*(4), 454–499. https://doi.org/10.3102/0034654307310317

Seyhan, H. G., & Türk, G. E. (2013). An investigation of the relationship between performance in problem-solving laboratory application and views about nature of science of pre-srvice science teachers. *Social and Behavioral Sciences*, *106*, 401–410. https://doi.org/10.1016/j.sbspro.2013.12.046

Shaughnessy, J. J., Zechmeister, E. B., & Zechmeister, J. S. (2012). *Research Methods in Psychology* (9th ed.). McGraw-Hill companies, Inc.

Shishigu, A. (2018). Foundation of curriculum in Ethiopia: Historical, philosophical, psychological and sociological perspectives. *Annual International Educational Conference of Bahir Dar University, Ethiopia, May 2015*. https://files.eric.ed.gov/fulltext/ED557354.pdf

Smith, C. L., Maclin, D., Houghton, C., & Hennessey, M. G. (2000). Sixth-grade students' epistemologies of science: The impact of school science experiences on epistemological development. *Cognition and Instruction*, *18*(3), 349–422. https://doi.org/10.1207/S1532690XCI1803_3

Snively, G., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education*, *85*(1), 6–34. https://doi.org/10.1002/1098-237X(200101)85:1<6::AID-SCE3>3.0.CO;2-R

Sormunen, K., & Köksal, M. S. (2014). Advanced science students' understandings on nature of science in Finland. *European Journal of Educational Research*, *3*(4), 167–176. http://www.eurojedu.com

Southerland, S. A., Golden, B., & Enderle, P. (2012). The bounded nature of science: An effective tool in an equitable approach to the teaching of science. In M. S. Khine (Ed.), *Advances in Nature of Science Research: Concepts and Methodologies* (pp. 75–96). Springer, Dordrecht. https://doi.org/10.1007/978-94-007-2457-0

Ssempala, F. (2019). Assessment and improving science teachers' conception of nature of science: A review of the literature. *International Journal of Scientific Research and Education*, *07*(04), 8163–8171. http://jsae.in

Stadermann, H. K. E., & Goedhart, M. J. (2020). Secondary school students' views of nature of science in quantum physics. *International Journal of Science Education*, *42*(6), 997–1016. https://doi.org/10.1080/09500693.2020.1745926

Taber, K. S. (2017). Reflecting the Nature of Scientific Knowledge in Science Education. *Science Education: An International Course Companion*, 23–37. https://doi.org/10.5040/9781474289450.ch-003

Tao, P. K. (2003). Eliciting and developing junior secondary students' understanding of the nature of science through a peer collaboration instruction in science stories. *International Journal of Science Education*, *25*(2), 147–171. https://doi.org/10.1080/09500690210126748

Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Sage pubs, Inc.

Tesfaye, T., Yitbarek, S., & Tesfaye, A. (2010). *Status of science education in primary schools of Addis Ababa* (pp. 1–113). https://aacaebc.files.wordpress.com/2018/02/a-study-on-status_science_education_aa_final.pdf

Toma, R. B., Greca, I. M., & Orozco Gómez, M. L. (2019). Attitudes towards science and views of nature of science among elementary school students in terms of gender, cultural background and grade level variables. *Research in Science and Technological Education*, *37*(4), 492–515. https://doi.org/10.1080/02635143.2018.1561433

Tsai, C. (2006). *Reinterpreting and reconstructing science : Teachers ' view changes toward the nature of science by courses of science education*. *22*, 363–375. https://doi.org/10.1016/j.tate.2004.06.010

Turiman, P., Omar, J., Daud, A. M., & Osman, K. (2012). Fostering the 21st century skills through scientific literacy and science process skills. *Procedia - Social and Behavioral Sciences*, *59*, 110–116. https://doi.org/10.1016/j.sbspro.2012.09.253

Urhahne, D., Kremer, K., & Mayer, J. (2011). Conceptions of the nature of science-are they general or context specific? *International Journal of Science and Mathematics Education*, *9*(3), 707–730. https://doi.org/10.1007/s10763-010-9233-4

Vincent-Ruz, P., & Schunn, C. D. (2018). The nature of science identity and its role as the driver of student choices. *International Journal of STEM Education*, *5*(1), 1–12. https://doi.org/10.1186/s40594-018-0140-5

