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THE NATURE OF SCIENCE AS VIEWED BY NON-SCIENCE UNDERGRADUATE STUDENTS

Arne Rannikmäe, Miia Rannikmäe, Jack Holbrook

Abstract. *The purpose of this exploratory study was to determine views held on the nature of science by tertiary level students who are not studying science subjects as an academic area of study, who are not seen as outstanding students in an academic sense, but who may cover a range of age groups from 18 upwards. The research sets out to determine their views on the nature of science based on their learning at secondary school and influences that may come from society. Essays written by 58 students were analysed. Using a phenomenographical approach, categories describing undergraduate students views were found.*

Key words: *nature of science (NoS), phenomenographical approach, the course on philosophy of science.*

Arne Rannikmäe, Miia Rannikmäe, Jack Holbrook
University of Tartu, Estonia

Introduction

Worrying underlying trends in young people's interest in science and science-based technologies were highlighted by an European Union High Level Group report (2004). Two major concerns were expressed - whether science education was addressing the needs of society and promoting the interest needed in science and technology, both within the school and in everyday life, and also whether teachers and teacher educators were guilty of presenting a poor image of science.

However, little attention has been paid to how students view science having completed their studies of science subjects in school. In particular little attention has been paid to the appreciation of the nature of science coming from teaching of science subjects in school (Holbrook, 1998).

Views of the Nature of Science (NoS) has been researched among scientists, teachers and students (El-Khalick and Lederman, 2000; Zeidler, Walker, Ackett and Simmons, 2002; Bell and Lederman, 2003; Sadler and Zeidler, 2004; Chen, 2006). The goal of such studies has been to describe these views in philosophical terms, rather than towards a style of teaching or the need for greater emphasis on student involvement in the learning process. The studies identified key components of NoS. These aspects include understanding that scientific knowledge is tentative (subject to change) empirically based (based on and /or derived from observation of the natural world); subjective (influenced by scientists' background, experiences and biases); partly the

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product of human imagination and creativity (involves the invention of explanations); and socially and culturally embedded. (Yager and Weld, 1999; Chen, 2006; Khishfe and Lederman, 2006).

The promotion of NoS within schools has been considered to be a component of two major factors. The first relates to conceptual learning, especially whether this is higher order (Zoller, 2001) and attempts to build up a fundamental framework around the big ideas and theories promoted by scientists. The second examines the manner in which scientists work and considers this through a variety of approaches related to process skills. Among these are inquiry learning, the investigatory approach, the development of problem solving skills, or simply through experimentation in which students follow written instructions (Tytler, Duggan and Gott, 2001).

This study is more on the implication of an understanding of NoS on further learning and views held which are taken into society. Much research has emphasized scientific literacy as a goal for science education and often related this to an understanding of NoS, or to NoS plus socio-scientific reasoning (NRC, 1996). Less research has been directed towards the nature of science education (NSE) as a wider entity encompassing the goals of education as a whole, the need to consider the relevance of science education and addressing the important of inter-disciplinarity in the teaching of science. And there has been little research on the impact of school studies on the impact of learning at the tertiary level related to the nature of science. Laugksch and Spargo (1996) and El-Khalick (1996) showed that undergraduate students held poor view on the Nature of Science, but there are no studies on the impact of this on tertiary level learning, especially by non-science major students.

The goals of the study were:

- To identify non-science major undergraduate students views concerning the relationship between the nature of science and how those are interrelated to science taught at school (the nature of science education).
- To identify how undergraduate students distinguish the nature of scientific work related to delineation of science from pseudoscience.
- To determine whether, and how, an undergraduate level philosophy of science course influences students' views of the nature of science.

The following research questions were put forward:

- What kind of views of NoS do students hold?
- Is there any relationship between school science education and the reactions of students towards science?
- Can we determine the influence of an undergraduate science philosophy course on students' views of NoS?

