Conceptualising Scientific Theory-Law Relationship among Pre-Service Teachers with Different Academic Abilities in Science

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Abstract: For learners to achieve science literacy and become effective citizens who can make informed judgement on science-related issues in their daily lives, many studies have called for robust understanding of Nature of Science (NOS) among science learners. This study echoed the same sentiment, focusing on an aspect of NOS- the relationship between scientific theories and laws, among first year pre-service teachers. In this phenomenographic study, 10 participants were involved to address two research questions, which are (1) What are the varied ways first-year pre-service teachers experienced NoS, specifically pertaining to the relationship between scientific theories and laws? (2) What is the variation in conceptions held by first-year pre-service teachers about the scientific theory-law relationship based on their academic ability in science? The findings suggest that the participants still conceptualise science knowledge as an objective epistemology, with 2 main categories of how theory-law relationship can be conceptualised. It was also found that there is no difference in terms of conceptualising these NOS aspects among participants of different academic science abilities. This paper also discusses the findings in relation to the current literature and provides some implications to the teacher preparatory programmes.

1. Introduction

The understanding of science and the understanding about science are the pillars of science education. For example, in a study in Turkey, the Science curriculum published by the Ministry of National Education (MoNE) in Turkey in 2018 consists of assessment-evaluation approach, area specific skills, content knowledge, and general objectives were primarily discussed (Yildirim, Acarli, & Kasap, 2020). Understanding of science refers to the understanding of contents in science, including but not limited to understanding of principles, theories and laws in science. Understanding about science, on the other hand, refers to the understanding of its components, i.e. its purpose, methodology, history, philosophy and sociology of science (Felske, 2000). The present study embarks on the understanding about science, or commonly referred to as the Nature of Science (henceforth NOS in this study).

Perceiving that science as a knowledge constructed by humans provides individuals a sense of belonging and control to encourage active involvements in scientific developments and inquiries. Learners, therefore, should grasp the understanding of science not only limited to science contents, but also the nature of this knowledge. Only adequate comprehension of these two facets of science epistemology can a person have a robust understanding of scientific tenets. In the global aim of science education, understanding NOS has been recognized as a key factor in producing scientific literate individuals.

Being literate in science entails the ability of an individual to be analytical and critical in evaluating daily life issues pertaining to science and making sound judgements that favour the betterment of self, nation and the world. In another word, literacy in science prepares learners in pursuing their individual life with fulfilment. It is after all, the fundamental purpose of education. In the endeavour of increasing science literacy among science learners, it is deem important that students understand the NOS well (Felske, 2000). The NOS has been listed as the first facet to be understood by the learners in order to achieve science literacy and make sense of the world. It is also documented that NOS should be the residue of students' total experiences in learning science in school, suggesting the importance of comprehending NOS in science learning (Keiser, 2010).

1.1 Background of the study

Responding to the importance for individuals to comprehend NOS, there is a large volume of published studies in NOS since the 1950s, which were well summarized by Lederman (2006). Lederman (2006) identified the foci of the previous research conducted generally were a) students' and teachers' conceptions of NOS, b) the curriculum which places emphasis on NOS, c) ways on improving teachers' and students' conceptions and d) the effectiveness of various instructional practices in promoting sound NOS understanding. Although understanding of NOS has been the most consistent element in science education for the past 25 years, Lederman (2006) and Keiser (2010) summarized that the research spanned over 50 years on students' and teachers' conceptions worldwide on various NOS aspects are surprisingly still inadequate.

In Malaysia, there are similar efforts looking into students' understanding of NOS. Most of the studies conducted in Malaysia used the Nature of Science Knowledge Scale (NSKS) developed by Rubba and Anderson (1978) in their research to gauge the understanding of NOS among their subjects of study. A local research with the youngest participants of study was conducted by Nyanaseakaran (2004) in which he revealed that the percent mean score for the overall NOS understanding of Form Five students (17 years old) in a technical school in Perak was 64.1%. Eng (2002) on the other hand, studied the NOS understanding of Lower Form Six students (18 years old) in Kuching and reported that the overall mean score was 53.6%. A survey on the more matured students of pre university students in Kuala Lumpur by Sathasivam (2002) offers a rather similar percentage for the overall mean score understanding of 69.1%. All the three studies provided a somewhat average percentage (over 50%) mean score for NOS understanding using the same instruments, namely Nature of Science Knowledge Scale (NSKS) developed by Rubba and Anderson (1978). Besides that, Low (2000) also reported similar findings with 58.8% of overall mean score understanding from a study with teacher trainees in Peninsular Malaysia, despite the use of a different instrument called Process Oriented towards Science Scale (POTSS). Another research which looked at the understanding of NOS in Malaysia earlier was by Norjaharudeen Mohd Nor (1996), in which he alleged that the in-service teachers in Malaysia possessed "adequate" understanding of NOS through his study using NSKS as instruments. All these studies share a similar conclusion drawn from their findings, claiming that the NOS understanding among their subjects of study were "satisfactory".