Waters-Adams, S. (2006). The relationship between understanding of the nature of science and practice: The influence of teachers' beliefs about education, teaching and learning. *International Journal of Science Education*, *288*, 919–944. https://doi.org/10.1080/09500690500498351

Widowati, A., Atun, S., Suryadarma, I., Wiyarsi, A., & Yani, L. A. F. (2018). The profile of students ' views of nature of science (NOS) in Junior High School of Yogyakarta city. *AIP Conference Proceedings 2014, 020092*, *020092*(September 2018). https://doi.org/https://doi.org/10.1063/1.5054496

Windschitl, M. (2004). Folk theories of "inquiry:" How preservice teachers reproduce the discourse and practices of an atheoretical scientific method. *Journal of Research in Science*

Teaching, *41*(5), 481–512. https://doi.org/10.1002/tea.20010

Wolfensberger, B., & Canella, C. (2015). Cooperative learning about nature of science with a case from the history of science. *International Journal of Environmental and Science Education*, *10*(6), 865–889. https://doi.org/10.12973/ijese.2015.281a

Wolpert, L. (1994). *The unatural nature of science*. Harvard university press.

Yalaki, Y., Doğan, N., İrez, S., & Doğan, N. (2019). Measuring nature of science views of middle school students. *International Journal of Assessment Tools in Education*, *6*(3), 461–475. https://doi.org/10.21449/ijate.561154

Yalçinoğlu, P., & Anagün, Ş. S. (2012). Teaching nature of science by explicit approach to the preservice elementary science teachers. *Elementary Education Online*, *11*(1), 118–136. http://ilkogretim-online.org.tr

Yenice, N., & Saydam, G. (2010). The views of the 8th grade students about nature of scientific knowledge. *Procedia - Social and Behavioral Sciences*, *2*(2), 5012–5017. https://doi.org/10.1016/j.sbspro.2010.03.812

Appendix A*: Questionnaire to assess students' conceptions of NOSK*

Bahir Dar University

College of Education and Behavioral Sciences

Department of Educational Psychology

Questionnaire to be filled by secondary school students

Dear students, I am a PhD student in Bahir Dar University post graduate program in the department of educational psychology. This questionnaire is prepared to investigate the ways how secondary school students conceive the nature of scientific Knowledge (NOSK). Your responses will be kept confidential; they will not be accessed by people other than me and my research advisors. The reports of this study will not use your names; rather it uses pseudonyms or code numbers. The result of this study is important in finding ways that improve the teaching and learning of NOSK. And the success of this study will depend on the information you provide, therefore, you are requested to provide answers to each question carefully so that it can reflect your understanding of NOSK as much as possible.

Note:

- There are no "right" or "wrong" answers to the following questions. I am only interested in your ideas relating to the following questions. Use examples to illustrate your responses.
- If there is ambiguity in any of the items or instructions, you are encouraged to ask.

I kindly request your cooperation in responding to this questionnaire. Thank you in advance for your cooperation!!!

Tadele Demelash,

PhD student, Bahir Dar University, college of education, department of educational psychology

Instruction I. Respondents background data. Give appropriate information to the following items.

Name of the school ____
Grade level ____
Section ____
Roll Number ____
Sex ____
Age ____

Instruction II. Give answers to the following questions. Illustrate your answers with examples. You can use space provided and the backs of the pages to answer a question.

1. What is science?

2. What makes science (or a scientific discipline such as physics, biology, etc.) different from other subject/disciplines (art, history, philosophy, etc.)?

3. Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.

4. If different scientist use the same data, do you think their conclusions be the same or different? Illustrate with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. 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.

7. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imaginations and creativity when they do these investigations / experiments?
   a) If NO, explain why.
   b) If YES, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in

both groups have access to and use the same set of data to derive their conclusions?

9. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? Explain and give an example.

10. With examples, explain how society and culture affect OR do not affect scientific research. Is there a relationship between science, society, and cultural values? If so, how? If not, why not? Explain and provide examples.