Methodology of Research

The population of this study comprised 58 fourth year tertiary students (first year at master's level), all from the same private Estonian University specializing in non-science areas. From the sample, 21% were studying psychology, 17% marketing and 62% law. The student's background differed greatly - 32% had no working experience, whereas 68% had working experiences in different areas. There was 30% male and 70% female students. The year of graduating from secondary school varied from 4 years ago to 8 years (87%); 13% graduated more than 10 years ago.

All students undertook a compulsory course in the philosophy of science. The aim of this course was to develop student's understanding of contemporary science. Stress was put on the relation between the needs of a rapidly changing society and modern science, especially postmodernism. As such, the philosophy of science course contained topics like knowledge and power, truth in a traditional and postmodern view, positivist and postmodern interpretations of scientific progress and discussions about scientific method.

Data for this study were collected immediately after the completion of the philosophy of science course, although this was before the end-of-course examination. The reasons for this were that the attitudes of the students were predicted to be negative towards further tasks related to the course after the examination and also it could prove difficult to involve the students in the study. For the study, the students were asked to be experts to help develop ideas for a real educational need. All answers were personalized (names given) but not marked as part of the course. They were required to write an essay based on the following:

> 'School science has become more and more unpopular among school students. Students are interested in horoscopes, UFOs, witches and their souls. Imagine the situation that you are the teacher who wants to convince students of the need to learn science and the power of a correct understanding of the nature of science'.

They were asked to design the course for school students, geared to the promotion of an understanding of the nature of science'. They were asked to describe the course and given 30 minutes to complete the task.

The task was grounded on the following research conclusions:

1. Students are likely to be more interested in science learning when topics are perceived as being more relevant for them (Fensham, 2004).
2. Students are interested in extraordinary phenomena and pseudoscientific issues (Sjøberg, 2002).
3. Non-science students hold poor understanding about the nature of science (Waters-Adams, 2006).
4. Many educators see potential benefits in instructional practices that differentiates science from pseudoscience by comparing and contrasting the methodology utilized to develop knowledge claims (Mattheus, 1998; Martin, 1994).

Results of Research

The essays from the 58 students were very varied. Some were a list of topics, others were a complete story with well reasoned statements. All essays were read through by researchers several times and independently by another person. The analysis was carried about by considering different components.

The table below identified the dominant views expressed by the participants in their essays (students often indicated more than one view and hence the total of student frequencies is greater than 58). Views were combined to create the descriptors indicated in the table. Some descriptors have overlap, for example, descriptor 2 and descriptor 4, where both may include experimentation in the school science laboratory, but presented in different contexts.

Table 1. Descriptors of the student's views on the NoS.

No.	Descriptor of views	Student frequency	% of total mentions
1.	Inclusion of a socio-scientific issue and/or socio-scientific decision making	6	4.7
2.	Vision of science equal to school science subjects	22	17.0
3.	Nature of science reproduced from course lectures at undergraduate level	17	13.2
4.	Nature of science means science method/ experimentation in the laboratory (school or research facilities by scientists)	19	14.6
5.	Emphasise or explain a link between science and technology	7	5.4
6.	Place/need of science to be found within the society	4	3.1

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No.	Descriptor of views	Student frequency	% of total mentions
7.	Science seen as made up of the classical sub-division of biology, chemistry and physics	16	12.4
8.	Describe pedagogical approaches to be applied within the school	5	3.9
9.	Explain the need for studying science from psychological aspects	6	4.7
10.	Promoting pseudoscience illustrating confused views of science	8	6.2
11.	Mistaken views of the nature of science (conceptual errors, approach errors)	9	7.0.
12.	Put forward definitions of science	10	7.8
	Total number of mentions of descriptors	129	100

The essays were also considered as a whole from the point of view of coherence in the logic put forward. The logic was determined by the manner in which the essay was introduced and the actions given, related to solving of the task. Each action was expected to be justified and lead towards the final conclusion. The ideas expounded by the essay were expected to be clearly indicated as this was seen as an indicator of understanding of the task given.

This was identified based on 4 aspects as shown in the table below:

Table 2. Descriptors of logic on which essays based.

