Malaysian In-Service Science Teachers' Conception of Nature of Science (NOS)

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Abstract: Nature of Science (NOS) has been enumerated as one of the important elements in education because robust conceptions of NOS is essential for individuals to be considered as scientific literate. As teachers are vital in imparting sound NOS conceptions to their students, they must possess sound NOS conceptions. However, studies have shown that teachers only possess naive conceptions of NOS which could be potentially passed down to their students during science instruction. So far, studies about in-service science teachers' conception on NOS were conducted in the West. The extensive literature search that was conducted on several renowned platforms found that the existing research available to the public focused on secondary school students or pre-service teachers but not in-service teachers. The conduct of this study bridges the gap in literature and informs relevant stakeholders about the current state of science education in Malaysia. This study shares the findings of a survey conducted with 33 in-service public school science teachers in Selangor, Malaysia. Results show that most teachers possess mixed conceptions about NOS. This study has implications on informing relevant stakeholders about the need of including NOS as a part of teacher training programmes and the need to conduct training sessions with in-service science teachers on NOS.

Keywords: Nature of Science (NOS), Nature of Science (NOS) Conceptions, In-Service Science Teachers

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Introduction

Global advancements are occurring every single day. Scientific and technological breakthroughs have continued to allow access to a wide range of knowledge. This creates the necessity for individuals to be scientifically literate to make informed decisions for the benefit of all citizens around the globe.

"Science should be regarded as a basic human right around the globe" (Maqbool et al., 2014, p.2). Science has gained more global attention over the years. Findings show that many countries have begun to place a greater emphasis on students achieving scientific literacy as their curriculum goals. For instance, United States of

America (Fortus et al., 2022), New Zealand (Bull et al.,2010), Singapore (Vinodhen, 2020), Thailand (Yuenyong & Narjaikaew, 2009) and many more including Malaysia (Mohd Syafiq Aiman Mat Noor, 2021).

Teachers play a crucial role for this goal to be achieved. Teachers were identified as the most prominent factor that contributes to learning in the classroom (Demirdogen et al., 2015). Hence, it is important for teachers to have profound Nature of Science (NOS) conceptions. This is because NOS education is essential for scientific literacy and an informed populace (Höttecke & Allchin,2020). It is clear that one cannot teach what they do not know. This study aims to investigate Selangor lower-secondary in-service teachers' NOS conceptions. Investigating Malaysian in-service science teachers' NOS conceptions is the first step in ensuring that NOS is taught in Malaysian classrooms.

So far, studies about in-service science teachers' NOS conceptions were conducted in the West. The extensive literature search that was conducted on several renowned platforms such as ResearchGate, Academia and many more, did not yield results to Malaysian in-service teachers' NOS conceptions. Moreover, it was found that the existing research available to the public focused on secondary school students or pre-service teachers but not in-service teachers. The conduct of this study bridges the gap in literature and informs relevant stakeholders about the current state of science education in Malaysia.

Nature of Science (NOS)

Nature of Science (NOS) is a hard to define concept. In the past years, researchers and philosophers have been debating on what NOS constitutes but have not reached consensus on a unified definition for NOS. The definitive list of the NOS tenets that will be wholly accepted by all does not and will not exist (Lederman & Lederman, 2019).

To explain it further based on Constructivism, "Constructivists believe that human learning is self-constructed where learners build new knowledge upon the foundation of previous learning" (Jain et al., 2013). Individuals actively develop their own perception of the universe based on their interactions with others and their surroundings. There will be a difference in the researchers and philosophers' point of view on what NOS constitutes.

Notwithstanding the difficulties in defining NOS, philosophers and educators agreed that pupils must comprehend these aspects of NOS, as delineated by Lederman et al. (2002) which includes:

> **The Empirical Nature of Scientific Knowledge Science** is at least partially based on observations of the natural world, and ''sooner or later, the validity of scientific claims is settled by referring to observations of phenomena'' (AAAS, 1990, p. 4). However, scientists do not have direct access to most natural phenomena. Observations of nature are always filtered through our perceptual apparatus

and/or intricate instrumentation, interpreted from within elaborate theoretical frameworks, and almost always mediated by a host of assumptions that underlie the functioning of scientific instruments (Lederman et al., 2002, p.499).

