In-Service Science Teachers’ Views of the Empirical and Tentative Nature of Science

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Abstract

According to research, teachers’ views about the nature of science influence their students’ views, as well as how they teach science. The goal of this study was to ascertain in-service science teachers’ views on the empirical and tentative nature of science. A mixed-methods approach was adopted. The sample comprised of ten in-service senior high school science teachers (7 males and 3 females) who were purposefully selected. In-service science instructors exhibited naive views of science (M = 2.81, SD = 0.33). Majority of the in-service science teachers (80%) held naive views, and 20% held informed views of the nature of science. The study revealed that in-service science instructors held a naive understanding of the empirical nature of science (M = 2.60, SD = 0.31). They did, however, held informed views about the tentative character of science (M = 3.77, SD = 0.79). The study recommends that research and professional development activities be directed toward assisting science teachers in developing a deep, comprehensive, and integrated grasp of science. Nature of science should be explicitly taught at the teacher education institutions to help prospective teachers understand the nature of science.

Keywords: nature of science, empirical nature of science, tentative nature of science, in-service teachers.


Introduction

The term "history and philosophy of science" (HPS) has been used to characterize the interaction of disciplines that inform scientific education regarding the nature of...
science itself. The nature of science (NOS) is a more comprehensive term for describing the scientific effort in science education. The nature of science is a fertile hybrid arena that combines aspects of various social studies of science, such as history, sociology, and philosophy of science, with research from cognitive sciences such as psychology to provide a rich description of what science is, how it works, how scientists operate as a social group, and how society both directs and reacts to scientific endeavors (McComas, Clough & Almazroa, 2002).

Studies in the History, Philosophy, and Sociology (HPS) of science and science teaching have drawn largely from the fields of history and philosophy. Learning how to think scientifically is an important skill for citizens in modern democratic states, and perhaps even more importantly in authoritarian states where serious and critical thinking is not encouraged. In order to have a democratic community of people who can make knowledgeable decisions, citizens need to be able to evaluate the reliability of evidence and be able to use logic and reason, particularly when voting on scientific issues but on many other matters as well (Matthews, 2018).

The failure of history and philosophy of science (HPS) to contribute to the mainstream of science education stems from teachers' lack of trust that a historical context adds anything to students' knowledge and skills. Most science teachers see their role as primarily concerned with transmitting knowledge, with the focus on "what we know" rather than "how we know" (Monk & Osborne, 1997). For science teachers, science is viewed as an established set of information and practices that require no justification. The development of a knowledge of science concepts, as well as the nature and techniques of science, is intrinsic to science education (Monk and Osborne, 1997).

Empiricism holds that knowledge is obtained and accumulated via experience, and that it is dependent on the five senses. Empiricism is founded on the concept that we can only know what the world tells us; true knowledge can only be realized and comprehended through objective, neutral observation. Empiricism includes the belief that authentic knowledge can be checked by experience and that claims to knowledge must be observable (Howell, 2013).

The development of scientific literacy has emerged as a primary goal of scientific education, with the nature of science regarded as an important component of scientific literacy. To achieve a discerning scientifically literate adult population, it is argued that science educators should encourage increased sophistication in understanding the intrinsic principles, beliefs, and assumptions that underpin science, also known as the nature of science (Lederman, 1992) as cited in (Provost et al., 2011).

Problem Statement

The goal of science education is to promote scientific literacy and understanding of science (Gioti, Stylos & Kotsis, 2023). One of the primary purposes of science education at all levels is to guide pupils in this direction. The nature of science is frequently used to establish the epistemological and ontological underpinnings of science, i.e., concerns concerning how scientists operate, function as a social group, and how society influences and responds to science (Gioti, Stylos, & Kotsis, 2023). Science educators believe that pupils must comprehend the nature of science and its principles in order to operate well in today's technologically advanced cultures (Khine, 2019).

It is widely acknowledged that students studying science should understand what science is, how it operates, and what it has accomplished. In short, kids should
understand the fundamentals of science (Matthews, 2022). This is a truism, but its implication, that science students and teachers should learn the history and philosophy of science (HPS), has received less attention and implementation (Matthews, 2022). It has become more crucial to investigate how both students and instructors understand the NOS, as knowing scientific information and how to gain it is an essential component of science literacy (Charupoom et al., 2022).