However, a recent disclosure from a brief study found that there is a reason to believe that such a claim may not be true in the local setting. An action research investigating the effectiveness of NOS instruction in a local university found through the pre-test, that 94.2% of the pre-service biology teachers felt that theories are the true depiction of the world which provide facts and proof, a substantial 77.8% believed that experiments in science generate proof for theories whereas 55.6% believed creativity and imagination are absent in science to avoid untruthful claims (Jain, Abdullah & Beh, 2013). Through a two-tiered instrument, the participants of the study provided naive views in almost all NOS aspects investigated which led to the conclusion that there is inadequate understanding of NOS among the participants of the study.

The local researches that diagnose various groups' understanding through quantitative design discussed earlier (Nyanaseakaran, 2004; Eng, 2002; Sathasivam, 2002; Low, 2000; Norjaharudeen, 1996) provided contrasting conclusions when compared with the study which used a different instrument. The contradicting summaries of these studies warrant further investigation into the issue of NOS understanding among Malaysians.

1.2 Problem Statement

The brief reviews about studies in the NOS area conducted is based on the heightened need for NOS understanding by all individuals, especially in the local setting. However, the majority of local studies carried out suffered from several drawbacks.

One major shortcoming can be seen through the religious and social differences inherent in the Malaysian culture. The characteristics of Malaysia as a nation comprises of multiracial citizens with Islam as the dominant religion made Malaysia unique. Such uniqueness positioned Malaysia differently when compared with the Western countries such as the United States. However, the NSKS and POTSS were used locally as instruments with erroneous assumption that local respondents understood and interpreted the statements of both instruments in the same way that the researcher understands (Nyanaseakaran, 2004). Previous local studies have overlooked the influence of cultural background- a key factor which is recognised to be influencing individuals' views on NOS (Sutherland & Dennick, 2002; Karabenick & Moosa, 2005). Other than that, NOS understanding of the local participants have been accessed through several aspects focused by the instruments used only. Other fundamental aspects of NOS such as the relationship between theory and law as understood by the participants have been loosely neglected. A better study should consider probing the understanding of other NOS aspects among local individuals, illuminating more understanding about the way Malaysians conceptualize science knowledge. Although a larger body of research worldwide can offer the various ways of how NOS aspects are perceived by individuals in other NOS aspects, there is a need to probe into such understanding in the local setting. This is because the differences in culture and religion as mentioned earlier might contribute to the different ways of how NOS can be conceptualized locally.

1.3 Research Questions

In line with the intended purpose, the research questions of this study are:

a) What are the varied ways first-year pre-service teachers experienced NoS, specifically pertaining to the relationship between scientific theories and laws?
b) What is the variation in conceptions held by first-year pre-service teachers about the scientific theory-law relationship based on their academic ability in science?

2. Literature Review

The Nature of science in Malaysian Science Education

The goal of placing science and technology as one of the prerequisites for economy development in Malaysia is articulated in the National Philosophy of Education, in which education in Malaysia strives to produce individuals who are integrated and holistic in various aspects, namely intellectual, spiritual, emotion and physical (Ministry of Education, 2006a). With these reasons, eleven objectives were tailored to give extra emphasis in inculcating thinking skills among the learners. Among these eleven objectives enumerated, there are two which are specifically related to the elements of NOS (Ministry of Education, 2006a). The objectives are:

> *Second objective: Understand the developments in the field of science and technology.*
> *Tenth objective: Realise that scientific discoveries are the result of human endeavour to the best of his or her intellectual and mental capabilities to understand natural phenomena for the betterment of mankind. (p.5).*