Observation, Inference, and Theoretical Entities in Science. Students should be able to distinguish between observation and inference. Observations are descriptive statements about natural phenomena that are directly accessible to the senses (or extensions of the senses) and about which observers can reach consensus with relative ease. For example, objects released above ground level tend to fall to the ground. By contrast, inferences are statements about phenomena that are not directly accessible to the senses. For example, objects tend to fall to the ground because of gravity. The notion of gravity is inferential in the sense that it can be accessed and/or measured only through its manifestations or effects, such as the perturbations in predicted planetary orbits due to interplanetary attractions, and the bending of light coming from the stars as its rays pass through the sun's gravitational field. An understanding of the crucial distinction between observation and inference is a precursor to making sense of a multitude of inferential and theoretical entities and terms that inhabit the worlds of science. Examples of such entities include atoms, molecular orbitals, species, genes, photons, magnetic fields, and gravitational forces (Hull, 1998, p. 146) (Lederman et al., 2002, p.500).

Scientific Theories and Laws. Scientific theories are well-established, highly substantiated, internally consistent systems of explanations (Suppe, 1977). Theories serve to explain large sets of seemingly unrelated observations in more than one field of investigation. For example, the kinetic molecular theory serves to explain phenomena related to changes in the physical states of matter, the rates of chemical reactions, and other phenomena related to heat and its transfer. More important theories have a major role in generating research problems and guiding future investigations. Scientific theories are often based on a set of assumptions or axioms and posit the existence of nonobservable entities. Thus, theories cannot be directly tested. Only indirect evidence can be used to support theories and establish their validity. Scientists derive specific testable predictions from theories and check them against tangible data. An agreement between such predictions and empirical evidence serves to increase the level of confidence in the tested theory. Closely related to the distinction between observation and inference is the distinction between scientific theories and laws. In general, laws are descriptive statements of relationships among observable phenomena. Boyle's law, which relates the pressure of a gas to its volume at a constant temperature, is a case in point. Theories, by contrast, are inferred explanations for observable phenomena or regularities in those phenomena. For example, the kinetic molecular theory serves to explain Boyle's law. Students often (a) hold a simplistic, hierarchical view of the relationship between theories and laws whereby theories become laws depending on the availability of supporting evidence; and (b) believe that laws have a higher status than theories. Both notions are inappropriate. Theories and laws are different kinds of knowledge and one does not become the other. Theories are as legitimate a product of science as laws (Lederman et al., 2002, p.500).

The Creative and Imaginative Nature of Scientific Knowledge Science is empirical. The development of scientific knowledge involves making observations of nature. Nonetheless, generating scientific knowledge also involves human imagination and creativity. Science, contrary to common belief, is not a lifeless, entirely rational, and orderly activity. Science involves the invention of explanations and theoretical entities, which requires a great deal of creativity on the part of scientists. The leap from atomic spectral lines to Bohr's model of the atom with its elaborate orbits and energy levels is an example. This aspect of science, coupled with its inferential nature, entails that scientific entities such as atoms and species are functional theoretical models rather than faithful copies of reality (Lederman et al., 2002, p.500).

T**he Theory-Laden Nature of Scientific Knowledge**. Scientific knowledge is theory-laden. Scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, experiences, and expectations actually influence their work. All these background factors form a mindset that affects the problems scientists investigate and how they conduct their investigations, what they observe (and do not observe), and how they interpret their observations. This (sometimes collective) individuality or mindset accounts for the role of theory in the production of scientific knowledge. Contrary to common belief, science never starts with neutral observations (Popper, 1992). Observations (and investigations) are always motivated and guided by, and acquire meaning in reference to questions or problems, which are derived from certain theoretical perspectives (Lederman et al., 2002, p.501).

