An Innovative Approach to Teaching and Learning about the Nature of Science: Student's Learning Outcomes

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ABSTRACT

This paper is based on the author's classroom experience. It looks into the content and the methodology used in the classroom for SCE500- Nature of Science (NOS), a course for pre-service science teachers. It highlights the innovative and creative elements of the class lessons especially pertaining to the variety of approaches used in the set induction of every class session. These approaches were based on the consensus model of the Nature of Science. Among the approaches were using optical illusions as illustrations of what constitutes observation and the notion that observation is theory laden, using the developmental model of the atom from the historical perspective as illustration for the tentativeness of scientific ideas, using ' magnetic field' as revealed by dusting iron filings around a bar magnet to illuminate the notion that scientific constructs are created by scientists, using specific examples of scientific law and theory in conceptualising the distinction between theory and law in view of the misconceptions harboured by students that theory with sufficient evidence will become law, and, using the duality of light as particles and waves to illustrate the possibility of multiple theories for a particular set of data. The paper also highlights the eight misconceptions of NOS commonly found among students and the effectiveness of the course in addressing these misconceptions based on students' course feedback and the quantitative data obtained before and after the course using an inventory designed by the author to gauge students' conceptual gain in the eight aspects of NOS.

Key words: Nature of Science (NOS), innovation, teaching & learning, course outcomes

Introduction

Science literacy emcompasses not only knowing about science content, but also about science in accordance with the current science education reform definition. For example, in the USA science literacy has been defined as having six domains: Concept, Process Skills, Application, Attitude, Creativity and Nature of Science as stated in the Iowa Assessment Handbook (Enger & Yager 1998). Nature of Science illuminates how scientific knowledge has developed and the roles scientists have played in this process. These are two fundamental aspects considered essential for students to learn. In tandem with the reform in science education, the subject SCE500-Nature of Science (NOS) has been included among the science based core subjects in the curriculum for pre-service science teachers. It is mandatory for all students majoring and minoring in science. However, in Malaysian schools, it is a common practice that teaching science focuses mainly on knowing science content and NOS has not been addressed explicitly. This has resulted in school students, even science based ones, harbouring misconceptions about NOS when entering our science education programs at a higher level.

The Nature of Science

The Nature of Science has many facets. The realist sees science as a discovery process, the constructivist sees science as a human construct and the instrumentalist sees science for its utility. Issues regarding the nature of science are not settled because of its complexity and its relation to context (Clough, 2007). However, science education reform documents such as *Science for All Americans*, AAAS 1990 have reached a consensus about the following non-controversial views of the nature of science as summed up by Liang, et al. (2008). In brief, the views are:

- Scientific knowledge is tentative but durable and reliable,
- Observation and inferences are guided by scientific theories,
- Science strives to be objective but subjectivity is inevitable,
- Science involves both creativity and rationality,
- Science as a human endeavor is subject to the influence of society and culture,
- Scientific theories explain scientific laws and theories do not become laws with additional evidence, and
- Scientific methods generally include analysis, hunches, speculations, experimentations and investigations.

However, research concerning students' understanding of NOS reveals that students, even the science based ones, harbour some general misconceptions when confronted with the notion of NOS.

Misconceptions of Nature of Science

Studies in students' conceptions of NOS abound. Among these studies, many have used the diagnostic tool designed by Lederman known as the Views of Nature of Science Form C (VNOS-C) for example Parker, Krocker, Lasher-Trapp & Eichinger (2008) using American students, and Tan and Boo (2003) using Singaporean pre-service teachers or its modification such as Lin, Chiu & Chou (2006).) The common findings from these studies were:

- Experiments in science confirm scientific ideas,
- Scientists use their imagination at the early stage of investigation only,
- Science provides explanations with facts and proofs,
- The content of scientific texts is certain facts,
- Theories become laws with sufficient evidence,
- Hypothesis-experiment-conclusion is the scientific method used by all scientists,
- The same piece of evidence or data cannot be subjected to multiple interpretations, and
- Scientists are people with "abnormal" behaviour as portrayed in most films.

The information on the accepted characteristics of NOS and the tenacity of misconceptions of NOS among students even after studying science in schools and colleges are important information to guide curriculum review in the teaching of science especially when deciding on the implementation of teaching NOS as a subject. Due consideration needs to be given to the misconceptions of NOS as highlighted by various studies. What follows are the author's views and experience of teaching NOS.