Teachers' ideas have been considered as critical in most educational reforms, as teachers must support students' co-construction of knowledge (Chai, 2010). Teachers must provide clear instruction to assist students build a deeper grasp of science and apply that knowledge in society (Charupoom et al., 2022). They also help to develop students' thoughts and increase student learning. They frequently give the most tangible science experiences for kids, and it is critical that these possibilities are as authentic and reflective of actual science as possible. A person must have an adequate understanding of a concept in order to effectively communicate that knowledge for the "knowledge train" to continue from person to person; thus, in order to teach about the NOS, a teacher must have a strong grasp of the concept (Charupoom et al., 2022).

Today, NOS is characterized in a postmodern framework based on the ideas of philosophers like Kuhn and Hanson. According to this postmodern conception, science is a subjective human endeavor based on theory and culture, as well as experimental observations (Schwartz, 2004, as cited in Aslan & Tasar, 2013). Teachers must have a thorough comprehension of science in order to teach it to their students. This is because students' comprehension of the nature of science is crucial to their academic progress (Provost et al., 2011). Thus, this study aims to address the following questions: (1) How do in-service science teachers view the empirical nature of science? (2) What are the perspectives of in-service science instructors on the tentative character of science?

Objectives

1. To determine in-service science teachers’ views of the empirical nature of science.
2. To determine in-service science teachers’ views of the tentative nature of science.

Research Questions

1. What are in-service science teachers’ views of the empirical nature of science?
2. What are in-service science teachers’ views of the views of the tentative nature of science?

Theoretical framework

The theoretical framework of the study is based on the family resemblance approach (Irzik & Nola, 2014). The Family resemblance approach provides a comprehensive representation of different aspects that characterise the scientific enterprise (Yeh et al., 2019). Family resemblance was used to denote similarities and differences shared among sciences (Yeh et al., 2019). For example, although observation is common to all science disciplines, the precise nature of observation and what counts as evidence may be fairly unique in different fields of inquiry (Yeh et al., 2019). Irzik and Nola (2014) suggested categories that researchers might use to group features of sciences. This categorical structure allows for both domain-general and domain-specific elements to be captured. They defined science as a cognitive system whose
investigative activities have a number of aims that it tries to achieve with the help of its methodologies and methodological rules, and when successful, produces a number of outcomes, ultimately, knowledge (p. 602) cited in (Yeh et al., 2019). The FRA embraces important features of NOS. It tells an inclusive and coherent meta-story about how science works, ranging from its aims and values to practices and knowledge, as well as the social context (Yeh et al., 2019). Scientists’ aims and values may shape their science activities, determine the methodologies they select, and seek societal applications for their work. From an FRA perspective, science is a cognitive-epistemic system (including aims and values, practices, methods and methodological rules, and scientific knowledge), as well as a social-institutional system (including social ethos, social values, professional activities, social certification and dissemination, social organisations and interactions, financial systems, and political power structures) (Erduran & Dagher, 2014).

Although there is some disagreement among philosophers of science about what ideas comprise the nature of science, there is considerable agreement among science curriculum reform documents what NOS views should be included in the curriculum (McComas et al. 2009). More recently, the consensus lists have been criticised for being oversimplified and for not representing NOS as contextual and heterogeneous features of science (Matthews, 2012). Researchers such as (Hodson, 2014; Allchin, 2011; Irzik & Nola, 2014) have called for revisions that would broaden the view of nature of science knowledge, keeping what is relevant from the consensus lists while embracing new concepts of science. The Family Resemblance Approach further consolidates epistemic, cognitive, and social aspects into a holistic model that characterises science as a “range of practices, methodologies, aims and values, and social norms that have to be acknowledged when teaching science” (Erduran & Dagher, 2014, p. 19).

Nature of science

Lederman (1992) argued that the core of nature of science includes the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge. Nature of Science is defined as the nature of knowledge, which is a complex concept involving philosophy, sociology, and history of knowledge (Wardani et al., 2023). Nature of science is the epistemology of science, science as a way to acquire knowledge or values and beliefs attached to scientific knowledge or to the development of science (Abd- El-Khalick & Lederman, 2000; Lederman et al., 2013).

