The Understanding of the Nature of Science of Form Six Science Students and Common Misconceptions of the Nature of Science Among The Students

by

Eng Guan Guch
SMK St Thomas, Kuching, Sarawak
hwaeng@tm.net.my

ABSTRACT

The purpose of this study was to assess the understanding of the nature of science among form six science students and to identify their misconceptions of the nature of science. The subjects of this study comprised 294 lower six science students from Kuching, Sarawak. The instrument used to measure the understanding of the nature of science was the Nature of Scientific Knowledge Scale (NSKS), while misconceptions of the nature of science were identified from the subjects' responses to the NSKS items. The findings of this study showed that (a) the overall understanding of the nature of science of form six science students was not satisfactory, (b) The overall understanding for the various aspects of the nature of science in descending order was: *Unified, Testable, Creative, Developmental, Amoral and Parsimonious, and (c) a total of 34 common misconceptions were identified from the students' responses in the NSKS. Arising from the findings, some specific implications to the teaching of science were discussed.*

INTRODUCTION

The development of adequate student conceptions of the nature of science has been a perennial objective of science instruction. There is a change in the belief system regarding science education (Meichtry, 1993) from the early 1950s to the 2000s. In the earlier years the concern was to educate future scientists to produce technology, whereas beginning from the early 1980s the concern was to educate citizens to participate in an increasingly scientific and technological world. Scientific literacy for all students thus emerged as a central goal of contemporary science education reform (AAAS, 1989). In particular, an adequate understanding of the nature of science is well recognized as an essential attribute of scientifically literate individual.

The importance of developing students' understanding of the science content as well as the nature of science itself - how science proceeds, how the scientific community decides what to accept and reject, how much faith there is in the large body of scientific knowledge and beliefs which are continuously developing is clearly conveyed in Griffiths and Barry's (1993) claim that "Understanding the substance of science without understanding its construction and limitation must be considered vacuous at best".

Science education in Malaysia has gone through different stages of reforms, and one of the greatest changes is the introduction of the Secondary School Integrated Curriculum (*Kurikulum Baru Sekolah Menengah*, or KBSM in Bahasa Melayu) in 1988. This curriculum emphasizes the development of wholesome individuals who are able to shoulder the nation's vision and aspiration to be a technologically advanced country by the year 2020. To achieve this vision, Malaysian citizens or students need to be scientifically literate so that they could make the right decisions in their everyday lives since more and more decision-making are scientifically and technologically based. Scientific literacy, and hence the understanding of the nature of science by Malaysian students should be of great concern to science educators in the country.

RESEARCH QUESTIONS

The primary objective of this study was to investigate the understanding of the nature of science of form six science students in Kuching using the Nature of science Knowledge Scale developed by Rubba and Anderson (1978). It also sought to identify common misconceptions of the nature of science of the students.

In this study, data will be collected to answer the following research questions:

1. What are the form six science students' levels of understanding of the nature of science in Kuching?
2. What are the form six science students' common misconceptions of the nature of science?

REVIEW OF RELATED LITERATURE

Models of the nature of science

Over the last 40 years, researchers had developed a number of models to interpret ideas and meaning associated with the nature of scientific knowledge and scientific enterprises. For the purpose of this study, the model developed by Rubba and Andersen (1978) is used. This model is developed based on the initial work of Showalter's (1974) scientific literacy definition at The Ohio State University. There were seven dimensions of scientific literacy and the first dimension suggested was the understanding of nature of scientific knowledge. Showalter (1974) listed nine factors under this dimension, i.e., tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic, and empirical. In a preliminary study done by Rubba and Anderson, they found that several of the factors overlapped; therefore a six-factor model of the nature of science knowledge was constructed following the factor-explication used by Showalter. The six aspects of nature of scientific knowledge are summarized in Table 1(see appendix).

Instruments for assessing students' understanding of the nature of science: Nature of scientific knowledge scale

There are a number of instruments reported in the literature that have been applied to measure both students' and teachers' understanding of the nature of science. For this study, the Nature of scientific knowledge scale or NSKS (Rubba and Anderson, 1978) was selected as the instrument to measure the students' understanding of the nature of science. The reliability of the NSKS was assessed with seven samples of students in grade 9 to 16. The alpha coefficients were found to range from 0.65 to 0.89 for the seven samples of students. In addition test-retest reliability was also established with two groups of sample, the Pearson product moment correlation coefficients were r = 0.59 and r = 0.87 respectively.