Appendix B: *Questionnaire for assessing students conception of NOSK (Amharic version)*

በባህር ዳር ዩኒቨርሲቲ

የትምህርትና ስነ ባህሪ ኮሌጅ

ሳይኮሎጂ ት/ት ክፍል

በሁለተኛ ደረጃ ተማሪዎች የሚሞላ መጠይቅ

ውድ ተማሪዎች፡- እኔ በባህር ዳር ዩኒቨርሲቲ የድህረ ምረቃ ፕሮግራም ኢዱኬሽናል ሳይኮሎጂ ት/ት ክፍል የ3ኛ ዲግሪ ተማሪ ነኝ፡፡ ይህ መጠይቅ የተዘጋጀዉ የሁለተኛ ደረጃ ተማሪዎች የሳይንስን ባህሪያት እንዴት እንደሚረዷቸዉ ለመገንዘብ ነዉ፡፡ ለመጠይቁ የምትሰጡት መልስ በሚስጥር ይያዛል፤ ከእኔና ከአማካሪ መምህሬ በቀር ሌላ አካል እንዲያገኘዉ አይደረግም፡፡ በጥናቱ ሪፖርት ላይ የኮድ ስሞችን ወይም ቁጥሮችን እንጂ የመላሽ ተማሪዎች ስም አይጠቀስም፡፡ የጥናቱ ዉጤት ተማሪዎች የሳይንስን ባህሪያት በተሻለ ሁኔታ የሚማሩበትን መንገድ ለማመላከት ጠቃሚ ነዉ፡፡ የዚህ ጥናት ውጤታማነት ደግሞ በምትሰጡት መረጃ ላይ ስለሚመሰረት ለእያንዳንዱ ጥያቄ የምትሰጡት መልስ በተቻለ መጠን ስለ ሳይንስ ባህሪያት ያላችሁን ግንዛቤ በትክክል እንዲገልጽ በጥንቃቄ መልሱ፡፡

ማሳሰቢያ፡-

- ለሁሉም ጥያቄዎች "ትክክል" ወይም "ስህተት" የሚባል መልስ የለም፡፡ በቀረቡት ጥያቄዎች ላይ ያላችሁን ሀሳብ ለመረዳት የቀረቡ በመሆናቸዉ ሁሉንም ጥያቄዎች በተቻላችሁ መጠን በምሳሌ አብራሩ፡፡
- ጥያቄዎች ግልፅ በማይሆኑበት ጊዜ እንድትጠይቁ ትበረታታላችሁ፡፡

ለዚህ መጠይቅ መልስ በመስጠት እንድትተባበር/ሪ በትህትና እየጠየቅሁ ስለትብብራችሁ በቅድሚያ አመሰግናለሁ!!!

ታደለ ደመላሽ

በባህር ዳር ዩኒቨርሲቲ በትም/ትና ስነ-ባህሪ ኮሌጅ የኢዱኬሽናል ሳይኮሎጂ የ3ኛ ዲግሪ ተማሪ

፩.መጠይቁን የሚሞላ ተማሪ አጠቃላይ መረጃ

1. የክፍል ደረጃ (የ “ ✓ ” ምልክት አድርግ/ጊ)፡ 9ኛ☐ 10ኛ☐ 11ኛ ☐ ☐
   12ኛ ሴክሽን --------------------------
2. የክፍል ተራ ቁጥር --
3. ፆታ፡ (የ “ ✓ ” ምልክት አድርግ/ጊ)፡ ወንድ ☐ ሴት ☐
4. እድሜ ---------------------------------

፪. ለሚከተሉት ጥያቄወች መልስ ስጡ፡፡ በተቻላችሁ መጠን መልሳችሁን በምሳሌ አብራሩ፡፡ መልስ ለመስጠት ቦታ ካነሳችሁ በጀርባ በኩል መጠቀም ትችላላችሁ፡፡

1. ሳይንስ (በአንተ/ች አስተያየት) ምን ማለት ነዉ?

2. ሳይንስን (ወይም የሳይንስ የጥናት ዘርፎችን፣እንደ ፊዚክስ፣ባዮሎጂ ወዘተ.) ከሌሎች የጥናት መስኮች (ለምሳሌ፡- ከሀይማኖት፣ ፍልስፍና ወዘተ) የሚለየዉ ምንድን ነዉ?