Knowledge about how science works plays an important role in changing people’s views about science. Nature of science is the processes and practices of science (Weisberg & Landrum, 2021). People who have informed the nature of science knowledge may be in a better position to understand the connection between scientific practices and the generation of knowledge (Weisberg & Landrum, 2021).

Thus, an understanding of the nature of science is correlated with increased scientific literacy (Khishfe et al., 2017; Lederman et al., 2002). Nature of science is a component of science literacy that supports critical thinking about science concepts, speaking to how and why science is conducted and connected to creating data and evidence. Nature of science is designed to be more than the standardised lessons of science; it helps children critically analyse and solve real-world and societal issues using scientific knowledge. The interpretation of science varies between the ideology and beliefs of each individual. Given the importance of this idea, it is necessary that teachers be able
to provide NOS opportunities to students; however, first, they must have a firm grasp of the concept (Charupoom et al., 2022).

Nature of science is designed to be more than the standardised lessons of science - it helps children critically analyse and solve real-world and societal issues using scientific knowledge. Science education relies on hard facts and textbook ideas that students may struggle to retain and store the information long-term without developing their science literacy and how they can apply to real-world situations (Lederman et al., 2002).

Science educators and practitioners have agreed on several recognized features of the nature of science, including comprehending the nature of empiricism and the distinction between theories and laws (Provost, Martin, Peacock, Lipp, Bath, & Hannan, 2011). Previous research identified seven key features of the nature of science: (1) tentativeness, (2) theories and law, (3) sociocultural embeddedness, (4) creativity, (5) scientific method, (6) subjective, and (7) empirical base. The empirical aspect is a critical component of NOS (Jumanto & Widodo, 2018). The empirical nature of science is that it is founded on observations of the natural world.

Science can be trusted if its findings are substantiated by observation and empirical data. Simply put, the empirical basis of science means that scientific knowledge is founded on evidence gathered through observation using the five senses and/or experimentation. The empirical part has two signs, namely: (1) Scientific knowledge is founded on evidence collected via observation using the five senses. (2) Scientific knowledge is based on data/evidence collected through experiments (Jumanto & Widodo, 2018), as mentioned in Wardani et al. 2023.

The empirical aspect means that, while knowledge is based on evidence, scientific activity is nonetheless guided by theory, and scientists conduct their research within a specific frame of reference. Second, while scientific research is logical and factual in nature, it also requires creativity and the development of explanation. Third, some knowledge may remain undiscovered because it cannot yet be studied. Fourth, even when not supported by empirical evidence, scientific information can be recognized as true as long as it is developed in an accountable manner (Wardani et al. 2023).

Aspects of the consensus view of nature of science

- Tentative Nature of Scientific Knowledge: Scientific information, including hypotheses, theories, and laws, is subject to change. New evidence, technological advancements, and new interpretations of data can lead to changes in scientific knowledge (Abd-El-Khalick, Bell, & Schwartz, 2002; Çelik, 2020).

- The Empirical Nature of Science: One of the most important characteristics of scientific knowledge is its experimental and observational nature. Science is separated from other disciplines such as logic, mathematics, and theology by its emphasis on experimentation and observation (Lederman et al., 2002; Lederman & Lederman, 2004).

- Observation and Inference in Science: Observation is a scientific talent that is developed immediately through sensation. It is possible that different people's observations agree. The fact that things higher than the ground fell to the ground is an observation, whereas calculating gravity from free fall is an assumption. It is not possible to observe every case directly. Gravity discussions are based on inferences. Inferences require more consensus than observations (Lederman et al., 2002; Lederman & Lederman, 2004).
• The theory-laden nature of science: Scientific knowledge is subjective. Science is a profession that includes art, literature, and philosophy. Scientists may have distinct opinions due to their knowledge, beliefs, and other personal differences. Subjectivity is also required for more innovative scientific research (Lederman et al., 2002).

• Creative and Imaginative Nature of Scientific Knowledge: Scientists apply their inventive and creative thoughts, as well as other personal attributes, to all phases of scientific study. Scientists’ originality is crucial for doing novel research (Lederman et al., 2002; Çelik, 2020).