The NSKS contains 6 subtests and 48 items displayed in a Likert scale format. The six subtests are Amoral, Creative, Developmental, Parsimonious, Testable and Unified. Each subscale comprises of eight items, four positive and four negative, pertaining to each aspects in the model of the nature of scientific knowledge. Thus, in addition to a total score, the NSKS yields scores on each of the subscale. The 48 items are randomly arranged. The NSKS employs a five-point Likert scale. Responses for each NSKS items are scored 5, 4, 3, 2, or 1 for "strongly agree", "agree", 'neutral", "disagree", or "strongly disagree" respectively. Scores are reversed for each negative item. The items of the NSKS are displayed in Table 2, while the item to subscale key SKS is presented in Table 3. .

METHODOLOGY

This was a quantitative research using a questionnaire to collect the data. The students' understanding of the nature of science was measured by the Nature of Scientific Knowledge Scale (Rubba & Andersen, 1978).

The subjects of this study comprised of form six science students from four secondary schools in Kuching, Sarawak. During the time of data collection, the students were at the first year of a two-year pre-university programme. These were the science students who had passed the Malaysian Certificate of Education (or *SPM* in Bahasa Melayu) Examination.

The four schools selected comprised all the secondary schools that offered sixth form science programme in Kuching Division. These schools are School P, School Q, School R and School S. All the lower six science students from the 13 classes in the four schools were used as the subjects of the study.

A total of 294 students, 134 male and 160 female, were involved in the study. At the time of the study, their age ranged from 17 to 19 years old. These students came from both urban and rural areas of Kuching Division.

RESULTS AND DISCUSSIONS

Form Six Science Students' Overall Understanding of the Nature of Science

An aggregate score for the overall understanding of the nature of science was obtained for the students by summing up individual correct responses to the 48 items in the NSKS. The scores of the subjects were then analyzed in terms of percent mean score, standard deviation, minimum and maximum score. Table 3 presents the mean, standard deviation, minimum and maximum scores for the understanding of the nature of science of the form six students.

A mean score of 25.75 (53.6%) was obtained, while the overall score ranged from a minimum of 10 (20.8%) to a maximum of 39 (81.3%) with a standard deviation of 5.22. From the results, it can be said that the overall understanding of the nature of science of the students was not satisfactory as the percent mean score was merely 53.6%. This mean score is lower than that obtained by Lederman (1986) and Sathasivam (2002) for senior high school and pre-university students respectively. Both of the studies used the NSKS to assess students' understanding of the nature of science. In Lederman's study, the overall NSKS mean score for pretest was 67.8%, while the while the overall NSKS mean score in Sathasivam's study was 69.1%.

Form Six Science Students' Understanding of Specific Aspects of the Nature of Science

The samples' understanding to the specific aspect of the nature of science was investigated by using the frequency of students having the correct response of the nature of science for every item in the NSKS. The percent mean score for each of the subscales was obtained by finding the mean of the 8 items in the subscale.

The Amoral nature of science was not well understood by the students as the percent mean score for the overall understanding of this subscale was only 46.6% (see Table 5), which is lower than the overall understanding of the nature of science (53.6%). A high percentage of the students did not understand that scientific knowledge is amoral and that moral judgments can be passed only on man's applications of scientific knowledge, not on the knowledge itself

The percent mean score for the overall understanding of the Creative subscale was 54.3 % and a wide range of level of understanding were exhibited for the items in this subscale. A substantial proportion of the students understood that scientific knowledge expresses the creativity of scientists. On the other hand, most of the students could not see that a scientific theory is similar to a work of art in that they express creativity, they did not believe that scientific theories are not discovered, but created by man. They were not exposed to the fact that laws and theories are not inherent properties of the physical world, but are created by members of the scientific community to explain the physical world. As it was pointed out by Monk (1997) that: "within the last two decades there has been an increasing emphasis on courses that give preeminence to the *processes* of science within science education. Furthermore, the process approach gives the strong impression that scientific investigation is an empirical process, which will lead inexorably to the derivation of the laws of science."

With regard to the developmental nature of science, it was found that the students did not possess a good understanding of the tentativeness of scientific knowledge. The percent mean score for the Developmental subscale is 52.7%, there was a marked disparity of performance among the items in this subscale. A good percentage of the students understood that scientific knowledge is subject to review and change and that today's scientific laws, theories, and concepts may have to be changed in the face of new evidence. On the contrary, most of the students perceived scientific knowledge as error free, flawless and its truth is beyond doubt. They failed to understand that in scientific knowledge there is always exception to the rule and we have to accept the best scientific explanation in spite of it not being applicable in all situations.