Teaching Nature of Science

There are two possible approaches: the implicit and the explicit to enhance students' understanding of NOS. The implicit approach believes that by "doing science" students will also come to understand the Nature of Science. The explicit approach applies the methodology of instruction based on.elements from the history and philosophy of science which are are used to improve students' view of the Nature of Science. However, research on these two approaches has indicated that the implicit approach has little impact on students' understanding of NOS, while the explicit one has been proven to be better (Lederman, 1998).

Lederman and Abd-El-Khalick (1998) have developed a set of activities with specific learning outcomes pertaining to certain specific aspects of NOS such as the Black-Box, the Real Fossil, and the Young? Old?. The Black-Box seeks to address the distinction between observations and inferences, the role of models and theories in science and creativity in devising scientific hunches. The Real Fossil seeks to help learners realize knowledge in science is partly a product of human inference, imagination and creativity and that there is no single scientific method which is followed in all scientific investigations. As for the Young? Old?, the old woman-young lady picture seeks to help students to understand that scientists' paradigms, resulting from their beliefs, preconceptions, training, experiences and expectations can influence their mind-set in collecting data and interpreting processes. The author has used the old woman-young lady picture as a pedagogical tool with much success in teaching NOS since 2004. The picture has not only been an effective way of showing that scientific observation is theory laden to students but is a sure way of getting students excited about the class. The visual experience with the picture for the first time was definitely an insight. The author would like to share the course content and some of the pedagogical approaches based on the constructivist paradigm in the teaching of NOS for the subject SCE 500.

The SCE500 Experience

The subject SCE 500 -The Nature of Science is a core subject taken by all undergraduates enrolled in the pre-service science teacher program at the Faculty of Education, UiTM. The course content has a philosophical bias and the approach is constructivistically inclined. This approach is deemed appropriate as it ensures the learning outcomes not only pertain to meaningful construction of content knowledge but also to the development of both cognitive and soft skills such as creative and critical thinking, leadership, communicative, presentation, problem solving and research skills. These skills are among the requirements suggested by the Malaysian Ministry of Higher Education in the OBE reform curriculum for tertiary education.

Course Content

In designing the curriculum for Science education program, the explicit approach was used in educating our students regarding the various facets of the Nature of Science. A book, entitled *Reading The Book Of Nature* (Kosso, 1997) was used to guide the students through the philosophical perspectives of the following topics as classified by the author.

- Theory, Hypothesis and Law,
- Theory: External and Internal Virtues,
- Explanation and Truth,
- Confirmation,
- Under determination,
- Observation,
- Blurring the internal-external distinction,
- Coherence and truth,
- Objective evidence, and
- Science and common sense.

The content of each topic can be rather abstract due to the nature of the language used. Hence, before a class embarked on the discussion of the above topics according to the sequence in the book, two chapters from *Science for All Americans*, that is, ”The Nature of Science” and ”The Nature of Mathematics and Technology” were incorporated as an overview. The objectives of the overview were twofold, first to provide a general framework of NOS as a prerequisite for enhancing understanding of the philosophical arguments set in the book, and second, as a complement to the book content where Kosso (1997) did not include explicit discussion. A topic on Religion and Science was introduced as the closure. The main objective was to enable students to internalise what was not science. The closure was executed in a debating mode where the class was divided into two sides, one side would argue the motion of the supremacy of scientific knowledge and the other would defend the supremacy of religious knowledge as the guiding principle in our daily life. The inclusion of religion is in the context of belief in God which is one of the five pillars in the national ”Rukunegara”. What the author hoped to achieve through the debate was realisation among the students of the difference between knowledge in science and knowledge in religion and the importance of these two knowledge as the guiding principles for the development of modern Malaysian society.

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Instructional Approach

The teaching approach was based on the constructivist paradigm where students are given the opportunity to demonstrate their creative and critical thinking skills via presentations, projects and assignments. The paradigm theorizes that learning with understanding is the result of learners active construction or generation of meaning from sensory input via accommodation and assimilation as modelled by Piaget and Kelly. No one can do the learning for the students.

Teachers cannot assume that students' mind is an empty bottle into which they can transfer knowledge directly and fill it up. Learning has to be viewed from the mechanism of knowledge construction and not transmission.