• The Social and Cultural Embedding of Science: Scientific knowledge is influenced by the social environment and cultural values in which it is created. Science influences both the culture in which it is practiced and the various characteristics of that society. Accepting the concept of a world-centered universe as a necessary religious belief for many centuries demonstrates how science and culture interact. Another example of science-culture connection is the belief that Darwin's explanations for natural species selection were affected by capitalist ideologies surrounding him (Lederman et al., 2002; McComas, 2004).

• Scientific theories, facts, and laws are distinct categories of scientific knowledge. One of the most widespread fallacies regarding NOS is the belief that theories become laws when properly proven. Scientific laws and theories differ in function and structure. Scientific laws are concise descriptions of natural phenomena. Scientific theories explain both scientific principles and connected facts (Lederman & Lederman, 2004; McComas, 2004).

Methodology

Design
Based on the pragmatist’s paradigm, the study adopted a mixed methods approach using a convergent parallel design. In mixed methods designs, the researcher collects and analyses both qualitative and quantitative data rigorously in response to research questions and hypotheses and integrates the two forms of data and their results (Poth, 2023). Mixed methods design involve the collection and analysis of both quantitative and qualitative data, the integration of the two databases in a design, and the drawing of insights from examining the integration (Poth, 2023).

Sample and Sampling Procedure
The sample consisted of ten (10) in-service science teachers purposively selected from four schools in the Kassena-Nankana Municipality. The sample consisted of four chemistry teachers, three biology teachers, two physics teachers, and one integrated science teacher.

Instruments
Two instruments were used to collect data. These are the Empirical and Tentative Views of Nature of Science Questionnaire (ETVNOSQ) and the empirical and tentative views of the nature of science inventory (ETVNOSI). The Empirical and Tentative Views of Nature of Science Questionnaire (ETVNOSQ) consisted of five open-ended questions adapted from (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The views of nature of science questionnaire (ETVNOSI) consisted of ten (16) Likert-type items with two factors: tentative nature of science (3 items) and empirical
nature of science (13 items). Cronbach's alpha reliability co-efficient of the ETVNOSI was determined to be 0.75. The ETVNOSI has five options, which are strongly agree, agree, undecided/neutral disagree and strongly disagree. The questions of the Empirical and Tentative Views of Nature of Science Questionnaire (ETVNOSQ) are:

1. What is science?
2. What is an experiment?
3. Does the development of scientific knowledge require experiments? If yes, explain, if no explain.
4. What is the difference between observation and inference?
5. Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.

Data analysis
QDA miner Lite and SPSS version 26 were used to analyze the data. The quantitative data was analyzed using descriptive statistics like means and standard deviations. The qualitative data was examined using content analysis. In-service teachers’ opinions on the empirical and tentative nature of science were classified as informed or naive using a rubric adapted from (Lederman et al., 2002).

Results
Demographic Characteristics of Respondents
Table 1 shows the demographic characteristics of the teachers. The majority of the teachers (70%) were male, while 30% were female. There were four chemistry teachers, three biology teachers, two physics teachers, and one integrated science teacher. Again, the majority of teachers (60%) had 6-10 years of teaching experience, 20% had 1-5 years, and 20% had 11-15 years of teaching experience.

Table 1. Demographic Characteristics of Respondents

<table>
<thead>
<tr>
<th>Sex</th>
<th>f</th>
<th>%</th>
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<tbody>
<tr>
<td>Male</td>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>30</td>
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<tr>
<td>total</td>
<td>10</td>
<td>100</td>
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<tr>
<th>Subject taught</th>
<th>f</th>
<th>%</th>
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<tbody>
<tr>
<td>Chemistry</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>Biology</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>Physics</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>Integrated science</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>100</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Teaching experience</th>
<th>f</th>
<th>%</th>
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<tbody>
<tr>
<td>1-5 years</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>6-10 years</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>11-15 years</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>total</td>
<td>10</td>
<td>100</td>
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In-Service Science Teachers’ Views of the Empirical Nature of Science