3. ሳይንቲስቶች በምርምር እዉቀት ያፈልቃሉ፡፡ ይህ እዉቀት ወደፊት ***ሊቀየር ይችላል ብለህ/ሽ ታስባለህ/ሽ*** ? መልስህን/ሽን በምሳሌ አስደግፈህ/ሽ አብራራ/ሪ፡፡

4. የተለያዩ ሳይንቲስቶች **አንድ አይነት መረጃ ቢጠቀሙ** የሚደርሱበት ድምዳሜ ተመሳሳይ ይሆናል ወይስ የተለያየ ሊሆን ይችላል? በምሳሌ አብራሩ፡፡

5. በሳይንሳዊ ቲየሪ (scientific theory) እና በሳይንሳዊ ህግ (scientific law) መካከል ልዩነት አለ ወይስ የለም? መልሳችሁን በምሳሌ አስረዱ፡፡

6. ሳይንቲስቶች ምርምር ወይም ኤክስፐርሜንት በሚሰሩበት ጊዜ **ምናባዊ እና የፈጠራ ችሎታቸዉን** (Imagination and creativity) ይጠቀማሉ ወይስ አይጠቀሙም? ለምን? መልሳችሁን በምሳሌ አስረዱ፡፡

ሀ) አይጠቀሙም ካላችሁ ለምን እንደማይጠቀሙ አብራሩ፡፡

ለ) ይጠቀማሉ ካላችሁ በየትኛዉ/ በየትኞች የጥናት ደረጃ/ዎች (በማቀድ፣ መረጃ በመሰብሰብ፣በመረጃ ትንተና ወቅት፣ ሪፖርት ሲያቀርቡ)

7. ዳይኖሰሮች ከ65 ሚሊዮን ዓመት በፊት ከምድረ ገፅ እንደጠፉ ይታመናል። ለመጥፋታቸዉ የተለያዩ ንድፈ ሀሳቦች ተሰጥተዋል፤ ከነዚህም ውስጥ ሁለቱ ሰፊ ተቀባይነት አግኝተዋል።

አንደኛዉ የሳይንቲስቶች ቡድን ዳይኖሰሮች የጠፉት መሬት በግዙፍ ሜቲዮሮይቶች (በጣም ግዙሁፍ በሆኑ አለታማ የክዋክብት ስብርባሪዎች) ስለተመታች በደረሰው አስከፊ ጥፋት ነዉ ብለዋል። ሁለተኛዉ የሳይንቲስቶች ቡድን ደግሞ ዳይኖሰሮች የጠፉት መሬትን ያጥለቀለቀ አውዳሚ የእሳተ ገሞራ ፍንዳታ በመከሰቱ ምክንያት ነው የሚል ድምዳሜ ላይ ደርሰዋል።

እነዚህ ሁለቱ ቡድን ሳይንቲስቶች አንድ አይነት መረጃ ተጠቅመዉ እንዴት የተለያየ ድምዳሜ ላይ መድረስ ቻሉ? የምትሰጡትን መልስ አብራሩ።

8. የመሬት ንብርብሮሽ ሞዴል (layers of the earth) የላይኛዉ የመሬት አካል (Crust)፣መካከለኛዉ (mantel) እና የታችኛዉ (core) በመባል ይታወቃሉ። ይህ የመሬት ንብርብሮሽ ሞዴል የታችኛዉን የመሬት አካል ምን ያህል በትክክል ይወክላል? የምትሰጡትን መልስ አብራሩ።

9. ሳይንሳዊ ቲየሪዎች *(ለምሳሌ- የአተም ቲየሪ(atomic theory)፣የዝግመተ ለዉጥ ቲየሪ(evolution theory)* <u>ይቀየራሉ ወይስ አይቀየሩም</u> ? ይቀየራሉ ወይም አይቀየሩም ብለህ/ሽ ያሰብህበትን/ ያሰብሽበትን ምክንያት በምሳሌ አስረዳ/ጂ፡፡

10. ማህበረሰብ እና ባህላዊ እሴቶች ሳይንሳዊ ምርምር ላይ ***<u>ተፅዕኖ ይፈጥሩ ወይም አይፈጥሩ</u>*** እንደሆነ በምሳሌ አስረዱ፡፡

Appendix C: *Questionnaire for assessing teachers conceptions of NOSK*

Bahir Dar University

College of Education and Behavioral Sciences

Department of Educational Psychology

Questionnaire to be filled by secondary school science teachers

Dear science teachers, I am a PhD student in Bahir Dar University in the department of educational psychology. This questionnaire is prepared to investigate the ways how secondary school science teachers conceive the nature of scientific Knowledge (NOSK). Your responses will be kept confidential; they will not be accessed by people other than me and this research advisors. The reports of this study will not use your names; rather it uses code numbers. The result of this study is important in finding ways that improve the teaching and learning of NOSK. And the success of this study will depend on the information that you provide. Therefore, you are requested to provide answers to each question carefully so that it can reflect your understanding of the NOSK.