The Social and Cultural Embeddedness of Scientific Knowledge. Science as a human enterprise is practised in the context of a larger culture and its practitioners are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion. Telling the story of hominid evolution, which is central to the biosocial sciences, may illustrate how social and cultural factors affect scientific knowledge. Scientists have formulated differing storylines about hominid evolution. Until recently, the dominant story was centred on the man-hunter and his crucial role in human evolution (Lovejoy, 1981), a scenario consistent with the White male culture that dominated scientific circles until the early 1970s. As feminist scientists achieved recognition in science, the story about hominid evolution started to change. One story more consistent with a feminist approach is centred on the female gatherer and her central role in the evolution of humans (Hrdy, 1986). Both storylines are consistent with the available evidence. Myth of The Scientific Method One of the most widely held misconceptions about science is the existence of the scientific method. The modern origins of this misconception may be traced to Francis Bacon's Novum Organum (1620/1996), in which the inductive method was propounded to guarantee ‘‘certain’’ knowledge. Since the 17th century, inductivism and several other epistemological stances that aimed to achieve the same end (although in those latter stances the criterion of certainty was either replaced with notions of high probability or abandoned altogether) have been debunked, such as Bayesianism, falsificationism, and hypothetico-deductivism (Gillies, 1993). Nonetheless, some of those stances, especially inductivism and falsificationism, are still widely popularised in science textbooks and even explicitly taught in classrooms. The myth of the scientific method is regularly manifested in the belief that there is a recipelike stepwise procedure that all scientists follow when they do science. This notion was explicitly debunked: There is no single scientific method that would guarantee the development of infallible knowledge (AAAS, 1993; Bauer, 1994; Feyerabend, 1993; NRC, 1996; Shapin, 1996). It is true that scientists observe, compare, measure, test, speculate, hypothesise, create ideas and conceptual tools, and construct theories and explanations. However, there is no single sequence of activities (prescribed or otherwise) that will unerringly lead them to functional or valid solutions or answers, let alone certain or true knowledge (Lederman et al., 2002, p.501).

Myth of The Scientific Method. One of the most widely held misconceptions about science is the existence of the scientific method. The modern origins of this misconception may be traced to Francis Bacon's Novum Organum (1620/1996), in which the inductive method was propounded to guarantee ‘‘certain’’ knowledge. Since the 17th century, inductivism and several other epistemological stances that aimed to achieve the same end (although in those latter stances the criterion of certainty was either replaced with notions of high probability or abandoned altogether) have been debunked, such as Bayesianism, falsificationism, and hypothetico-deductivism (Gillies, 1993). Nonetheless, some of those stances, especially inductivism and falsificationism, are still widely popularised in science textbooks and even explicitly taught in classrooms. The myth of the scientific method is regularly manifested in the belief that there is a recipelike stepwise procedure that all scientists follow when they do science. This notion was explicitly debunked: There is no single scientific method that would guarantee the development of infallible knowledge (AAAS, 1993; Bauer, 1994; Feyerabend, 1993; NRC, 1996; Shapin, 1996). It is true that scientists observe, compare, measure, test, speculate, hypothesise, create ideas and conceptual tools, and construct theories and explanations.(Lederman et al., 2002, p.501) .

The Tentative Nature of Scientific Knowledge. Scientific knowledge, although reliable and durable, is never absolute or certain. This knowledge, including facts, theories, and laws, is subject to change. Scientific claims change as new evidence, made possible through advances in thinking and technology, is brought to bear on these claims, and as extant evidence is reinterpreted in the light of new theoretical advances, changes in the cultural and social spheres, or shifts in the directions of established research programs. Tentativeness in science does not arise solely from the fact that scientific knowledge is inferential, creative, and socially and culturally embedded. There are compelling logical arguments that lend credence to the notion of tentativeness. Indeed, contrary to common belief, scientific hypotheses, theories, and laws can never be absolutely proven irrespective of the amount of supporting empirical evidence (Popper, 1963). For example, to be proven, a law should account for every instance of the phenomenon it purports to describe. It can logically be argued that one such future instance, of which we have no knowledge whatsoever, may behave in a manner contrary to what the law states. Thus, the law can never acquire an absolutely proven status. This equally holds in the case of theories (Lederman et al., p.502).

It could be seen from the NOS tenets that there is an emphasis whereby science is an ongoing process of inquiry. Scientific knowledge that we have now will be subjected to revision. This is due to the fact that Science is dynamic. Medawar (1982) stated that Science is a social enterprise not an "isolated search of the truth" (p.116). Collaboration and communication between different philosophers, researchers and scientists is evitable. These ideas are well aligned with Constructivism which asserts that individuals construct their own understanding of the world by being actively engaged in the learning process and through interacting with others. It can be inferred that the theoretical basis of the seven NOS tenets is Constructivism as it emphasises that it is necessary for individuals to play an active role when constructing scientific understanding. The development of scientific knowledge relies on communicating and collaborating with one another.

Hence, the various lists compiled by other researchers and philosophers are still accepted and used in various studies. Some lists were delineated by drawing consensus between the findings and conclusions of other researchers and philosophers. For instance, the seven NOS tenets delineated by Chen (2006) which will be discussed in Views on Science Education (VOSE) Questionnaire section.

Views of Science Education (VOSE) Questionnaire

This study, however, subscribes to the NOS tenets delineated by Chen (2006) who drew consensus among different researchers including Lederman.