The general guidelines for the weekly 3-hour block session are briefly as follows:

- Students are divided into groups of not more than five each.
- Every week, each group is responsible for sharing the content based on the assigned reading materials. The content is shared via a methodology created by the group after consultation with the instructor.
- The instructor acts as a facilitator.
- Inquiry method that emphasizes the student-centred mode of instruction is applied.
- Students experience cooperative, reflective, and experiential learning.
- There is a focus on creative learning with critical thinking.

To enhance students' conception of NOS, a session called "induction" was incorporated at the beginning for each of the 3-hour block weekly discussion. Students reported in their reflective essay that the inductions were interesting, illustrative, and illuminating. The following are some of the inductions created by students.

Induction 1

Figure 1 Optical Illusion

Source: http://www.moillusions.com/2010/03/lg-phone-detects-up-to-16-faces.html

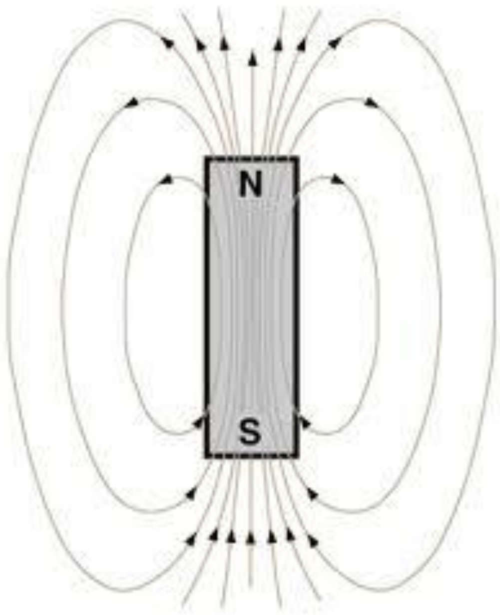
The main objective of using this optical illusion (Figure 1) is to illustrate the followings:

- Science demands evidence to support claims. Evidence is obtained by observations and measurements. In some cases, controlled experiments are done deliberately and precisely to obtain evidence. However, observation is theory laden.
- The role of theory is to enable scientists to make decision regarding what data to look for and what data to ignore. For example, if one is familiar with "a lady's face", one would then be able to see a face prominently in the picture. One sees not only a lady's face but one can recognise or can "see" the eye, the eyebrow, the nose and the mouth although in close examination, the eye and the eyebrow are leaves, the nose is a butterfly, and the mouth is a flower. However, if one is familiar with "flower', "butterfly' and "leaf' one will be able to "see" these entities in Figure 1. A person is able to see the face, the flower, the leaves and the butterfly because he possesses mental constructs regarding these entities. Theory in science is analogous to these mental constructs.

- Science seeks to construct theories to describe nature. As in this case, one can possibly come out with many theories to describe and explain the natural world. This multi perspectives lead to the notion of uncertainty in science and the issue of ”science is about truth” is a fallacy. Science by nature is dynamic, changing, tentative, yet durable.

Induction 2

Students are asked to draw the magnetic field around a bar magnet. Many do not have a problem with the drawing which appears in science textbooks as in Figure 2.



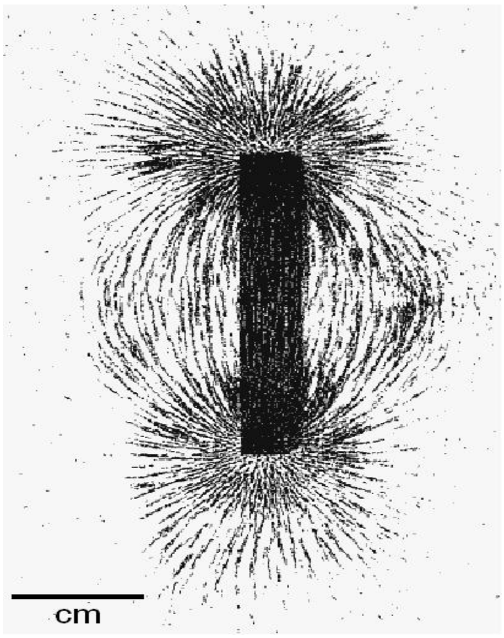


Figure2. Textbook drawing (source: http://www. :hyperphysics.phy-astr.gsu.edu)