	Descriptor of the logic exhibited in the essay	Frequency	% students
a.	logical based on social issues	6	10.3
b.	logical based on the outcomes from the undergraduate course followed	15	25.9
c.	sometimes logical based on (a) or (b) but not completely	24	41.4
d.	poor logic or coherence in the essay	13	22.4

Interpretation

From table 1 it appears that 5 descriptors (descriptors 2, 4, 7, 8 and 12) were linked with an image of school science with an overall frequency of 72 mentions (56% of the total). On the other hand, only 1 descriptor (descriptor 3 – 13% of mentions) was identified as coming directly from the recently taught course on the philosophy of science. Descriptors 5, 6 and 10 (15% of mentions) can mostly probably be linked with social experiences outside of school.

From table 2 it appears that only one third of students (36.2%) presented their ideas logically

Social-issue related essays included aspects from both science and society and the coherence was built up towards everyday life. The students who followed the logic of the undergraduate course tended not to expand their ideas outside the framework of the course. We may predict that the latter students have not gained the skill to link taught courses and applications to social needs (to promote school education). These students transferred ideas that had been part of the taught course to other situations without modification or taking into consideration its relevance. The logic was largely unclear in essays included in aspects c and d, but where the logic was clear in parts of the essay coming through statements, the ideas were directly related to school science.

From the findings, 5 categories were constructed. These are described in table 3.

The first category was by those students consider the value of socio-scientific issues which were used as a starting point for science learning. The nature of science is part of the science process and cannot be taught in isolation from the context. This category was labelled exhibiting multidimensional literacy.

For example, one student started his essay by suggesting students have read from the newspapers about bird flu and the type of risks this give to the population. The student noted that because of this many people avoided eating chicken meat in Estonia. Starting from this scenario indicates that this writer seems to understand that science does not directly point out the risk.

In the second category, science was portrayed as being the same as school science. Here examples form school science textbooks were stated such as how Mendeleev discovered the Periodic Table. School science experiments were described and scientific method was explained as carrying out experiments based on instructions. Science was broken down in to Biology, Chemistry and/or Physics. New branches of science such as molecule biology or gene technology were not mentioned. The word science was promoted in the context of school science (identifiable because of the use of different word for science in the Estonian language for school science and academic science)

For example, in explaining the nature of science there is a need to do many experiments. Student should do experiments to be convinced that earlier findings were correct.

Students in category III put forward arguments using knowledge gained from the undergraduate course on the philosophy of science. They explained what was meant by theory, law and fact, brought examples from the course in which for example, pictures could be seen as difference from different perspectives (the old lady or the young woman). They gave a definition of the meaning of pseudoscience and referred to philosophers such as Kuhn and Popper.

For example, one should explain to students what is meant by law and what is meant by theory. Horoscopes are not theory, law nor fact and therefore they are not scientific.

Students in category IV wished to convince students not to waste time on non – scientific phenomena such as horoscopes. The essay was dominated by examples of pseudoscience and there was perceived the danger that this may guide students to become interested in this area. The essays were usually not logical and were discussion-related with no clear guidance on how to promote 'real' science

For example, let students discuss whether UFOs exist and to guide students to bring examples into the classroom.

Essays in the last category were generally poor and had little by way of a message. There were mistaken scientific views expressed. Students put forward a collection of ideas, but these ideas lack coherence and said little about the meaning of science.

In some cases there were scientific mistakes.

For example distinguishing between theories and laws and what is meant by fact.

Table 3. Descriptors of categories.

Category	Descriptor	% students
I	Exhibiting multidimensional scientific literacy.	10.3
II	Science equals school science	31.0
III	Views repeating those from under-graduate course	25.9
IV	Advocating non-pseudoscience	10.3
V	Non-logical presentation with possible mistakes	22.4

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The validity of these categories was checked by independent experts who were asked to identify suitable categories and then group students into the categories put forward. The correlation between the experts was found to be 80%. Categories I, II and III were shown to be statistically significantly different. Categories IV and V require further research considering other factors not exhibited in the current study.