The NOS tenets delineated by Chen (2006) which includes:

Tentativeness of scientific knowledge. On the one hand, scientific knowledge is durable and not easily changed. On the other hand, all scientific knowledge is subject to change. The change could take at least two forms, evolutionary (Popper, 1975/1998) or revolutionary (Kuhn, 1970). New knowledge may arise by refining the old knowledge according to new evidence or interpreting data from a new standard and worldview (Chen, 2006, p.806).

Nature of observation. Observations are theory laden due to the existing possibility of the assumptions and preconceived ideas of the observer (Chen, 2006).

Scientific methods. A universal scientific method is non-existent. Various methods will be applied by scientists when conducting research (Chen, 2006).

Hypotheses, laws, and theories. A hypothesis is generally used to represent an immature theory, a speculative law, or a prediction of experimental results (McComas, 1996). A law is used to express what has been observed and to predict what has not yet been observed (Carnap, 1966/1998). A theory is defined in many ways by philosophers of science (Carnap, 1966/1998; Hacking, 1983; Radder, 2003; Suppe, 1977). In this text, theory is defined as an explanation of phenomena and associated laws according to Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993). Furthermore, scientists create theories and laws to interpret and describe phenomena. Theories and laws are two different types of knowledge. They both have substantial supporting evidence, and one does not become the other (Chen, 2006, p.806).

Imagination. Imagination is a source of innovation. Scientists use imagination, along with logic and prior knowledge, to generate new scientific knowledge. Imagination and creativity are often presented together in documents of science education reforms. However, the pilot study found that students who object to imagination and creativity as aspects of NOS have more doubts about imagination but fewer problems with creativity. Therefore, VOSE focuses on imagination to avoid the mixed results created by these two terms (Chen, 2006, p.806).

Validation of scientific knowledge. This issue focuses on how a theory is accepted by the science community. In principle, the merit of a theory is evaluated based on empirical results. Nevertheless, the science community may also choose a theory by conventions like simplicity and the reputation of the theory's proposers. Furthermore, the norm of the paradigm such as a particular way of practising science, a worldview, and core theories may influence the science community's judgement of competing theories (Chen, 2006, p.806).

Objectivity and subjectivity in science. Scientific knowledge is empirically based. Scientists try to be open-minded and apply mechanisms such as peer review and data triangulation to improve objectivity. On the other hand, personal beliefs, values, intuition, judgement, creativity, opportunity, and psychology all play a role in scientific activities. Additionally, science and scientists are influenced by the society, culture, and discipline in which they are embedded or educated. This subjectivity may be reflected in their observations, interpretations, use of imagination, and theory choice. In this text, subjectivity is used to represent factors other than objectivity and rationality (Chen, 2006, p.806).

The original questionnaire by Chen (2006) consists of a total of 15 questions. Each question in the questionnaire covers different NOS tenets or a combination of NOS tenets. After reviewing the original questionnaire, the researchers decided to extract questions 1 to 9 for the purpose of the research, which is to assess the teachers' NOS conceptions. This decision is in consideration of the relevance of the questions towards the said objectives of the study. Teachers' knowledge on the seven NOS tenets were able to be tested via the 9 questions extracted.

Table 1.NOS Tenets, Philosophical Positions, and Item Number Tested by VOSE adapted from Chen (2006)

NOS Tenets	Position	Items
Tentativeness	Revolutionary	4A

	Cumulative *b*	4B
	Evolutionary *b*	4C
Nature of observations	Theory laden	8A, 8B, 8E
	Theory independent	8C, 8D
Scientific methods	The universal scientific method *b*	9A, 9B, 9F
	Diverse methods	9C, 9D, 9E
Theories and laws	Epistemology	
	Discovered *b*	5A,5B (Theory),6B (Law)
	Invented	5D,5E,5F (Theory),6D,6E (Law)
	Discovered or invented	5C (Theory), 6C (Law)
	Comparison	
	Laws being more certain b	7A, 7B
	Different types of ideas	7C, 7D
Use of Imagination	Yes	3A, 3B
	No *b*	3C, 3D, 3E
Validation of Scientific Knowledge	Empirical Evidence	1A, 1H
	Paradigm	1C, 1F
	Parsimony	1D
	Authority	1E
	Intuition	1G
Subjectivity and objectivity	Subjectivity	
	Parsimony	1D (Actual)
	Authority	1E (Actual)
	Paradigm	1C, 1F, 8A*d*, 8B (Actual)
	Personal Factors	1G, 8Ad (Actual)
	Sociocultural Influence	2A, 2B(Actual)
	Imagination	3A, 3B(Actual)
	Methodology	9D (Actual)
	Neutral	1B (Actual)
	Objectivity	
	No influence of socioculture	2C, 2D(Actual)
	Use no imagination	3C, 3E(Actual)
	Based on experimental facts	5B, 6B, 8D(Actual)
	No influence of personal beliefs	8C (Actual)
	Methodology	8E, 9A, 9B(Actual)
	Overall	1A, 1H(Actual)