Figure 3. Real life image (source: http://www.people.web.psi.ch)

In Induction 2, a bar magnet was placed under a piece of transparent paper on an overhead projector. A student was asked to sprinkle iron filings over the magnet and subsequently, to give the paper a gentle tapping at the edge. The filings traced out a pattern of magnetic field lines in the surrounding space as in Figure 3. Students were intrigued and amazed with the visual image of the formation of the magnetic field pattern. The following questions were subsequently posted to the students:

- Do you see Figure 2 in Figure 3? Where are N and S and the arrow signs in Figure 3?
- Do you see the lines of force in Figure 3?
- Do you think magnetic fields come with lines in its natural setting? If not, how do you get to see the pattern as traced out by the filings?

In the class discussion, relating to the phenomena of magnetic field patterns, the following ideas were introduced:

- This particular pattern is formed by the filings because each tiny iron filing has been induced into becoming a temporary magnet. The iron filings with the magnetic property of ' different poles attract and similar poles repel" align themselves to form lines. The gaps between the lines are due to the repulsive force created between filings that are aligned side by side. The magnetic lines of force is a physics construct invented by scientists. This construct is just a representation of an invisible entity but useful in that it has predictive value.
- As for the labels N and S and the arrow signs which appear in Figure 2, these are conventions agreed by scientists in defining the directions of a magnetic field, that is, the directions indicated by the needle of a compass when it is placed in the field.

The following features of NOS were then introduced:

- Scientific constructs are generated to make the natural world comprehensible and intelligible.

- The constructs do have predictive value. Based on these constructs, for example, we can predict the magnetic field pattern of two bar magnets placed side-by-side.
- Scientific ideas are grounded on agreements among scientists.
- Since ”magnetic lines of force’ is a human construct, it can be subjected to change when a better representation has been created in future.
- What constitute observation is the effect of the unobservable scientific entity and not the scientific entity itself.

Induction 3

Students were requested to carry out the following activity according to the instructions below with reference to Figure 4

Figure 4. Optical illusion (source: http://www.eyetricks.com/jesus.htm)

* 1) Stare at the four little dots in the middle of the picture for 30 seconds.
* 2)Then look at a wall near you.
* 3) A bright spot will appear.

* 4) Wink a few times and you‘ll see a figure.
* 5) What do you see? Or even WHO do you see?

In this sensational experience, students will see a face of an old man in 3D. If they are of Christian faith, they may associate the 3D image with Jesus. This 3D illusion is an effective way for the students to get the message that science gains its believability through observation. However, observation alone is insufficient. This is because our eyes may deceive our mind at times as in the case of Figure 4. The object in Figure 4 is made up of patches of ink mark in two dimension but our eyes see it in the form of a human face in the three dimensional form. This experience hopefully would convince students regarding the message that science is not about truth but is about its explanary power. As has been indicated earlier under the section of Misconception, many students habour the misconception that scientific knowlege is fact with certainly rather than the correct conception that ideas in science are tentative but durable.

Magic Eye, the 3D Illusions series published by N.E. Thing Enterprise in 1994 is another amazing source for similar optical illusions that can be used to similarly illustrate that "SEEING IS BELIEVING“ is necessary but not sufficient in science since hypothetico-deductive method of confirmation is a myth in describing process of science. This leads to Karl Popper‘s proposal that falsification rather than proof is the most crucial phase of the scientific process.

Induction 4

Dalton’s Billiard ball model(1800-1900): An atom is a tiny, hard, indestructible sphere

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Thompson’s “plum-pudding“ model (1856-1940): An atom as a volum of positive charge with electrons embedded through the volum.

⇩

Rutherford’s planetary model of atom(1910)

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Bohr‘ shell model with quantum concept (1913)

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Erwin Schrödinger’s cloud model or quantum mechanical Model based on probability theory (1926)