The data in Table 5 shows that the percent mean score for the overall understanding of the parsimonious aspect of science was the lowest (33.8%) among the six subscales. None of the items in this subscale was answered correctly by more than 54% of the students; hence the level of understanding was unsatisfactory. The students disagreed that there is a continuous effort in science to develop a minimum numbers of laws and concepts to explain the greatest possible number of observations. Moreover, only a minority of the students knew that scientific knowledge is comprehensive as opposed to specific.

The percent mean score for the Testable subscale was 64.8%, which was higher than the percent mean score for the overall understanding of the nature of science (53.8%). This implied that the students had a moderate understanding of the empirical nature of science. However, the students were not consistent in their understanding. For example, a high proportion of the students knew that scientific laws, theories, and concepts are tested against reliable observations but only 28.6% of the students understood that scientific knowledge needs to be capable of experimental test. As a whole, the results show that the students generally understood that evidence of scientific knowledge has to be replicable and open to public examination.

The unify nature of science was the most well understood aspect of nature of science among the six aspects, with a percent mean score of 71.1%. The findings implied that the students knew that the knowledge produced by the various specialized sciences contributes to a network of laws, theories, and concepts and thus granting science its explanatory and predictive power. In spite of the high scores for most of the items in this subscale, surprisingly many of the students (71.8%) were treating biology, chemistry and physics as different kinds of knowledge. These three science subjects were taught separately to the students in the classroom, as a result the students may realized the unity nature of science but through their everyday experiences in the classroom they tend to treat these subjects as different kinds of knowledge.

With regard to the understanding of the various aspects of nature of science, the ranking for the students' understanding (in terms of percent mean score) in descending order is displayed in Table 5. Table 5 reveals that the highest rank for the six aspects of the nature of science was the Unified subscale (71.1%) and the lowest rank was the Parsimonious subscale (33.8%). The level of understanding, indicated by the percent mean score, for all the subscales is lower than that obtained by Rubba and Andersen (1978), Lederman (1986) and Sathasivam (2002) in their studies with college freshmen, Grade 10 students and pre-university students respectively. However, the understanding of Parsimonious subscale was ranked the lowest in all the four studies. This implies that the parsimonious nature of science was the least understood by all the student samples in the studies.

Form Six Science Students' Common Misconceptions of the Nature of Science

Misconceptions of the nature of science among students were common as it was concluded by various researchers since the 1960s' (Brickhouse, Dagher & Letts, 2000; Cooley & Klopfer, 1963; Griffiths & Barry, 1993; Mackay, 1971; Moss, 2001; Walker, Zeidler & Simmons, 2000). The common misconceptions of the nature of science were operationally defined, as those misconceptions possessed by at least one-third or more (33.3% or more) of the students in this study. These common misconceptions were obtained from the analysis of the students' responses to all the 48 items in the NSKS as presented in Table 6. There were 34 items from the NSKS where the students held specific common misconceptions.

As it is shown in Table 6, misconception pertaining to the amoral nature of science was held by most of the students. 84.0% of the students held the common misconception that it is meaningful to pass moral judgment on both the application of scientific knowledge and the knowledge itself (Item 21). Moreover, 61.9% of the students misconceived that moral judgment can be passed on scientific knowledge (Item 18) while 57.5% of them did not accept that even if the applications of scientific theory are judged to be good, we should not judged the theory itself (Item 8). The data in Table 6 also revealed that slightly more than 40% of the respondents misconceived that scientific knowledge could be judge good or bad (Items 4, 5, 7, 36 and 48). They failed to understand that scientific knowledge is free from moral considerations. This belief was also shown by the pre-university students in Sathasivam's (2002) study where 63.0% of them holding the misconception that it is meaningful to pass moral judge on scientific knowledge.

Students possessed misconceptions on 5 of the items in the Creative subscale.. Generally they did not believe that scientific knowledge is a product of human imagination (Items 32 and 23). Moreover they disregarded the work of creativity in scientific theories, laws and concepts (Items 20, 28 and 41). Students in other studies were found to hold similar misconceptions. In a study, Mackay (1971) concluded that grades 7-10 students lacked sufficient knowledge of the role of creativity in science. Further more Grade 10 students in Lederman's(1999) study believed that imagination and creativity had limited place in the development of scientific knowledge. In another study, Abd-El-Khalick and Lederman (2000) found that 70% of college students in their study "did not use imagination and creativity to refer to the invention of explanation, models or theoretical entities". In a similar vein, Walker et al. (2000) reported that by the time students reach the senior year in college, many perceived science as a rote and clinical process.