Both objectives entail that acquiring robust NOS helps to develop holistic and well balanced individuals who understand science. The blueprint was designed and developed to cater to the increasing demand of individuals who are able to think and make discerning decisions in the highly modern world. However, there was no available guideline on how to blend in the elements of NOS into the science teaching and learning process. The new blueprint through its curriculum specification only places emphasis on the development of critical and creative thinking, thoughtful learning, the process and scientific skills, manipulative skills as well as inculcating scientific attitudes and noble values among the learners (Ministry of Education, 2006a). The understanding of NOS by the learners, as highlighted in the aim of science education, is somehow expected to be implicitly acquired as an end product of science learning. To produce science literate learners, the blueprints have been meticulously designed in meeting the aims it sought to achieve. However, there is an apparent gap in bridging the theory and practise which hampers these endeavours. According to Rivas (2003), learning climates which encourage the engagement of scientific inquiries and not focusing on the content alone provides the avenue for students to convey NOS misconceptions and construct new knowledge for understanding. A teacher should encourage such learning and convey the idea of the non-absolute nature of science to the students.

2.1 The relationship between scientific theory and law

One of the National Science Teacher Association (NSTA) position statements stated that "laws are generalizations or universal relationships...[which] behaves under certain conditions" (NSTA, 2000, para. 9). In another word, scientific laws describe relationships of variables studied, which were found to have certain properties or patterns. Although the laws in science are not usually questioned about its truth, Cartwright (1983; 1988) alleged that law does not necessarily entail true generalization of the world. She points this out through a classical example of the ideal gas law which is supposed to hold and predict gases' behaviours in 'ideal' and uncommon conditions. The ideal gas referred to is gas which experiences no intermolecular forces and possesses no volume. Although this law was formulated and said to be applied to "ideal" gases only, it is well founded that even normal gas under ordinary conditions conforms very well to this ideal gas law. Thus, the truth of the law is still questionable.

Another factor that contributes to the tentativeness of scientific knowledge is its empirical nature of this epistemology. Empirical nature of science includes two facets which are observation and inference. Observation provides the basis for empirical data through the senses or the extensions of it involving the use of instruments or aids. Through these observations, scientists are able to recognise the existing relationships where patterns emerged (Kosso, 1997). These patterns eventually gained its status as scientific laws if they sustained repeated testing by the scientists. Thus, laws can only express what will and can happen under certain conditions, but do not explain how a phenomenon happens (McComas, 2004). The question of how something happens requires conjectures that go beyond observations which is called inferential explanations. These explanations are regarded as scientific theories once it is well substantiated by other evidence (AAAS, 1990). The kinetic theory of atoms was able to explain the ideal gas law in terms of the movement of the molecules when volume, pressure and temperature changes. All in all, theories and laws in science are two different kinds of scientific claims based on different evidence (Bell, 2006). Both are changeable in the light of new evidence found (Horner & Rubba, 1979).

2.2 Misconceptions in the relationship of scientific theory and law

In contrast to what has been the sound understanding, it is reported that most people believed that theory is able to develop into law when it has been proven (McComas, 1998). McComas's (2004) analysis on 15 American biology books entails a factor that might be causing this issue. McComas revealed that in all the 15 books reviewed, none of the books accurately portray exact views of the terms ``theory `` or"law `` despite ubiquitous explanation on the concepts. In another study, Abd-El-Khalick (2003) investigated the understanding about the relationship between theory and law among 153 college graduates and undergraduates. He inferred from his findings that 90% of the participants agreed that laws are proven and

97% of them felt that there are hierarchical relationships between scientific theory and law. Abd-El-Khalick (2003) inferred from his findings that the understanding of the relationship between theory and law is very naive even among the college and university students. However, a review of literature in the local setting into studies that look specifically into this aspect of NOS revealed that the local students' understanding on the relationship between theory and law in science has been left underexplored.

2.3 NOS across achievements in science

In the literature surveyed, the specific study investigating the relationship between science achievement and the understanding of NOS is scarce. However, a study by Philpot (2007) probed into the understanding of eight science Olympiad students' in regards to NOS. Olympiad students are regarded as high ability students in science subjects, who participate in regional and national competitions in the United States. The high achievers perceive learning something new as rewarding and hence, acquire out-of-school experiences in science more than the non science Olympiad students.