Note:

- There are no "right" or "wrong" answers to the questions presented. I am only interested in your ideas relating to the questions. Use examples to illustrate your responses.
- If there is ambiguity in any of the items or instructions, you are encouraged to ask.

I kindly request your cooperation in responding to this questionnaire. Thank you in advance for your cooperation!!!

Tadele Demelash,

PhD student, Bahir Dar University, college of education, department of educational psychology

Part I. Respondents background data. Provide your answers by a tick mark "✓" or writing short answers to the following items.

- Sex: Male ______ Female ______
- Age: _______
- Major field of study ____
- Work experience (Service Year): By teaching ______ Other________
  - Grade level/s you have taught ______________________________
  - The subject/s you have taught _____________________________

Part II. Questions that are related to your science understanding

Give answers to the following questions. Illustrate your answers with examples. You can use the space provided and the backs of the pages to answer the questions.

1. What is science (in your opinion)?

2. What makes science (or a scientific discipline such as physics, biology, etc.) different from other subject/disciplines (art, history, philosophy, etc.)?

3. Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.

4. If different scientist use the same data, do you think their conclusions be the same or different? Illustrate with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imaginations and creativity when they do these investigations / experiments?
   c) If NO, explain why.
   d) If YES, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

7. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

8. 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.

9. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? Explain and give an example.

10. With examples, explain how society and culture affect OR do not affect scientific research. Is there a relationship between science, society, and cultural values? If so, how? If not, why not? Explain and provide examples.

Appendix D: *Questionnaire for assessing teachers conceptions of NOSK (Amharic Version)*

በባህር ዳር ዩኒቨርሲቲ

የትምህርትና ስነ ባህሪ ኮሌጅ

ሳይኮሎጂ ት/ት ክፍል

የሳይንስ መምህራንን የሳይንስ ባህሪያት አረዳድ ለመዳሰስ የተዘጋጀ መጠይቅ

ውድ የሳይንስ መምህራን :- እኔ በባህር ዳር ዩኒቨርሲቲ የድህረ ምረቃ ፕሮግራም በኢዱኬሽናል ሳይኮሎጂ ት/ት ክፍል የ3ኛ ዲግሪ ተማሪ ነኝ፡፡ ይህ መጠይቅ የተዘጋጀዉ የሁለተኛ ደረጃ መምህራን የሳይንስን ባህሪያት እንዴት እንደሚረዷቸዉ ለመገንዘብ ነዉ፡፡ ለመጠይቁ የምትሰጡት መልስ ከእኔና ከአማካሪ መምህሬ በቀር ሌላ አካል እንዲያገኘዉ አይደረግም፡፡ በጥናቱ ሪፖርት ላይም የኮድ ቁጥሮችን እንጂ የመላሽ መምህራን ስም አይጠቀስም፡፡ የጥናቱ ዉጤት ተማሪዎች የሳይንስን ባህሪያት በተሻለ ሁኔታ የሚማሩበትን መንገድ ለማመላከት ጠቃሚ ነዉ፡፡ የዚህ ጥናት ውጤታማነት ደግሞ በምትሰጡት መረጃ ላይ ስለሚመሰረት ለእያንዳንዱ ጥያቄ የምትሰጡት መልስ በተቻለ መጠን ስለ ሳይንስ ባህሪያት ያላችሁን ግንዛቤ በትክክል እንዲገልጽ በጥንቃቄ መልሱ፡፡ይህንን መጠይቅ ለማጠናቀቅ 45 ደቂቃ ያህል ሊወስድ ይችላል፡፡

ለዚህ መጠይቅ መልስ በመስጠት እንድትተባበር/ሪ በከፍተኛ አክብሮት እጠይቃለሁ፡፡

ስለትብብራችሁ አመሰግናለሁ!