The students also held misconceptions pertaining to the developmental nature of science. A substantial proportion of them (more than 75%) believed that we do not accept a piece of scientific knowledge unless it is free of error (Items 27 and 16). About half of them (52.4%) also held the misconception that the truth of scientific knowledge is beyond doubt (Item 25). This erroneous conception was also identified in Rubba's (cited by Meichtry, 1993) study where by 30% of high school students believed that scientific knowledge is incontrovertible and is absolute truth. Additionally, 58.0% of the pre-university students in Sathasivam's (2002) study thought that we do not accept a piece of scientific knowledge unless it is free of error.
Data in Table 6 shows that about 40% of the students were inadequate in their understanding of the tentativeness of science, they viewed scientific knowledge as unchanging (Item 43) and that scientific beliefs do not change over time (Item 31). The studies conducted by Brickhouse et al. (2000), Abd-El Khalick and Lederman (2000) and Walker et al. (2000) also had similar findings. 47% of the college students interviewed by Brickhouse et al. perceived that theories do not change while 90% of the participants in Abd-El Khalick and Ledermans' study did not seem to believe that scientific knowledge is tentative. Moreover, Walker et al. (2000) also revealed that some high school and college students in their study thought that science theory is static. On the other hand, the students in both Lederman's (1986) and Moss's (2001) studies believed that science knowledge is tentative.

The students in this study held misconceptions about the parsimonious nature of science. More than 33% (one third) of them held misconceptions in all the 8 items in this subscale. They did not think that there is an effort in science to minimize the number of scientific laws, theories and concepts (Item 15 and 29). About 80% of them believed that science is specific as opposed to comprehensive (Items 40 and 46). Roughly half of them held the misconception about the simplicity of science (Items 2, 6, 14, and 39). This result is consistent with that of Sathasivam's (2002) study where 75.3% of the subjects did not understand that the aim of science is to keep the number of laws, theories and concepts at a minimum. The poor performance of the students in the Parsimonious subscale also corresponds with the result obtained from Lederman's (1986) studies where Grade 10 students were found to hold misconceptions of the Parsimonious subscale.

In their understanding of the testability of scientific knowledge, 71.4% of the students held the misconception that scientific knowledge needs not be capable of experimental test (Item 9), while 57.8% believed that consistency among test result is not a requirement for the acceptance of scientific knowledge (Item 11). In addition, 35.7% of the students held the misconception on the idea that scientific knowledge must be replicable (Item 12). This finding contradicts that of Sathasivam's (2002) study where pre-university science students did not hold any misconception about the testability of scientific knowledge.

There were only two items from the Unified subscale in which the students had common misconceptions. More than 70% of the students thought that biology, chemistry and physics are different kind of knowledge (Items 35 and 44). They were unaware that the different branches of science contribute to the same body of scientific knowledge. Again, this finding is in contrast with that of Sathasivam's (2002) results where the subjects in her study did not exhibit misconception about the unity of science.

CONCLUSION

The primary objective of this study was to determine form six science students' understanding of the nature of science and to identify their misconceptions of the nature of science. Through analysis of the students' responses to the 48 items in the NSKS instrument, the students in this study were found to possess inadequate understanding of the nature of science. The overall understanding of the nature of science of the form six science students in term of percent mean score was 53.6%. The overall understanding for the various aspects of the nature of science (in terms of percent mean score) in descending order was: Unified, Testable, Creative, Developmental, Amoral and Parsimonious.

34 common misconceptions were identified from this study. The students held common misconceptions on all the 8 items on the Amoral and Parsimonious subscale. In the Creative subscale the students held common misconceptions in 5 items (Items 20, 23, 28, 32 and 41) while in the Developmental subscale there were 6 items (Items 16, 25, 27, 31, 42 and 43) where students held common misconceptions. Additionally, 4 items (Items 9, 11, 12, and 45) from the testable subscale and 2 items (Items 44 and 47) from the Unified subscale were identified as having common misconceptions held by the students.