Utilizing adapted VNOS-HS (Schwartz, Lederman, & Thompson, 2001), individual interview and focus group interview, Philpot (2007) investigated the participants' understanding based on five aspects of NOS. The study discovered that the science Olympiad students involved have naive understanding about the role of human imagination in science, empirical nature of science and the relationship between theory and law in science. However, the study reported that there is informed understanding on a few aspects, namely the tentative nature of science and the role of inferences in science. From the findings based on the understanding of the participants in Philpot's study, she concluded that "grade and exposure in science have little to do with students' [NOS] understanding" (p. 74). The concluding remark based on Philpot's (2007) study suggests that achievement in science subject does not influence students' NOS understanding.

However, the studies conducted locally by Eng (2002) and Nyanaseakaran (2004) provide a contrasting conclusion from what Philpot has reported and addressed a difference between the understanding of NOS locally and globally. Although both Eng and Nyanaseakaran used NSKS in their studies, they focused on different groups where Eng (2002) investigated the NOS understanding among Form Six students and Nyanaseakaran (2004) probed on the similar NOS understanding among Form Five students. Both studies concluded that there is a significant difference in NOS understanding between the high achievers and low achievers in their overall understanding of NOS. Besides that, it was also reported that the high achievers performed significantly well in the "Developmental" subscale of NSKS when compared with the low achievers, which depicts their understanding that science is tentative.

3. Methodology

With the arguments brought to the fore, it is reckoned that phenomenographic approach is the most suitable methodology for the present study. Phenomenography is used in this study to explore the conceptions of NOS held by the participants as it provides holistic descriptions of the phenomenon under study by capturing a wider range of how certain phenomena can be conceptualized (Bruce, 1997). Phenomenographic studies result in variations of conceptions about how learning was experienced in very descriptive ways (Marton, 1981), which is regarded as suitable in exploring the conceptions of NOS held by learners as experienced by them. In addition to that, constructivism as a theory underlying the current study is best complemented by phenomenography which adopts the interpretivist's perspective due to the similarity in paradigm for both the theoretical and methodological framework of the present study.

Participants in this study are purposefully selected from a university located in Petaling District, Malaysia. The 10 students were matriculation graduates who had just registered for a teacher preparatory programme in July 2019. The respondents were science students during their matriculation years, and they were primarily chosen based on their Matriculation Cumulative Grade Point Average (CGPA). This was an appropriate scale of measurement as matriculation's CGPA for science stream students was calculated by taking into account the science and mathematics subjects only. They were interviewed by researchers, using questions guided by VNOS. They are referred to as pre-service teachers herein, and labelled as M1-M10.

4. Findings

In the effort to establish the rigor of research through its internal consistency (Spencer, Richie, Lewis & Dillon, 2003), the analysis of the data collected were highly centred on identifying the structure of awareness of each response received. Structure of awareness is made up of two parts which are used to describe the different ways NOS aspects as experienced by the subjects of the present study are presented as follows:

a) Referential Aspect
The meaning as attached to the scientific theory-law relationship referred to the researcher by the interviewee when prompted during the interview session. This usually describes the initial response provided by the interviewee when the questions about the scientific theory-law relationship were asked.

b) Structural Aspect
The structural aspect details the referential aspect earlier with the elements which are brought to the foreground of awareness when the context of scientific theory-law relationship was asked. The structure are made up of three parts which are a) Theme, which is the focus of the conception when the subject articulate about their experience and thoughts; b) Thematic field; what is directly relevant with the theme but not focused upon when they shared their notions about the scientific theory-law relationship, and c) Margin; subjects' awareness about the context which have indirectly contributed to, but indirectly related to what they have focused upon while discussing about the scientific theory-law relationship. The three different degree of awareness held by the subjects of the present study when conceptualizing certain aspects of NOS were also illustrated in Figure 3.2.

4.1 Categories on the variation of The Scientific Theory-Law Relationship

This aspect intends to gauge the variation in conceptualizing the relationship between scientific laws and theories as experienced by the participants as they learn science. There were two variations that emerged in the way the relationship of theory and law was conceptualized. The findings of the variation are presented as follows.

a) Category 1: Law is More Superior to Theory

- Referential Aspect

When contemplating the relationship of laws and theories in science, law was referred to as having a more superior or higher status compared to theories.