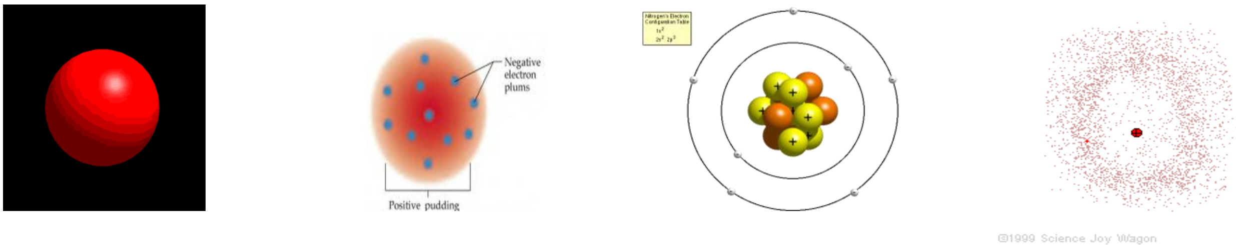


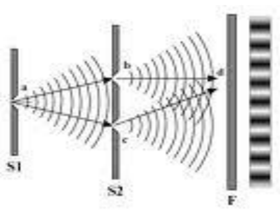
Figure 5. **Models of Atom: Historical perspective (Source:**

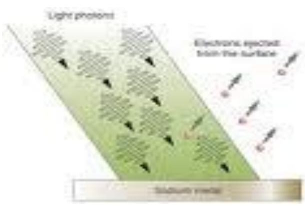
https://www.google.com.my/search?q=Models+of+atom+pictures&hl=en&prmd=imvns&tbm=isch&tbo=u&source=univ&sa=X&ei=inOLT6_dKIHkrAegmrSqCw&ved=0CCMQsAQ&biw=853&bih=570

The chart in Figure 5 shows the historical development of the idea of an atom. The message on the chart hopes to convince students that ideas in science are tentative yet durable. This aspect of the tentative and durable nature of science has been used as the theme for the term paper as well.

Induction 5

Wave Particle Duality in Light





Interference Photoelectric Effect

In the 1600s, Christiaan Huygens and Isaac Newton proposed two competing theories for the behaviour of light. Huygens proposed a wave nature of light while Newton invented a "corpuscular" (particle) theory of light.

Thomas Young's double slit experiment resulted in obvious wave behaviour and seemed to firmly support the wave theory of light over Newton's particle theory.

In 1905, Albert Einstein published his paper to explain the photoelectric effect, which proposed that light travelled as discrete bundles of energy. The energy contained within a photon was related to the frequency of the light. This theory came to be known as the photon theory of light (although the word photon wasn't coined until years later). The photon theory defines the particle nature of light.

So light has wave and particle duality.

The question of whether such duality also showed up in matter was tackled by the bold de Broglie hypothesis, which extended Einstein's work to relate the observed wavelength of matter to its momentum. Experiments confirmed the hypothesis in 1927, resulting in a 1929 Nobel Prize for de Broglie.

So matter has particle and wave duality.

Figure 6. Wave Particle Duality in Light (Source: http://physics.about.com/od/lightoptics/a/waveparticle.htm)

The passage in Figure 6 was shared with students and the following questions were posed:

Do you really think that light can possess two different natures; wave and particle? If de Broglie's hypothesis is right, humans consisting of matter also possess the wave nature. If so, can we go through Young's double slit? This last question always elicited students' laughter.

This reflects the notion that science is not about "truth" but about the power of explanation. Theories generated are introduced to explain natural phenomena such as wave theory for interference pattern and particle theory for photoelectric effect. Science can have multiple theories for a particular scientific entity but the theories need to be congruent with each other. As in this case of light, it is necessary to come out with a new theory of duality to unify the wave and particle theories.

Induction 6

Why do science textbooks name the following as Laws?

- Newton's 3 Laws
- Snell's Law of Refraction
- Boyle's Law

Why do science science textbooks name the following as theories?

- The Kinetic theory of gas
- Charle Darwin's theory of evolution

Figure 7 Laws and Theories

In science teaching, students are seldom asked to make a distinction between the terms law and theory. The questions in Figure 7 are used with this intention.

Research has indicated that most science students hold a simplistic, hierarchical view of the relationship between theory and law, that a theory is elevated to the status of law if the theory is well tested with sufficient supporting evidence(Lederman, 1998).

Lederman (1998, p. 3) offers a clear explanation to differentiate between theory and law.