Implications of the Findings

Several important implications to science education in upper secondary school could be drawn from the findings of this study.

In general, the findings indicate that the subjects of the study did not possess adequate understand of the nature of science. This is a cause of concern in view of the fact that these students had completed 2 years of science education at the forms 4 and 5 level prior to selection into lower six science classes. The findings therefore highlight the need to foster a better understanding of the nature of science among high school science students since an understanding of the nature of science is an important component of scientific literacy (AAAS, 1989).

This study revealed that, despite having completed science course at forms 4 and 5 level, the students still held numerous misconceptions pertaining to the various aspects of the nature of science. This implies that remedial work to address the science students' misconceptions of the nature of science should be carried out during form 4 and 5 level if it is desired that the students will not harbor these misconceptions to higher form. As it was noted by Moss (2000) that students' conceptions of the nature of science remained unchanged over the years, therefore it is recommended that the teaching of the correct conceptions of the nature of science (or any remedial work) be done as early as possible.

One of the ways to enhance the understanding of the nature of science among students is to infuse philosophy of science and history of science into the science curriculum as it has been established by various studies (Abd-El-Khalick & Lederman, 2000; Akindehin, 1988; Klopfer & Cooley, 1963; Meichtry, 1992; Solomon, Duven & Scott, 1992) that students receiving instruction using materials derived from the history of science and philosophy of science exhibited better understanding of the nature of science. Hence, curriculum planner in the Ministry of Education of Malaysia should rise to the challenge of designing a science curriculum with balance treatment of factual content and the more abstract nature of science such as philosophy of science and history of science. Science teachers should also be trained to convey the nature of science to the students effectively so that students will develop better understanding of the nature of science.

REFERENCES

Abd-El-Khalick, F., & Lederman, N.G. (2000). The influence of history of science course on students' view of nature of science. *Journal of Research in Science Teaching,* 37(10), 1057-1095.

American Association for the Advancement of Science (1989). *Project 2061: Science for all American.* New York: Oxford Press.

Brickhouse, N.W., Dagher, Z.R., Letts, W.J., & Shipman, H.L. (2000). Diversity of students' view about evidence, theory, and the interface between science and religion in an astronomy course. *Journal of Research in Science Teaching*, 37(4**),** 340-362.

Griffiths, A.K. & Barry, M. (1993). High school students' view about the nature of science. *School Science and Mathematics*, 93(1), 35-37.

Lederman, N.G.(1986). Students' and Teachers' understanding of the nature of science: A Reassessment. *School Science and Mathematics*, 86(2), 91-99.

Lederman, N.G. (1999) Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching*, 36(8)**,** 916-929

Mackay, L.D. (1971). Development of understanding about the nature of science. *Journal of Research in Science Teaching*, 8(1**),** 57-66.

Meichtry, Y.J. (1992). Influencing student understanding of the nature of science: Data from a case of curriculum development. *Journal of Research in Science Teaching,* 29(4), 389-407.

Meichtry, Y.J. (1993). The impact of science curricula on student views about the nature of science. *Journal of Research in Science Teaching,* 30(5), 429- 443.

Moss, D.M. (2001). Examining student conceptions of the nature of science. *International Journal of Science Education*, 23(8), 771-790.

Sathasivam, R. (2002). *Pre-university science students' understanding of the nature of science and its relationships with academic achievement and gender*. Unpublished master's project paper, University Malaya.

Rubba, P.A., & Andersen, H. O. (1978). Development of an instrument to assess secondary school students' understanding of the nature of scientific knowledge. *Science Education*, 62(4), 449-458.

Showalter, V.M. (1974). What is unified science education? Program objectives and scientific literacy. *Prism II*, **2**, 3-4.

Walker, K.A., Zeidler, D.L., Simmons, M.L., & Ackett, W.A. (2000). *Multiple views of the nature of science and socio-scientific issues.* Paper presented at the Annual Meeting of the American Educational Research Association. New Orleans, LA, April 2000. (ERIC Document Reproduction Service No. ED441697)