Method

This study is a part of a bigger research that examines lower-secondary in-service teachers' NOS conceptions as well as how these teachers integrate their NOS conceptions into practice. The report will focus only on the quantitative data obtained which regards lower-secondary in-service science teachers' NOS conceptions. The instrument adapted for this questionnaire was the Views of Science Education (VOSE) questionnaire by Chen (2006). After reviewing the original questionnaire, the researchers decided to extract questions 1 to 9 for the purpose of the research, which is to assess the teachers' NOS conceptions. This decision is in consideration of the relevance of the questions towards the said objectives of the study.

The questions were then combined into a Google Form with a five-point Likert-scale that can be distributed online to the participants of the study. The questionnaire is available in both English and Bahasa Malaysia (BM), the national language of Malaysia. This allows the participants to answer the questionnaire in their preferred language. The BM version was professionally translated by the Malaysian Institute of Books and Translation to ensure accuracy.

Each question consisted of a main statement and participants were required to rate how much they agree or disagree to the options which represent different philosophical standpoints that is in-response to the main statement using the five-point Likert-scale.

Prior to the distribution of the questionnaire, a pilot test was conducted to ensure the clarity of the questions and also to identify other issues with the questionnaire before putting it into use in the actual study. No issues were identified with the questionnaire during the pilot test.

The study commenced after obtaining the necessary permission to conduct the study. A total of 33 lower-secondary in-service science teachers answered the online questionnaire. Assessing teachers' NOS conceptions is crucial. Inadequate NOS conceptions contribute to misconceptions about NOS.

Teachers are the key players in instilling accurate NOS conceptions to students. Therefore, teachers must have accurate NOS conceptions to teach the right NOS conceptions to students. By answering the questionnaire, data which regard lower-secondary in-service science teachers NOS conceptions can be obtained.

The data collected via the questionnaire were analysed descriptively. Individual results for each participant were calculated. An analysis based on participants' conceptions per tenet was also conducted to provide an in-depth view on participants' NOS conceptions.

Results

As mentioned, the total number of teachers who answered the questionnaire are 33 lower-secondary in-service teachers. The data collected via the questionnaire were analysed descriptively. The mean score of each participant and mean score per NOS tenet were derived.

A total of three categories to provide meaning for the mean scores derived which includes naive conceptions, mixed conceptions, sophisticated conceptions. In the situation when the mean score of a participant falls between 1.00 to 2.50, the participant possesses naive conceptions of NOS. In the situation when the mean score of a participant falls between 2.51 to 3.49, the participant possesses mixed conceptions of NOS. In the situation when the mean score of a participant falls between 3.50 to 5.00, the participant possesses sophisticated conceptions of NOS.

Table 2. Categories determined with indicators and descriptions

Range of Mean Scores	Categories	Descriptions
1.00 to 2.50	Naive Conceptions	Possess mostly naive NOS conceptions
2.51 to 3.49	Mixed Conceptions	Possess some naive and sophisticated NOS conceptions (often equal amounts)
3.50 to 5.00	Sophisticated Conceptions	Possess mostly sophisticated NOS conceptions

A difficulty during the calculation process was whether to include neutral responses, whereby the participants selected “3- uncertain or no comment” as a response to the items in the questionnaire when calculating the overall mean of the participant as well as the mean score per tenet. This is because selecting a neutral response does not necessarily mean that the participant has a naive conception of NOS.

The researchers are of the view that the neutral response from the participant may just indicate that participants do not have knowledge on that area to make a stand or does not want to make a stand. It is unfair to include the neutral response of the participant when calculating the mean score as the mean score calculated will not be an accurate representation of the participants’ NOS conceptions.

Individual Results of Each Participant

Table 3. Overview of Number of Participants in each category

Range of Mean Scores	Categories	Number of Participants
1.00 to 2.50	Naive Conceptions	5
2.51 to 3.49	Mixed Conceptions	24
3.50 to 5.00	Sophisticated Conceptions	4

Out of the 33 participants, 5 participants fall under the category of having naive NOS conceptions, 24 participants fall under the category of having mixed NOS conceptions while 4 participants fall under the category of having sophisticated NOS conceptions. This shows that the majority of the teachers have mixed NOS conceptions.