Table 2 presents the means and standard deviations of empirical and tentative NOS scores, and the overall view of NOS score.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>M</th>
<th>SD</th>
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<tbody>
<tr>
<td>Overall NOS score</td>
<td>10</td>
<td>2.81</td>
<td>0.33</td>
</tr>
<tr>
<td>Empirical NOS score</td>
<td>10</td>
<td>2.60</td>
<td>0.31</td>
</tr>
<tr>
<td>Tentative NOS score</td>
<td>10</td>
<td>3.77</td>
<td>0.79</td>
</tr>
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</table>

It was found that in-service science teachers have naïve views of the nature of science (M = 2.81, SD = 0.33). Table 4 presents frequency and percentage of in-service science teachers with informed and naïve views of nature of science. The majority of science teachers (80%) had naïve views, while 20% of the in-service science teachers had informed views.

<table>
<thead>
<tr>
<th>NOS view</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informed view</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>Naïve view</td>
<td>8</td>
<td>80</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>

In-service science teachers exhibited both naïve views on the empirical nature of science (M = 2.60, SD = 0.31) and informed views on the tentative nature of science (M = 3.77, SD = 0.79). Table 5 shows the mean values and standard deviations of the items in the view of the nature of science inventory. Overall, in-service science teachers exhibited naïve ideas about the nature of science (mean = 2.81, standard deviation = 0.33).

They held naïve views on many of the issues, with mean values below 3. However, they had informed views on items such as 'much of the development of scientific knowledge depends on observation' (M = 4.70, SD = 0.483), 'scientists collect data to support their interpretation of the world and there is no one method of doing science' (M = 4.30, SD = 1.05), and 'a theory is an attempt by scientists to explain why nature is the way it is' (M = 4.10, SD = 1.19). Again, the teachers were informed that science is prone to change with new evidence and interpretations of that evidence (M = 4.70, SD = 0.675), and scientific theory is liable to alter and be shown erroneous at any time (M = 4.40, SD = 1.075).

<table>
<thead>
<tr>
<th>sn</th>
<th>item</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Scientists observed facts to prove that theories are true.</td>
<td>10</td>
<td>1.50</td>
<td>.707</td>
</tr>
<tr>
<td>2</td>
<td>Much of the development of scientific knowledge depends on observation.</td>
<td>10</td>
<td>4.70</td>
<td>.483</td>
</tr>
<tr>
<td>3</td>
<td>An experiment cannot prove a theory or a hypothesis.</td>
<td>10</td>
<td>1.40</td>
<td>.516</td>
</tr>
</tbody>
</table>
Science deals with using an exact method so we can duplicate our results. That way, we know we have the right answer.

Laws started as theories and eventually became laws after repeated and proven demonstration.

Scientists are very objective because they have a set of procedures they used to solve their problems.

Scientists collect data to support their interpretation of the world. There is no one method of doing science.

A theory is an attempt by scientist to explain why nature is the way it is.

An experiment just discredits or adds validity to a theory.

A good theory can never be proven correct, but can be shown to be false.

The key difference between science and other enquiries is that science follows a rigid set of rules.

An experiment is a sequence of steps performed in order to prove a proposed theory.

Science is subject to change with new evidence and interpretation of that evidence.

A scientific theory is likely to change and be proven false at any time.

Scientific knowledge is fallible and not reliable.

Science is about facts.

The findings from the open-ended data were identical to those of the quantitative data. Teachers' perspectives on the empirical nature of research were elicited through four questions: what is science? What constitutes an experiment? Is it necessary to conduct experiments to advance scientific knowledge? What's the distinction between observation and inference? On the definition of science, 50% of participants had informed views and 50% had naive views. Science teachers who hold educated opinions properly claim that scientific knowledge is partly obtained by experimentation and observation of nature. The following are extracts from teachers' viewpoints:

'Science is simply a way of obtaining knowledge through observation and experimentation. For instance, simple scientific concepts such as diffusion, evaporation and condensation can be observed' (Case#6, male).

'Science is a study structure, behaviours of both physical and natural worlds through the use of systematic approach of observation, experimentation, testing of theories' (Case#4, male).

'Science is an experimental science that deals with the study of nature and behaviour of natural things and the knowledge we obtain about them' (Case#10, male).

Again, on the definition of science, teachers with naïve views of the nature of science think that scientific knowledge is obtained only through experimentation. The following are excerpts of teachers’ views:

'Science is the method of obtaining knowledge through enquiry and experimentation (Case#3, male).