APPENDIX

Table 1: Major Aspects of Scientific Knowledge in Rubba and Anderson's Model

	Aspect of scientific knowledge	Description
1.	Amoral	Scientific knowledge provided man with many capabilities, but does not instruct him on how to use them. Moral judgment can be passed on man's application of scientific knowledge, not on the knowledge itself.
2.	Creative	Scientific knowledge is a product of the human intellect. Its invention requires as much creative imagination as does the work of an artist, a poet, or a composer. Scientific knowledge embodies the creative essence of the scientific inquiry process.
3.	Developmental	Scientific knowledge is never "proven" in an absolute and final sense. It changes over time. The justification process limits scientific knowledge as probable. Beliefs, which appear to be good ones at one time, may be appraised differently when more evidence is at hand. Previously accepted beliefs should be judged in their historical context.
4.	Parsimonious	Scientific knowledge tends toward simplicity, but not to the disdain of complexity. It is comprehensive as opposed to specific. There is a continuous effort in science to develop a minimum number of concepts to explain the greatest possible number of observations.
5.	Testable	Scientific knowledge is capable of empirical test. Its validity is established through repeated testing against accepted observations. Consistency among test results is a necessary, but not a sufficient condition for the validity of scientific knowledge.
6.	Unified	Scientific knowledge is born out of an effort to understand the unity of nature. The knowledge produced by the various specialized sciences contributes to an interrelated network of laws, theories, and concepts. This systemized body gives science its explanatory and predictive power.

Table 2: Nature of Scientific Knowledge Scale (NSKS): Original Version (Rubba & Andersen, 1978, p. 456-457)

Item No.	Statement
1.	Scientific laws, theories, and concepts do not express creativity
2.	Scientific knowledge is stated as simply as possible.
3.	The laws, theories, and concepts of biology, chemistry, and physics are related..
4.	The applications of scientific knowledge can be judged good or bad, but the knowledge itself cannot.
5.	It is incorrect to judge a piece of scientific knowledge as being good or bad.
6.	Certain pieces of scientific knowledge are good and others are bad.
7.	Even if the applications of a scientific theory are judge to be good, we should not judge the theory itself.
8.	Scientific knowledge need not be capable of experimental test.
9.	The laws, theories, and concept of biology, chemistry and physics are not linked.
10.	Consistency among test results is not a requirement for the acceptance of scientific

knowledge.

Item No.	Statement
11.	A piece of scientific knowledge will be accepted if the evidence can be obtained by other investigators working under similar conditions.
12.	The evidence for scientific knowledge need not be open to public examination
13.	Scientific laws, theories, and concepts are stated as simply as possible.
14.	There is effort in science to build as great number of laws, theories, and concepts as possible.
15.	We accept scientific knowledge even though it may contain error.
16.	Scientific knowledge expresses the creativity of scientists.
17.	Moral judgment can be passed on scientific knowledge
18.	The laws, theories, and concepts of biology, chemistry and physics are not related.
19.	Scientific laws, theories, and concepts express creativity.
20.	It is meaningful to pass moral judgment on both the applications of scientific knowledge and the knowledge itself.
21.	The evidence for scientific knowledge must be repeatable.
22.	Scientific knowledge is not a product of human imagination.
23.	Relationships among the laws, theories, and concepts of science do not contribute to the explanatory and predictive power of science.
24.	The truth of scientific knowledge is beyond doubt.
25.	Today's scientific laws, theories, and concepts may have to be changed in the face of new evidence.
26.	We do not accept a piece of scientific knowledge unless it is free of error.
27.	A scientific theory is similar to a work of art in that they both express creativity.
28.	There is an effort in science to keep the number of laws, theories, and concepts at a minimum
29.	The various sciences contribute to a single organized body of knowledge.
30.	Scientific beliefs do not change over time.
31.	Scientific knowledge is a product of human imagination.
32.	The evidence for a piece of scientific knowledge does not have to be repeatable.
33.	Scientific knowledge does not express the creativity of scientists.
34.	Biology, chemistry, and physics are similar kinds of knowledge.
35.	If the applications of a piece of scientific knowledge are generally considered bad, then the piece of knowledge is also considered to be bad.
36.	Scientific knowledge is subject to review and change.
37.	Scientific laws, theories, and concepts are tested against reliable observations.
38.	If two scientific theories explain a scientist's observation equally well, the more complex theory is chosen.
39.	Scientific knowledge is specific as opposed to comprehensive.
40.	Scientific theories are discovered, not created by man.
41.	Those scientific beliefs which were accepted in the past and since have been discarded, should be judged in their historical context.
42.	Scientific knowledge is unchanging.
43.	Biology, chemistry, and physics are different kinds of knowledge.
44.	Consistency among test results is a requirement for the acceptance of scientific knowledge.
45.	Scientific knowledge is comprehensive as opposed to specific.
46.	The laws, theories, and concepts of biology, chemistry, and physics are interwoven.
47.	A piece of scientific knowledge should not be judged good or bad.
48.	A piece of scientific knowledge should not be judged good or bad.