ታደለ ደመላሽ

በባህር ዳር ዩኒቨርሲቲ በትም/ትና ስነ-ባህሪ ኮሌጅ የኢዱኬሽናል ሳይኮሎጂ

የ3ኛ ዲግሪ ተማሪ

ክፍል አንድ፡ መጠይቁን የሚሞላ ሰዉ አጠቃላይ መረጃ

የሚከተለትን መረጃዎች በተሰጠዉ ክፍት ቦታ ላይ <u>የ‹‹ ✓ ››</u> ምልክት በማድረግ ወይም <u>አጭር መልስ በመፃፍ</u> መልሱ፡፡

- ጾታ፡ ወንድ ------------ ሴት ------------------
- እድሜ -----------------
- የት/ት ዋና የጥናት መስክ፤ ባዮሎጂ ------------- ኬሚስትሪ ----------- ፊዚክስ ----------------
- የስራ ልምድ፡ በማስተማር ------------ በሌላ መስክ ------------
- የማስተማር ልምድ ፣
  - ያስተማርህበት/ ሽበት የት/ት ደረጃ ---
  - ያስተማርህዉ/ሽዉ የት/ት አይነት/ አይነቶች ---

ክፍል ፪፤ ስለ ሳይንስ ካለችሁ አረዳድ ጋር የተገናኙ ጥያቄዎች

ቀጥሎ የቀረቡትን ጥያቄዎች በተቻላችሁ መጠን ዘርዘር አድርጋችሁ፣ በተጨማሪም ምሳሌዎችን በመጠቀም ሀሳባችሁን በማብራራት እንድታቀርቡ እጠይቃለሁ፡፡

መልስ ለመስጠት ቦታ ካነሳችሁ በጀርባ በኩል መጠቀም ትችላላችሁ፡፡

1. ሳይንስ (በአንተ/ች አስተያየት) ምን ማለት ነዉ?

2. ሳይንስን (ወይም የሳይንስ የጥናት ዘርፎችን፣እንደ ፊዚክስ፣ባዮሎጂ ወዘተ.) ከሌሎች የጥናት መስኮች (ለምሳሌ፡- ከሀይማኖት፣ ፍልስፍና ወዘተ) የሚለየዉ ምንድን ነዉ?

3. ሳይንቲስቶች በምርምር እዉቀት ያፈልቃሉ። ይህ እዉቀት ወደፊት ***ሊቀየር ይችላል ብለህ/ሽ ታስባለህ/ሽ*** ? መልስህን/ሽን በምሳሌ አስደግፊህ/ሽ አብራራ/ሪ።

4. የተለያዩ ሳይንቲስቶች **አንድ አይነት መረጃ ቢጠቀሙ** የሚደርሱበት ድምዳሜ <u>ተመሳሳይ ይሆናል ወይስ የተለያየ</u> ሊሆን ይችላል? በምሳሌ አብራሩ።

5. በሳይንሳዊ ቲየሪ (scientific theory) እና በሳይንሳዊ ህግ (scientific law) መካከል ልዩነት አለ ወይስ የለም? መልሳችሁን በምሳሌ አስረዱ።

6. ሳይንቲስቶች ምርምር ወይም ኤክስፐርሜንት በሚሰሩበት ጊዜ **ምናባዊ እና የፈጠራ ችሎታቸዉን** (Imagination and creativity) ይጠቀማሉ ወይስ አይጠቀሙም? ለምን? መልሳችሁን በምሳሌ አስረዱ።

   ሀ) አይጠቀሙም ካላችሁ ለምን እንደማይጠቀሙ አብራሩ።

   ለ) ይጠቀማሉ ካላችሁ በየትኛዉ/ በየትኞች የጥናት ደረጃ/ዎች (<u>በማቀድ፣ መረጃ በመሰብሰብ፣በመረጃ ትንተና ወቅት፣ ሪፖርት ሲያቀርቡ</u>)

7. ዳይኖሰሮች ከ65 ሚሊዮን ዓመት በፊት ከምድረ ገፅ እንደጠፉ ይታመናል። ለመጥፋታቸዉ የተለያዩ ንድፈ ሀሳቦች ተሰጥተዋል፤ ከነዚህም ውስጥ ሁለቱ ሰፊ ተቀባይነት አግኝተዋል።

አንደኛዉ የሳይንቲስቶች ቡድን ዳይኖሰሮች የጠፉት መሬት በግዙፍ ሜቲዮሮይቶች (በጣም ግዙሁፍ በሆኑ አለታማ የክዋክብት ስብርባሪዎች) ስለተመታች በደረሰው አስከፊ ጥፋት ነዉ ብለዋል፡፡ ሁለተኛዉ የሳይንቲስቶች ቡድን ደግሞ ዳይኖሰሮች የጠፉት መሬትን ያጥለቀለቀ አውዳሚ የእሳተ ገሞራ ፍንዳታ በመከሰቱ ምክንያት ነው የሚል ድምዳሜ ላይ ደርሰዋል፡፡