'Science is the study of laws of nature (Case#9, male).
Science is a process to acquire knowledge and scientific skills to help in observing, formulating hypothesis, getting data, analysing data, and drawing conclusion and inferences (Case#7, female).

Some teachers held the naïve view that there is a systematic, one way of doing science, that is to the myth of the scientific method. For example, one teacher said:

Science is a subject that involves analysing, observation and a systematic way of solving daily life problems (Case#8, female).

On the definition of experiment, 70% of the teachers had naïve views and 30% had informed views. Teachers that held informed views correctly think that an experiment is any procedure or operation that involves manipulation and controlling of variables. The following are excerpts of teachers’ views:

An experiment is any operation conducted by an individual to expect an outcome which cannot be predicted with certainty (Case#6, male).

An experiment is planning and performing procedures in order to get results and make meaning out of the results (Case#7, female).

An experiment is a scientific procedure that involves controlling of variables and manipulation of data to test hypothesis (Case#2, male).

Science teachers with naïve views think that an experiment is a step-by-step procedure, suggesting their belief in the myth of the scientific method, to prove a theory, test hypotheses, make discovery or demonstrate a known fact. The following are excerpts of the teachers’ views:

An experiment is a sequence of steps performed in order proof a proposed theory at any time (Case#8, female).

An experiment is a method, procedure and tools or materials that scientists undertake to make a discovery, test a hypothesis or demonstrate a known fact (Case#4, male).

An experiment is a systematic process or procedure used to discover new knowledge or test hypothesis (Case#3, male).

On whether the development of scientific knowledge requires experiments, 70% of the teachers held naïve views and 30% held informed views. Teachers who held informed views think that experiments add validity to scientific knowledge. They also think that experiments provide evidence to support or refute scientific knowledge. The following are excerpts from the teachers’ views:

Scientific knowledge requires experiments because experiments allow scientists to test their hypothesis and gather empirical evidence to support or refute their ideas, and again help in understanding the underlying principles and mechanism of various phenomena. Scientific knowledge does not depend only on experiments, but also on observation, simulations and theoretical models (Case#2, male).

Yes, experiments help to add validity to a theory (Case#8, female).

The development of scientific knowledge requires experiments because scientific knowledge has to be verified and validated through experiments (Case#3, male).

Teachers who held that naïve views think that experiments are used to affirm a theory or law, justify scientific knowledge or make scientific authentic.
Scientific knowledge requires experiments because when experimental results agree with theoretical results, then the law/theory is affirmed (Case#9, male).

Yes. Scientific knowledge requires experiments because most scientific knowledge can be understood and appreciated better through experiments. For instance, knowledge from acids, bases and salts can be understood better through testing for acids, bases and salts using indicators such as methyl orange and litmus papers (Case#6, male).

Scientific knowledge requires experiments because experiments will make the scientific knowledge authentic (Case#5, male).

Scientific knowledge requires experiments because that is the only means to justify your findings, whether true or false (Case#1, female).

On the differences between observation and inference, 60% of the teachers held informed views and 40% held naïve views. The teachers with informed views think that observation makes use of the senses to gather information, whereas inferences are explanations of observations.

‘Observation is what is seen, felt, heard, or smell from an experiment. For example, blue gelatinous precipitate is an observation when an alkaline is added to a sample containing copper (II) ions, but an inference is an explanation of the observation. For example, the observed blue gelatinous precipitate observed means that copper (II) ions are present’ (Case#6, male).

‘Observation deals with physical features by the use of the senses, whereas inference is an explanation or commentary of observation’ (Case#3, male).

‘Observation is the act of gathering factual information through direct sensory perception, whereas inference is making conclusions (interpretations) based on those observations. Observation deduce a lot of perception, but after the test (experiments) that would bring the exact results (inference)’ (Case#2, male).

‘Observation has to do with viewing objects with the naked eye, whereas inference is drawing conclusions about your views on something’ (Case#1, female).

‘Observation is all about gathering information with the help of your sense in the environment, whereas inference is all about making explanations as to the reasons for the observations. Inference gives meaning to what you have observed’ (Case#4, male).