Mean Score Per Tenet

Table 4. Mean Score Per NOS Tenet

NOS Tenets	Mean	Category
Tentativeness	4.22	Sophisticated
Nature of Observations	2.91	Mixed
Scientific Methods	2.19	Naive
Theories and Laws	3.41	Mixed
Use of Imagination	3.10	Mixed
Validation of Scientific Knowledge	2.41	Naive
Subjectivity and Objectivity	2.78	Mixed

Table 5. Overview of NOS Tenets that fall under each category.

Range of Mean Scores	Categories	Quantity of NOS Tenets
1.00 to 2.50	Naive Conceptions	2
2.51 to 3.49	Mixed Conceptions	4
3.50 to 5.00	Sophisticated Conceptions	1

Out of the seven NOS tenets, only the mean score of Tentativeness falls under the category of sophisticated conceptions. This shows that most participants believe that scientific knowledge is subject to change and science in an ongoing endeavour.

Four NOS tenets which include Nature of Observations, Theories and Laws, Use of Imagination as well as Subjectivity and Objectivity falls under the category of mixed conceptions which means that the participants have a mixture of some naive and some sophisticated conceptions of the tenets.

Based on the results above, it could be seen that the participants have naive conceptions for two of the seven NOS tenets which includes Scientific Methods and Validation of Scientific Knowledge.

Discussion

This study investigates in-service lower secondary science teachers' NOS conceptions in Malaysia. As shown in the findings, most teachers fall under the category of having mixed NOS conceptions. This is similar with the findings of Akerson et al. (2009), Dogan & Abd-El-Khalick (2008), Dumcho Wangdi et al., 2020) and Guerra-Ramos et al. (2010) whereby it was found that naive conceptions and numerous misconceptions were possessed by science teachers. Comparing the results of this study to studies that were conducted locally, such as studies conducted by Eng (2002) and Nyanaseakaran (2004) as cited in Jain & Luaran (2020) have shown that secondary students' conception of NOS is only at satisfactory level. A study by Jain et al. (2013) on pre-service teachers possess partial understanding of NOS and possess several misconceptions of NOS. These findings are similar to the findings of the study. However, it is not surprising that the current results of this study are similar with the results obtained by Jain et al. (2013) which was conducted over a decade ago as limited actions have been taken to educate teachers about NOS.

Studies have shown that NOS conceptions can be improved when NOS issues were explicitly raised during intervention. This is because inquiry sets a suitable context for the development of informed NOS conceptions. Abd-El-Khalick (2012) suggests that it is important for an opportunity to reflect about the inquiry experience as it is the core for an individual to develop a sound NOS conception (explicit-reflective approach). Didactic and implicit teaching is ineffective in the development of sound conceptions of different aspects of NOS (Lederman & Lederman, 2019). A study by Kelly & Duschl (2002) states that NOS is learned, like language, by being part of a culture which cannot be taught directly. Kelly & Duschl (2002) findings support the findings of Abd-El-Khalick (2012) as well as Lederman & Lederman (2019).

As mentioned, the current educational goal of Malaysia is to achieve scientific literacy and the key players that determine the success of this goal are the teachers. It is important for teachers to have sophisticated NOS conceptions as the naive NOS conceptions of teachers may be passed down to their students during science instruction. If these naive conceptions were passed down by the teachers and are not challenged, future generations will also possess naive NOS conceptions.

This study has implications on informing relevant stakeholders about the need to include NOS as a part of teacher training programs and the need to conduct training sessions with in-service science teachers on NOS. This study also identified the tenets that need reinforcements which may help in determining the focus of the development of the training programs with pre-service and in-service science teachers.

Conclusion

Table 3, Table 4 and Table 5 show the findings of the study. The findings above show that most teachers have mixed NOS conceptions. This shows that immense efforts are needed to enhance teachers' NOS conceptions.

Inaccurate NOS conceptions should be properly addressed. This is to ensure that Malaysia's current educational goal of achieving scientific literacy could be met. As teachers have inaccurate NOS conceptions, these “NOS conceptions” may be passed down to their students which distance the future generations of Malaysia from the nation’s educational goal.

Recommendations

This study reveals that Malaysian lower-secondary in-service teachers NOS conceptions. On this basis, it is prudent to look at teachers’ practices and teachers’ pedagogical content knowledge in integrating NOS in science instruction.

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