- Structural Aspect

i) Focused Theme

The theme that was brought to the foreground of learners' awareness to be emphasized compared to other themes was the superiority of law. The status of law was higher compared to theories under this category. However, two different elements encompassed this category describing the different structure in which law is more superior. The elements are Hierarchical relationship of theory and law and branched relationship of theory and law.

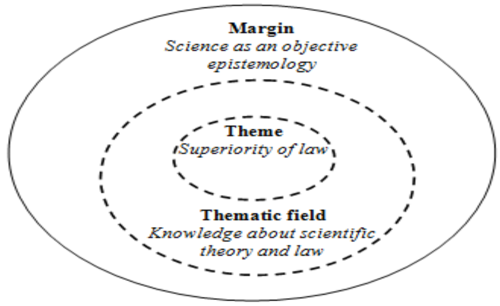

Fig 1: Structure of Learners' Awareness of Category 1: Law is More Superior to Theory

1. Element 1: Hierarchical

The hierarchical element referred to the one-to-one progression from theory to law. The responses grouped under "hierarchical" described scientific theories as tentative, while law as proven and unchangeable. The focus of description here centred on the change of theory that will finally achieve the status of absolute truth such as law. Law, in this element, is a final product of science. They experienced science learning that inferred theory as able to evolve into something more concrete and promising such as laws. They even mentioned that a law will not change as it is a stable idea proven to be true. Therefore, it is no surprise when M1's response suggested that laws develop from theories. He said *"[I feel that] theory is the initial part of law".* In a similar vein, M5 too, indicated the conception favouring scientific laws as proven facts. When asked about their opinion in regards to the relationship between laws and theories, they said

> *" I think law is the final. Law is the foundation of science, the last result. I think it won't change but theory is changing. Like it is real already. But for theory, there are more to be discovered"* (M5)

He felt that theories which are proven and are supported with ample evidence can be upheld as laws. This is because laws "will not change". M6 too, speculated the ability of theory to provide real facts. He felt that theory is prone to change as it is only logic made up by humans in understanding the world. Law on the other hand, is something which has been fixed and believed. M6 said

> *"I think law is more real because theory follows logic and most probably it will change. Law is something which is fixed, therefore it is more believable until now. That's what I understand. As long as there is no research and new discovery that is able to change the theory, maybe it cannot become law".*

M8 seemed quite surprised when questioned by the researcher as the theory-law relationship has not brought him to focus his awareness prior to the interview. He roughly explained his view, saying that

> *"Law? Right, I wonder why I never thought of this...[paused]...I have the idea but I don't know how to explain...it is more or less like a theory, but law is a more stable idea, it is more proven."*

All of the responses discussed above projected a conception in which law is the confirmed claims of nature, governing the world. Theories under this element of focus have been undermined as an unreliable knowledge that requires more evidence in order to be believable. Only when this stage of confirmation has been achieved will theory be regarded as law. Law hence, was regarded as more superior in science.

2. Element 2: Branched

Under this element, law was similarly experienced and conceptualized as more superior compared to theory in science. Students expressed their notions perceiving theories and laws in science developed from the same knowledge construct. To them, a law was more superior compared to theory. However, their responses inferred scientific law as being made up and consisted of multiple scientific theories. Therefore, law is more resistant to change as it needs all the theories to change first before the law can change as a whole. The focus of description in this element was on an orderly structure in scientific knowledge.

M2's explanation inferred the following conception:

> "*Law is…law is fixed. For me it is the end. Maybe combination of theory and theory, then it becomes law, or form new law"*

The conception brought to focus that law is made up of myriad theories, placed it as a more superior entity compared to theory in science. This might be due to the perception that law is a more powerful entity compared to theory, hence giving it control in governing theories.

ii) Thematic Field

When contemplating the status of law in comparison to theory, the immediate context in which the focused theme was based on is the learners' knowledge about the ability for theories to change.

iii) Margin

In the margin of learners' awareness, it was found that the background from which the focal of awareness was derived was the experience of science as a true knowledge. Law in the responses was inferred as an entity which has achieved a stable status in science that has developed from theories or constituted by theory. This was however only peripheral as it was not brought up to the theme of awareness during the interview.

b) Category 2: Law is Different from Theory

- Referential Aspect

The identification of the relationship between theory and law in science is attached to the roles and functions of scientific theories and laws. By attaching such meanings, the theory was regarded as not directly related to law. In other words, law and theory in science are different.