> "Laws are statements or descriptions of the 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. The kinetic molecular theory, which explains Boyle's law, is one example. Moreover, theories are as legitimate a product of science as laws. Scientists do not usually formulate theories in the hope that one day they will acquire the status of "law." Scientific theories, in their own right, serve important roles, such as guiding investigations and generating new research problems in addition to explaining relatively huge sets of seemingly

unrelated observations in more than one field of investigation. For example, the kinetic molecular theory serves to explain phenomena that relate to changes in the physical states of matter, others that relate to the rates of chemical reactions, and still other phenomena that relate to heat and its transfer, to mention just a few."

Students' Learning Outcomes

In the constructivist classroom as implemented for the subject SCE500, knowing students' misconceptions about NOS and to what extent the subject has effected a conceptual change in students about NOS are essential in the learning outcomes. In this subject, an inventory as shown in Figure 8 (Appendix) has been designed and used for this purpose, that is to gauge students' conceptual change about the Nature of Science after finishing the course. The inventory has been constructed based on the eight common misconceptions as revealed by the work of Parker et al. (2008) with American students, Tan and Boo (2003) with Singaporean pre-service teachers and Lin, Chiu and Chou (2006) with pre-service elementary teachers.

The inventory was administered to 18 undergraduate students before and after they took the subject SCE500. It was administered in class during the December -- May 2011 semester. The students were required to make their responses in the Likert scale of 1-5 where 1 indicates "Strongly agree" to 5 which indicates "Strongly disagree" before (Entrance) and after (Exit) the course. Scales of 1 and 2 indicate students' misconceptions and scales of 4 and 5 indicate students' correct conceptions.

Table 1 shows the average score for each of the eight items in the inventory.

Table1: Entrance-Exit Mean Score

Question	Entrance	Exit
1. Experiments in science confirmscientific ideas.	2.1	3.2
2. Scientists use their imagination at the early stage of investigation only.	2.7	4.0
3. Science provides explanations with facts and proofs.	1.8	3.9
4. The content in scientific texts is certain fact.	2.8	4.2
5. Theories become laws with sufficient evidence.	1.9	4.4
6. Hypothesis-experiment-conclusion is the scientific method used by all scientists.	1.8	2.6
7. The same piece of evidence or data cannot be subjected to multiple interpretations.	3.2	4.5
8. Scientists are people with "abnormal " behaviour as portrayed in most films.	3.9	4.00

Table 1 reveals that before taking the subject, the level of misconception among the students about the Nature of Science was high except for item 8 as most students tended to disagree with the statements. However, after completing the subject, most of the students changed significantly about disagreeing with the statements and acknowleged their earlier misconceptions for item 1 to item 7. However, the change in item 6 was rather small indicating that the misconception regarding the notion of the scientific method had not been addressed convincingly by the subjects or that this notion was too tenacious to change as these students had been trained in writing laboratory reports in a particular sequence starting with a hypothesis since studying science in school. It is interesting to note that before the class, very few students were in disagreement with item 8; only one indicated "disagree" and two were "not sure". However, after the class, these three students maintained their view which was not surprising as the course content did not address this issue explicitly.

The positive improvement in students' understanding of NOS can be substantiated by the course feedback from students. The following is an example of the verbatim feedback by a student of his view about this course.

"Learning the Nature of Science was very interesting to me. It brought a whole new experience. When I was a kid, I used to have a different point of view about science. Science was the truth. Having knowledge of science makes me proud. When we were talking about science, it never disappoints me. Talking about science makes me feel big. I was proud of having scientific mind, scientific method and scientific explanation. Why? Because I though I was at the truth side of everything. I even still remember having the habit of arguing my science teacher before. Being able to come out with arguments that sometimes even my teacher could not answer makes me feel smarter than my teacher. Yet, I never ask myself why they could not answer the question. Not until I am in secondary school. During secondary school, I love to watch Discovery Channel, even until now. They come out with so many convincing facts and scientific knowledge yet sometimes leaves more questions on every show. So I asked myself. If science was the truth, then why sometimes there are still questions to ask. Is the truth itself is not perfect? If science is the truth, why sometimes it is against my religious believe?