እነዚህ ሁለቱ ቡድን ሳይንቲስቶች አንድ አይነት መረጃ ተጠቅመዉ እንዴት የተለያየ ድምዳሜ ላይ መድረስ ቻሉ? የምትሰጡትን መልስ አብራሩ፡፡

8. የመሬት ንብርብሮሽ ሞዴል (layers of the earth) የላይኛዉ የመሬት አካል (Crust)፣መካከለኛዉ (mantel) እና የታችኛዉ (core) በመባል ይታወቃሉ፡፡ ይህ የመሬት ንብርብሮሽ ሞዴል የታችኛዉን የመሬት አካል ምን ያህል በትክክል ይወክላል? የምትሰጡትን መልስ አብራሩ፡፡

9. ሳይንሳዊ ቲየሪዎች *(ለምሳሌ- የአተም ቲየሪ(atomic theory)፣የዝግመተ ለዉጥ ቲየሪ(evolution theory*) ይቀየራሉ ወይስ አይቀየሩም ? ይቀየራሉ ወይም አይቀየሩም ብለህ/ሽ ያሰብህበትን/ ያሰብሽበትን ምክንያት በምሳሌ አስረዳ/ጂ፡፡

10. ማህበረሰብ እና ባህላዊ እሴቶች ሳይንሳዊ ምርምር ላይ ***ተፅዕኖ ይፈጥሩ ወይም አይፈጥሩ*** እንደሆነ በምሳሌ አስረዱ፡፡

Appendix E*: Scoring guide for the conception of NOSK*

Scoring guide of NOSK understanding for the open ended items, adapted from Agustian (2020), *Lederman et al.,* (2002), *Miller et al.* (2010), *Stadermann & Goedhart* (2020)

NOS aspect	Naïve conception, score = 1	*Syncretic/Intermediate c*onception, score = *2*	Informed *c*onception, score = *3*
Empirical NOSK	Focuses responses on only empirical evidence and has a particular focus on being able to see all aspects of what is being studied.	Understands that a model cannot be seen but still overly focused on empirical data.	Knows that inferences have to be made to create knowledge, particularly about things that cannot be seen.
Tentative NOSK	Scientific theory/ law is certain and unchangeable or thinks that scientific theories change because they are opinions or guesses.	Acknowledges that scientific theories change, but the explanation is general or vague or there is no explanation.	Understands that everything in science is open to development, it is subject to change with new evidence or interpretation of existing evidence.
Subjective NOSK	Science is universal, and scientists are objective. Indicates that coming to different conclusions from the same set of data would be because the data are bad or says that two scientists would not come to a different conclusion about the same data.	Scientists can look at the same set of evidence and come up with different interpretations, but failed to provide reasons for justification.	Scientists' observations and interpretations may be different because of their prior knowledge, personal perspectives, or beliefs.
Nature of Scientific theories and laws	Scientific laws are more certain than theories, or theories become laws when they are proven (a hierarchical view between them)	The participant provides valid example(s) of scientific laws and theories without further elaboration.	Scientific theories are well-substantiated explanations of natural phenomena or scientific laws. Both scientific laws and theories are subject to change.
Creativity and Imagination in science	Scientists cannot be creative or cannot use imagination or they can use it only at some phases of the investigation, notably during data collection. The scientist has to be objective- they follow strict rules (the scientific method).	Scientists use creativity and imagination but without elaboration	Scientists use their creativity and imagination throughout their scientific investigations. Imagination and creativity are essential for the formulation of novel ideas, to explain the observed results.
Inferential nature of scientific knowledge	Scientists know things by looking at them and writing down what they see. They don't guess or infer; they just observe.	Reflects a basic yet incomplete grasp of key concepts related to inference.	They understand that observations are direct, like seeing the fossils, while inferences are conclusions drawn from these observations.
Social and cultural embeddedne ss	Science is a search for universal truth and fact which is not affected by culture and society.	The participant states that science is influenced by culture and society without further elaboration	Scientists are informed by their culture and society. Culture determines what and how science is conducted, or accepted

Note: The participant's response is rated as not classifiable (NC) if there is no response; they state that they do not know; the response does not address the prompt; or the response cannot be classified based on the rubric descriptions.