The teachers with naïve views think that observation is to watch occurrences and ask questions. They also believe that observation is the study of experiments, and the scientific method.

Observation is the study of the experiment with something, whereas inference is a conclusion reached based on evidence of reasoning (Case#8, female).

Observation is a scientific method, whereas inference is a deduction or results through observation (Case#5, male).

To observe means to watch or monitor an occurrence and ask questions, whereas inference is making an evidence of the occurrence or the question been asked (Case#7, female).

Observation is physical whereas inference is intuitive (Case#9, male).

In-Service Science Teachers’ Views of the Tentative Nature of Science

On the tentative nature of science, 90% of the science teachers held informed views, whereas 10% held naïve views. Most of them believe that scientific knowledge is tentative and subject to change. They also think that science is subjective and theory-
laden. Different scientist may conduct experiments and come out with different results. Scientific knowledge may change because the body of scientific knowledge is continually evolving. The following are excerpts from the teachers’ responses:

‘Scientific knowledge may change because most of this knowledge was obtained through observation and experimentation. Different scientist may conduct experiments and come out with different results. For example, knowledge of the atomic structure has changed over the years’ (Case#6, male).

‘Scientific knowledge may change because the world evolves with a lot of changes in it. For example, before the invention of the haematological analyser for blood analysis, doctors were using ordinary observation and past to determine whether one is short of blood’ (Case#4, male).

‘Scientific knowledge may change because scientific knowledge shows that humans (power resources) are needed at all times to carry out activities in order to improve productivity with the use of some machines, but this man power can change or diminish when robots (artificial intelligence) are considered faster and bring accurate results and increase productivity over the time been as compared to human resources. So the idea that human resources is important than machine will be disproved as time goes on’ (Case#7, female).

‘Scientific knowledge may change because an experiment can be conducted and discredit or add validity to a theory’ (Case#8, female).

‘Scientific knowledge may change because the body of scientific knowledge is continually evolving. Example, from J. J Thompsons primitive experiment to today’s large hadron collider proves that science has indeed come a long way’ (Case#10, male).

‘Scientific knowledge may change because nature is dynamic and behaviour change with time and already known facts will be questioned. For example, the earth was initially considered being the centre of the solar system until Galileo Galileo discovered it was the sun that is the centre of the solar system rather (Case#9, male).

‘Scientific knowledge may change because of new science observation and societal needs. When there is a new discovery, changes can be made in the old scientific knowledge’ (Case#3, male).

‘Scientific knowledge may change because science is not static but dynamic. Knowledge can indeed change in the future because knowledge is constantly evolving as new discoveries are made. For example, in the past, the earth was believed to be flat, but now the earth is said to be round. Again, spontaneous creations talk about meat begot maggot, but now scientists proved that maggots are the larva hatched from the egg of housefly’ (Case#2, male).

Discussion

It was found that in-service science teachers held naïve views of the nature of science (M = 2.81, SD = 0.33). The majority of in-service science teachers (80%) held naïve views, whiles 20% of the in-service science teachers held informed views. The study found that in-service science teachers had naïve views of the empirical nature of science (M = 2.60, SD = 0.31). However, they held informed views on the tentative nature of science (M = 3.77, SD = 0.79).

The findings of this study are congruent with those of previous investigations. Charupoom et al. (2022) discovered that most in-service middle school instructors had a naïve knowledge of the nature of science. The study indicated that most teachers had a limited understanding of the empirical nature of science.
Carter, Thomas & Vo (2022) discovered that 69.5% of in-service instructors had a naive understanding of the tentative nature of science.

In an examination of students' and teachers' understandings of science, Cofré et al. (2019) found that most secondary school instructors maintained naive ideas, such as believing that scientists utilize a universal scientific method based solely on experiments. This study's findings on the empirical nature of science differ from those of Cofré et al. (2019), who found that the most understood element of science is that it is founded on empirical facts.

Tairab (2001) reported that a third of in-service science instructors (35·2%) held the naive belief that science is a methodical investigative process, which is consistent with this study's findings. Similarly, they held the naive assumption that science is a corpus of information explaining the world (Tairab, 2001). 24.1% of in-service science instructors maintained static perspectives about scientific knowledge. They also agreed that science is a corpus of knowledge that explains the world and that the goal of scientific inquiry is to acquire as much evidence as possible (Tairab, 2001).