Table 3: Item to Subscale Key of NSKS

NSKS subscale	Positive item numbers	Negative item Numbers
Amoral	4, 5, 8, 48	7, 18, 21, 36
Creative	17, 20, 28, 32	1, 23, 34, 41
Developmental	16, 26, 37, 42	25, 27, 31, 43
Parsimonious	2, 6, 29, 46	14, 15, 39, 40
Testable	12, 22, 38, 45	9, 11, 13, 33
Unified	3, 30, 35, 47	10, 19, 24, 44

Table 4: Mean, Standard Deviation, Minimum and Maximum of NSKS Scores Attained by Form Six Science Students

	Mean (%)	S.D (s)	Minimum (%)	Maximum (%)
NSKS score	25.75 (53.6%)	5.22	10 (20.8%)	39 (81.3%)

Table 4: Rank Order of Form Six Science Students' understanding f the Nature of Science

Rank Order	Subscale of the nature of science	Number. of items	Level of understanding (percent mean score)
1	Unified	8	71.1%
2	Testable	8	64.8%
3	Creative	8	54.2 %
4	Developmental	8	52.7%
5	Amoral	8	46.6%
6	Parsimonious	8	33.8%

Table 5: Form Six Science Students' Common Misconceptions of the Nature of Science

Aspect of the nature of science	Item number	Misconception involved	Percentage of students having misconceptions (%)
Amoral	4	The application of scientific knowledge can be judge good or bad: but the knowledge itself cannot.	43.9
	5	It is incorrect to judge a piece of scientific knowledge as being good or bad.	51.4
	7	Certain pieces of scientific knowledge are good and others are bad.	39.1
	18	Moral judgment can be passed on scientific knowledge.	61.9
	21	It is meaningful to pass moral judgment on both the application of scientific knowledge and the knowledge itself.	84.0
	48	A piece of knowledge should not be judge good or bad.	47.3

Aspect of the nature of science	Item number	Misconception involved	Percentage of students having misconceptions (%)
Amoral	36	If the applications of a piece of scientific knowledge are generally considered bad, then the piece of knowledge is also considered to be bad.	42.2
Creative	20	Scientific laws, theories, and concept express creativity.	36.7
	23	Scientific knowledge is not a product of human imagination.	56.1
	28	A scientific theory is similar to a work of art in that they express creativity.	60.9
	32	Scientific knowledge is a product of human imagination.	63.6
	41	Scientific theories are discovered, not created by man.	74.5
Developmental	16	We accept scientific knowledge even though it may contain error.	76.9
	25	The truth of scientific knowledge is beyond doubt.	52.4
	27	We do not accept a piece of scientific knowledge unless it is free of error.	84.7
	31	Scientific beliefs do not change over time.	40.8
	42	Those scientific beliefs, which were accepted in the past and since have been discarded, should be judge in their historical context.	46.3
	43	Scientific knowledge is unchanging.	37.1
Parsimonious	2	Scientific knowledge is stated as simply as possible.	49.7
	6	If two scientific theories explain a scientist's observation equally well, the simpler theory is chosen.	50.7
	14	Scientific laws, theories, and concepts are not stated as simply as possible.	48.0
	15	There is an effort in science to build as great a number of laws, theories, and concepts as possible.	88.4
	29	There is an effort in science to keep the number of laws, theories, and concepts at a minimum.	83.0
	39	If two scientific theories explain a scientist's observation equally well, the more complex theory is chosen.	46.9
	40	Scientific knowledge is specific as opposed to comprehensive.	83.7
	46	Scientific knowledge is comprehensive as opposed to specific.	79.6

Aspect of the nature of science	Item number	Misconception involved	Percentage of students having misconceptions (%)
Testable	9	Scientific knowledge need not be capable of experimental test.	71.4
	11	Consistency among test results is not a requirement for the acceptance of scientific knowledge.	57.8
	12	A piece of scientific knowledge will be accepted if the evidence can be obtained by other investigators working under similar conditions.	35.7
	45	Consistency among test results is a requirement for the acceptance of scientific knowledge.	38.1
Unified	35	Biology, chemistry and physics are similar kind of knowledge.	73.8
	44	Biology, chemistry and physics are different kinds of knowledge.	71.8