- Structural Aspect

i) Focused Theme

The relationship of theory and law brought to focus was regarded as non-directional as they were perceived as two different entities serving different purposes in science.

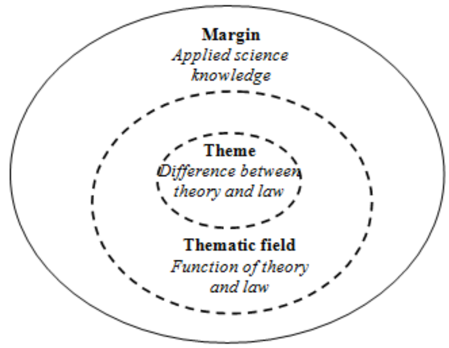

Fig 2: Structure of Learners' Awareness of Category 2: Law is Different from Theory

Theory was reckoned to be different from law because law was made to be readily followed and cannot be changed.

M7 provided a specific account and expressed that law in science involved formula and calculations in dealing with computational problems. Although able to recognise the generalization of laws forming formulas and principles, this particular respondent perceived that theory and law in science were different. This was mainly due to the unapparent presence of theories during calculations of problem solving.

"Laws are more like formulae. It has formulae which solve problems. I feel law will not change, because it is formula, its different" (MR7L)

The absence of direct relationships between law and theory in science were gained from the different ways respondents experienced scientific laws. There were conceptions of reckoning law as formulas for calculations, as the rules governing nature, and also as fixed rules explaining different phenomena compared to scientific theories.

ii) Thematic Field

While contemplating the theory-law relationship in science, a theme that was related but not focused upon was the function of theory and law as they experienced science learning. The experience of learning science provided them with knowledge about the roles that is undertaken by both theory and law in explaining phenomena.

iii) Margin

The margin of the theme brought to awareness while contemplating the relationship of theory and law was their knowledge obtained from their experience during scientific problem solving. The previous problem solving activities in science which use the formula derived from laws were placed at the peripheral of their awareness and to allow the theme of this category to surface while reflecting about the relationship of scientific theory and law.

The variation in conceptions regarding Scientific theory-law relationship according to academic achievement in science

When putting together the analysed responses, it was found that there is no tangible difference in terms of experiencing and interpreting the relationship between theory and law in science.

Table 1: Presence of categories according to academic ability in Science among the participants of this study

Categories		Participants' Science achievement	
		Low	High
Law is more superior to theory	Hierarchical	√	√
	Branched		√
Law is different from theory		√	√

5. Discussion

Referring back to research question one, which is

> "What are the varied ways first-year pre-service teachers experienced NoS, specifically pertaining to the relationship between scientific theories and laws?",

All of the participants in this study perceived scientific law as objective tenets of science. As the conceptions held by students about theory and law in science has been left underexplored, the findings of this study have elicited categories of description in regard to those aspects which may shed some light in understanding the way learners think about this aspect. The categories found under this aspect were

- Law is more superior to theory; with the elements 'Hierarchical' and 'Branched';
- Law is different from theory

An endeavour in understanding these categories of description about the respondents' conceptions of the relationship between theory and law in science were illustrated as in Figure 3.

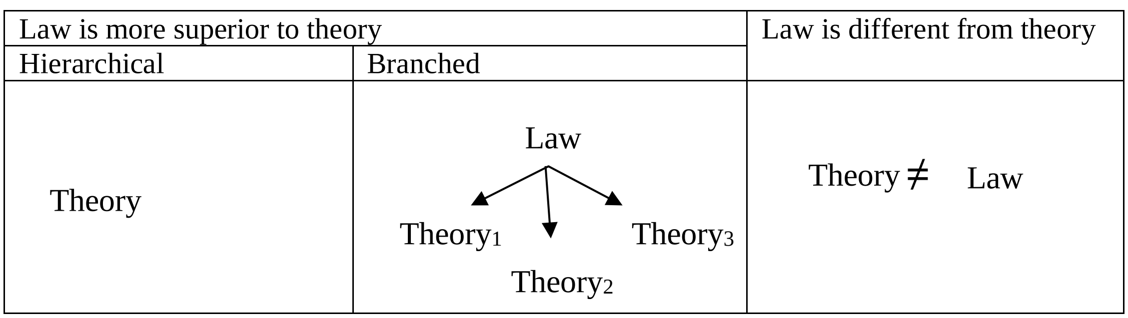

Fig 3: The illustrations of the relationships between scientific theory and law contributed by participants of this study