These categories were compiled based the dominant view plus other views expressed. The frequency of the responses by students is given in the table below:

Table 4. Frequencies of views related to each category.

Category	No. of students	Dominant view	Frequency	Other Views	Frequency	Other Views	Frequency	Other Views	Frequency	Dominant aspect
I	6	1	6	5	4	6	2	-	-	a
II	18	2	18	12	5	8	5	-	-	c
III	15	3	15	7	6	12	5	-	-	b
IV	6	10	6	9	2	11	4	-	-	b/c
V	13	4	12	7	10	11	5	2	4	d

This table points out the number of students grouped in each of the categories and the frequency of descriptors of dominant and additional views (the content of the given descriptors are indicated in table 1). For example, category II groups 18 students holding views on "Science equals school science", each having the dominant view "the vision of science is equal to school science subjects". In this category 12 students also included a view associated with "putting forward definitions of science" while 8 students included the description of pedagogical approaches to be applied within the school) as being essential. The dominant aspect, indicated in the last column, describes the logic exhibited in the students' essays (see Table 2).

Discussion

It was interesting to note the different views expressed, even though all these students had shied away from the study of science and could therefore be considered as views brought forward into adulthood based on learning in school linked to everyday experiences.

The emphasis of the descriptors mentioned was strongly towards school science, where the nature of science has been presented through a limited vision without links between science and technology and to future careers. Similar outcomes from studying teacher's views were found by El-Khalick and Lederman (2000).

Category I

The goal of science education is scientific literacy and whether these students could be considered scientific literate would depend on their responses to the question.

One component of scientific literacy is an understanding of the nature of science. By determining the ideas on the nature of science, it might be possible to interpret the students' literacy levels in the area of science.

Based on these findings only the first category shows of some form of scientific literacy.

Category II

The largest number of students equated science with the science being taught in school. These students described the processes from their school and came up with the common ideas they had experienced. The brought examples that science is aspects such as atomic theory and thus the nature of science is related to understanding of such models.

Category III

Students gave data which was heavily related to the undergraduate course they had just received. A further study would be need to determine whether their understanding of their nature of science was present or whether they were simply memorising aspects from the course and repeating this for the essay.

Not withstanding the comments above, the study shows that was very little influence coming through from the taught course of the philosophy of science. In this course the nature of science was an integral part of the teaching yet none the students placed within category C gave any views on this aspect of the course.

Category IV

These students had difficulty in distinguishing the nature of science, although they recognised that pseudoscience is not science.

This group tried to build their arguments around pseudoscience phenomena e.g. horoscopes. If students read horoscopes, different horoscopes tell different stories depending on the author and hence horoscopes are not products of science. However they did not attempt to explain what is science.

Category V

Students put forward a collection of ideas, but these ideas lack coherence and said little about the meaning of science.

In some cases there were scientific mistakes, e.g. distinguishing between theories and laws and what is meant by fact.

The course on philosophy of science seemed to have little impact in changing students views on their way of thinking about the nature of science or how science should be presented to school students. Even where the course components came strongly through, they tended to be stated, but not explained. The overall approach put forward by students in their essays was similar to a teacher-centred approach shown by many teachers and which has been heavily criticised by Zeidler, Walker, Ackett and Simmons (2002). One could argue whether tertiary level courses are able to promote the level of scientific literacy that students had gained on leaving school. If true this is of major concern as it implies that school has a strong lasting effect on student views which are carried in to adulthood. Driver (1985) has pointed out how difficult it is to change student views. It is strongly indicated that views coming from school science block the development of wider views on the nature of science.

Hence this study shows the importance of knowing previously held views by students related to the nature of science as these will give an important indicator on how to make the course more effective in playing a positive society impact.

Conclusion

This being the case, the school obviously has not paid enough attention to this aspect. From the 58 students, it appears that 50 students have a very limited understanding of the nature of science. The students came up with very divergent views. The dominant view is that science is the science as taught in school. The views put forward in the undergraduate course were largely seen as unrelated to the requirements of this task.