All the answer I discover it in this subject. I learn about the nature of theory and law. Not forgetting the internal and external virtue that it has. Then only it answers my entire question. Apparently, science fact is not a truth. Science is always close to the truth but it never touches the truth. However, although it never touches the truth, yet why many people believe in it? In this class I learned the reason why people believe it. It is simply has the power to explain and predict. Curiosity is a human nature. We always ask why and demand explanation about things that happened around us. Science has this characteristic and it suit human nature perfectly. As for predict, human always want to control what is around us. Therefore, if any *changes happen we always want to be prepared for it. Hence, science has the power to predict things that happens, it helps us to adapt to these changes and survive in this world.*

I learn many things in the class. The book itself is the first philosophical book I ever read. So it was quite a challenge to understand it. Not forgetting the content which is quite difficult to understand. Yet with helps from lecturer and friends, I was able to sort thing out and understand the content. Therefore I would like to express my gratitude to all who help me throughout the class. For my group members, thank you to all of you for the endless commitment and support. Thank you also to the lecturer, XXX for the encouragement and the patient in teaching us a quite challenging subject. With the help from you, now I am able to see science in a new different view. Thank you."-by XXXX

Conclusion

Students find SCE500 subject useful and interesting but difficult to digest at times. It is useful because it addresses the issue of what is this thing called science. Before the class, students' ideas about science were very limited. Most students anchor science with specific discipline content such as physics, chemistry or biology that they have studied at school. Some associate science with doing experiments, a unique laboratory experience that the non science couses do not offer. None of the students can offer a glimpse of what science is about, how it operates, the epistemological and ontological foundation of science, how scientists operate in personal and social contexts and how society influences and reacts to scientific endeavours. These features of NOS have not been included explicitly in school science testbooks.

Students love the inductions. They can relate to the messages easily and find the presentations illuminating. However, admittedly, both the text and the content in the book (Kosso, 1977) is hard, abstract and beyond visualisation at times.This is especially so when most of the students do not possess the English language proficiency demanded by the book. Most students require a dictionary to help them while reading the chapters since English is not their mother tongue.

Due to the complexity of NOS, Clough (2007) suggests an innovative idea for teaching , that is making the "tenets" of NOS into questions to embrace such as:

- In what sense is scientific knowledge tentative? In what sense is it durable?
- To what extent is scientific knowledge empirically based (based on and/or derived from observations of the natural world)? In what sense is it not always empirically based?
- To what extent are scientists and scientific knowledge subjective? To what extent can they be objective? In what sense is scientific knowledge the product of human inference, imagination and creativity? In what sense is this not the case?
- To what extent is scientific knowledge socially and culturally embedded? In what sense does it transcend society and culture?
- In what sense is scientific knowledge invented? In what sense is it discovered?
- How does the notion of a scientific method distort how science actually works? How does it accurately portray aspects of how science works?
- In what sense are scientific laws and theories different types of knowledge? In what sense are they related?
- How are observations and inferences different? In what sense can they not be differentiated?

- How does private science differ from public science? In what ways are they similar? (Clough, 2007, p.3)

Investigating NOS as questions rather than ‘tenets’ creates opportunities for addressing issues pertaining to context, conceptual understanding and various philosophical positions. However, this approach may be too challenging and beyond the cognitive ability of most students if NOS is to be introduced at an introductory level. It may be appropriate to be used as a framework for an advanced course in NOS. At the advanced level, students can then relate NOS to the issue of context and complexity of various science disciplines to expose the multi facets of science. The tenets are used to expose the general characteristics of NOS as the foundation to introduce ”special cases” as posted by the questions that have been transformed from the ”tenets”. If the Nature of Science is to be introduced in science in schools, it is likely that the content similar to those in the inductions would be suitable.

Appendix

Name: **Gender:** ☐ Male ☐
Female

Please indicate with a tick (√ *the extent of your agreement with these statements using the following:* ***1***.**Strongly agree 2. Agree 3. Not sure 4.Disagree 5.Strongly disagree**

Please provide a brief explanation for the choice you make.

		1	2	3	4	5
1	**Experiments in science confirm scientific ideas.** Explanation:					
2	**Scientists use their imagination at the early stage of investigation only.** Explanation:					
3	**Science provides explanations with facts and proofs.** Explanation:					
4	**The content of scientific texts is certain facts.** Explanation:					
5	**Theories become laws with sufficient evidence.** Explanation:					
6	**Hypothesis-experiment-conclusion is the scientific method used by all scientists.** Explanation:					
7	**The same piece of evidence or data cannot be subjected to multiple interpretations.** Explanation:					
8	**Scientists are people with "abnormal" behaviour as portrayed in most films.** Explanation:					

Figure 8 Conceptions in Nature of Science

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