The responses mentioned that law is the final product of science, which has been improvised and developed from the refined theories. This finding was consistent with McComas's (1998) report about one of the pervasive misalignment among the learners' and experts' understanding in NOS which was the false hierarchical relationship between law and theory. He referred the misconception as "myth" because it was widely misperceived by adults and can be commonly found in science textbooks or learning discourse involving science (McComas, 1998).

Other two categories in this study which were not explicitly found in the literature were the 'branched' and 'law is different from theory' categories. These were the unique conceptions adapted by the respondents in understanding what they have learnt and experienced from science in their surroundings. McComas

(2004) who reviewed the textbooks in the United States suggested the factors to why the students did not hold clear conceptions about the relationship in scientific theory and law. His analysis deduced that none of the fifteen books he reviewed accurately portrayed precise elaborations, explanations or views in regard to what theory and law are. Such fallacies in the textbooks might cause such conceptions among the participants of this study as these books are also being made as the references by the local tertiary students or even local authors in providing the contents for local educational institutes. Although there was no much referral can be made to the local setting as the studies in looking at the content of the local textbooks are scarce, a survey by the researcher on the curriculum specifications in science subject (Ministry of Education, 2006) in the public schools of Malaysia did not emphasize the definition of law and theory as part of learning science. As a result, the students were left to anticipate the meaning of law and theory by themselves and adopt the conceptions which best suit their mental framework. This also explains why more variations of categories were discovered when the educational tiers increased. The richer experiences possessed by the students in the higher tiers provided the "hooks" for them to relate their experiences in learning and develop their own understanding unique to themselves.

Answering research question two, analysis on the categories of descriptions between the higher and lower achiever of science subjects at each educational level found that there is no difference in understanding NOS among the learners despite their achievements in science subjects. This findings concluded differently from other research done locally, where it was previously noted that there is a significant difference between the high achievers and low achievers in their overall understanding of NOS. These contrasting findings warranted a further investigation.

Implications for Teaching and Learning Process

The findings of this study implied that there were vast room of improvements, particularly where it was revealed the aspects of NOS probed in this study are still considered as naive when compared with the accepted views of scientists.

A close scrutiny at the local science curriculum offered an understanding of the possibilities of why the naive conceptions dominate the thinking of the participants of this study. Although the curriculum specification of science learning in Malaysia emphasized discovery learning to be blended alongside the science contents in schools (Ministry of Education, 2006), the features of NOS has not been highlighted explicitly to the learners. Notwithstanding the transformation in approaches introduced by the reform of blueprints in guiding the teaching and learning which changed from "didactic" to "problem-solving" and to the current "inquiry-discovery", it is lamented that the learners' understanding about NOS only received minimal attention and changes.

The deficiency of NOS in the science curriculum in Malaysia does not promote the gradual shift from naive to more informed understanding as the students accumulate more experiences in learning science despite the inquiry-discovery approach. In fact, the way NOS was conceptualized became varied and complicated. It was therefore deemed important for pre-service teachers to be exposed to explicit-reflective instruction of NOS as early as their first year into the programme to equip them with robust views in science. In addition to that, the notions shared by them were developed from a single paradigm and only suggested that the explicit reflective instruction should emphasize the revolutionary development of science knowledge. The teaching of NOS explicitly, with the inceptions of the historical perspectives will enhance the understanding of NOS among the pre-service teachers significantly. It is also prudent to examine the prior conceptions held by learners before any instruction to ensure effectiveness of the intervention to the instructions taken place (Burbules & Linn, 1991). The categories revealed under the aspects probed in this work were able to provide insights to the various ways students think about NOS and subsequently help in designing courses suitable for learners.

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