This tends to indicate the strong link between the teaching in school and the views that are then held on the nature of science after leaving school. And these views seem to be quite resistant to change.

This study showed the strong link between the teaching of science in school and the views held by students on the nature of science. The idea that science is content or experimentation only is very strong and the views that there is a tentativeness about science, that ingenuity and creativity play a role in the development of science are poorly understood.

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This study tried to finds out different view about science held by students. Based on this study, the course called philosophy of science should be redesigned to promote meaningful understanding about the nature of science among students. It would seem that there is a need for greater interaction and discussion on the nature of science.

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Резюме

ПОНИМАНИЕ СУЩНОСТИ НАУКИ СТУДЕНТАМИ МАГИСТРАНТУРЫ СОЦИАЛЬНЫХ НАУК

Арне Ранникмае, Миих Ранникмае, Джаск Голбрук

Главная цель исследования заключалась в том, чтобы выяснить, как студенты магистратуры социальных наук понимают сущность науки. Также нас интересовало влияние среднего уровня школьного обучения на современные взгляды студентов о сущности науки и сохранность знаний курса философии науки на их взгляды в будущем.

Целевой группой исследования были выбраны магистранты первого курса Эстонского университета. Из них: 21% специализировались по психологии, 17% по маркетингу и 62% по правоведению. Большинство магистрантов, принимавших участие в эксперименте, обладало опытом профессии, однако на период завершения среднего уровня их обучения он сильно варьировался. Все студенты прослушали курс современной философии науки, в котором основной акцент делался на сравнение модернистской и постмодернистской трактовки науки. Данные эксперимента были собраны перед экзаменом по предмету.

Студентов попросили написать в течение 30 минут краткое эссе, с позиции учителя, а также составить план курса, для того чтобы объяснить студентам среднего уровня сущность современной науки и ее преимущество перед псевдонаукой.

Работы студентов были проанализированы исследователем и независимым экспертом. На основании полученных данных были сформулированы 12 признаков описания студенческих взглядов. Далее, на их основании было выделено 5 категорий, которые описывают все имеющиеся взгляды магистрантов в эссе.

Первая категория включала студентов, которые понимали, что сущность науки является частью научного процесса и что её невозможно изучать раздельно от контекста. Научная грамотность мультиразмерна и понимание сущности науки этих студентов адекватна.

Вторая категория включает студентов, которые отождествляют науку с изученными учебными предметами средней школы и теми экспериментами, которые они осуществляли. Следовательно, их понимание сущности науки ограничено рамками учебных предметов.

Третья категория студентов, характеризовалась тем, что они использовали в эссе знания, полученные из курса философии науки.

Четвёртая категория включала студентов, которые акцентируют внимание на дифференциации науки и псевдонауки.

Пятая категория включала студентов, в чьих структуре эссе отсутствовала гармония и внутренняя логика, и в которых присутствовали ошибки.

В качестве вывода можно утверждать, что у студентов, чьи знания были получены за период обучения в среднем уровне о сущности науки, весьма устойчивы. Эти взгляды трудно поддаются изменениям. Поэтому, большее значение следует придавать курсу современной философии науки в магистратуре и осуществлять дискуссию о ее сущности.

Ключевые слова: понимание сущности науки, философия науки, естественнонаучное образование.

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Arne Rannikmäe	Ph.D. student in the Science Didactics Department, University of Tartu. Vanemuise Street 46-226, Tartu 51014, Estonia. Phone: +372 6737-989; Fax: +372 7375-082. E-mail: arne.rannikmae@nord.ee
Miia Rannikmäe	Ph.D., Senior Researcher in the Science Didactics Department, University of Tartu. Vanemuise Street 46-226, Tartu 51014, Estonia. Phone: +372 7375-083; Fax: +372 7375-082. E-mail: miia@ut.ee
Jack Holbrook	Ph.D., Visiting Professor in the Science Didactics Department, University of Tartu. Vanemuise Street 46-226, Tartu 51014, Estonia. Phone: +372 7375 083; Fax: +372 7375 082. E-mail: icase@logos.cy.net