Furthermore, Buaraphan (2013) discovered that many of the teachers (28.77%) believe that science demonstrates reality through experiments. Nearly half of the participants (40.65%) felt that scientific experimentation is a method of proving realities (Buaraphan, 2013). Almost all participants (93.79%) agreed that experiments are necessary for the creation of scientific knowledge. Buaraphan (2013), on the other hand, discovered that 10.14% of participants had a clear comprehension of science as both knowledge and a process.

In a study of the nature of science as seen by science teachers, Saif (2016) discovered that the majority of science instructors had an incorrect belief that the scientific method is a fixed step-by-step process. Again, Saif (2016) discovered that participants disagreed with the notion that science and the scientific method can solve any question. The majority of participants held the incorrect belief that scientific knowledge could only be obtained through experiments (Saif, 2016).

Mudavanhu and Zezekwa (2017) found that in-service teachers learning History and Philosophy of Science had a limited understanding of the empirical nature of science and believed that scientists always used the scientific method to design experiments. Torres and Vasconcelos (2020) discovered that only one respondent (11.1%) had an informed opinion about the empirical basis of scientific knowledge. The majority of respondents stated that science is founded on facts and concrete objects, emphasizing the importance of experiments in the advancement of scientific knowledge. However, when asked if there is a single scientific approach, the majority of respondents (66.7%) acknowledged that there are various ways to conduct science prior to the intervention plan (Torres & Vasconcelos, 2020).

Similar to the findings of this study on the tentative nature of science, Tairab (2001) discovered that the majority of in-service science teachers saw scientific knowledge as a product of scientists' perspectives and ideas interpreted from the past, which supports the tentative nature of scientific knowledge. Buaraphan (2013), in a study on in-service science teachers' common understanding of the nature of science, found that the majority of participants (89.60%) believed that scientific ideas could be revised. Sixteen percent (16%) of teachers said the key cause for change was the finding of fresh developing facts or proof.
Mudavanhu and Zezekwa (2017) discovered that teachers believe that scientists develop theories that change with new data, and that "scientific theories change with new ways of looking at old evidence". In-service teachers have a well-informed perspective on the function of observations in scientific knowledge production. The majority of participants say that scientists always follow the scientific method to develop experiments. In a study to investigate science teachers' perspectives on the nature of science and the consequences of their pedagogical content knowledge, Chuene and Singh (2024) reported that some educators disagreed with the premise that science is subject to change. The teachers believed that once knowledge was tested and proven, it could not be changed in light of new knowledge.

Conclusion

In-service science instructors exhibited naive ideas on science. The majority of in-service science teachers have simplistic beliefs about the nature of science. The study revealed that in-service science instructors had a naive understanding of the empirical nature of science. They did, however, have informed opinions about science's uncertain character. Science teachers' perspectives on the nature of science are crucial to the formation of scientifically literate students.

According to research, teachers are more successful in teaching the nature of science when they are well prepared to do so; thus, their perspectives on the nature of science should be established at the pre-service teacher education stage. Science instructors' perspectives on the nature of science can be improved by incorporating history and philosophy of science (HPS) courses into teacher preparation curricula, as well as explicit, reflective, and contextual instructional approaches. Science teachers' misconceptions about the nature of science can impact overall scientific literacy. This is because they are likely to influence students' attitudes about science, student learning, and their choice of science for future study. Again, this understanding has consequences for teaching science through inquiry and determining what science knowledge is essential for scientific literacy. Effective inquiry teaching necessitates that science teachers comprehend the essence of science (Clough 2000).

Research and development activities aimed at assisting science teachers in developing deep, strong, and integrated understandings of science would enable teachers to effectively teach science and engage in scientific practice that is consistent with the history, philosophy, and sociology of science. It will also assist teachers in creating robust inquiry learning environments that mimic actual scientific practice, as well as implementing successful pedagogical approaches that share features with the finest science teaching practices (teaching with NOS) (Abd-El-Khalick, 2013).

Conflict of Interests

The authors have No conflict of interest.

References


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