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Abstract

The nature of science (NOS) remains a central issue of pre-service teacher education. We considered the student teacher as a scientist, their background from undergraduate, previous postgraduate and life experiences as well as monitoring changes in their responses to a short questionnaire derived from McComas *et al* (1998).

The study aimed to map the students' understanding of (NoS) with a view to developing their pedagogical content knowledge as well as establishing baseline data to measure the effect of future interventions during the pre-service programmes (such as teaching about NoS or the Philosophy of Science) It is also anticipated that we will be well placed to promote ACfE aspirations as well as informing our programme in relation to developing *Responsible Citizens and Effective Contributors* who can contribute meaningfully to debates about controversial scientific issues.

Student teachers views on the nature of science: do they change during a one year pre-service programme?

Paper presented at the BERA Conference, Edinburgh 2008

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Abstract

Background

The nature of science (NOS) remains a central issue of pre-service teacher education. Abd-El-Khalick (2005) asserted ". . . (NOS) has been a central goal for science education during the past 85 years." He went on to cite major reform efforts in science education in the United States and in England while reiterating the concerns of other researchers that "pre-college students have not attained the desired understandings of NOS". We considered the student teacher as a scientist, their background from undergraduate, previous postgraduate and life experiences as well as monitoring changes in their responses to a short questionnaire derived from McComas *et al* (1998).

Initial teacher education is located in the University sector in Scotland, Souter (2007). This was the result of a series of mergers that took place between April 1993 and December 2001 following funding changes in Higher Education in 1993. The study group were following the standard one year pathway to entering teaching which has been renamed "Professional Graduate Diploma of Education". All pre-service programmes are subject to a process of periodic internal review by the Universities and accreditation by the General Teaching Council for Scotland (4) (GTCS). The non-statutory requirements for all courses (5) including the 36 week PGDE determine that programmes must include arrangements for interviewing applicants; that they must include partnerships between the Universities and schools; and must provide a curriculum to include professional studies, subject studies and school experience. Internal review is designed to ensure that robust and rigorous teaching; learning and assessment practices are in place to ensure that the graduates are suitably prepared to meet the Standard for Initial Teacher Education (6). GTCS accreditation requires detailed documentation including course reports, self evaluation and supportive evidence to be presented for peer and professional review. The Guidelines (5) also require secondary courses "leading to a Teaching Qualification in physics, chemistry or biology must undertake at least 60 hours of study in general science". This is designed to support the tradition of Integrated Science during the junior years of the Scottish Secondary school. According to HM Inspectors of Schools (7) "An integrated science course during the first two years of secondary stages remains the norm in most Scottish schools." "Most pupils in S1 (Secondary year 1) and S2 follow versions of the integrated Science course presented in Curriculum Paper 7 , although large sections are clearly identifiable as biology, chemistry or physics." Draft experiences and outcomes for science were published in September 2007 for review during session 2007-08 to describe expectations about learning from ages 3 to 15 as a significant part of the Scottish curricular reforms under the banner of "A Curriculum for Excellence" (ACfE). The Memorandum on Entry (8) describes the minimum entry

requirements for programmes leading to teaching qualifications in Scotland. The PGDES demands a degree and a pass in Higher Grade English or an equivalent qualification.

The study aimed to map the students' understanding of (NoS) with a view to developing their pedagogical content knowledge as well as establishing baseline data to measure the effect of future interventions during the pre-service programmes. (such as teaching about NoS or the Philosophy of Science) It is also anticipated that we will be well placed to promote ACfE aspirations as well as informing our programme in relation to developing *Responsible Citizens and Effective Contributors* who can contribute meaningfully to debates about controversial scientific issues.

Research Questions

What are student science teachers' initial views about NoS?
How do these change over the course of the course?
What is the effect of our current teaching about NoS?
Do student teachers' identities change as they move from professional scientists to professional teachers?

Methodology

This study involved repeating a questionnaire based on McComas et al (2) prior to the first and second periods of school experience and following the third and final one towards the end of the course. 75 student teachers were in the study group were analysed in relation to several factors including the first or second teaching subject, Biology, Chemistry or Physics; home or overseas, gender, subject combinations and the subject of their degrees and previous postgraduate qualifications. We audited inputs on NOS in the General Science, Biology, Chemistry and Physics programmes. We reviewed NoS issues derived from school experience with on-line free response questions in addition to

Research findings will be reported in relation to several factors including the first or second teaching subject, Biology, Chemistry or Physics; home or overseas, gender, subject combinations and the subject of their degrees and previous postgraduate qualifications.

Introduction

The nature of science (NOS) remains a central issue of pre-service teacher education. (Abd-El-Khalick, 2005) asserted ". . . (NOS) has been a central goal for science education during the past 85 years." He went on to cite major reform efforts in science education in the United States and in England while reiterating the concerns of other researchers that "pre-college students have not attained the desired understandings of NoS". We considered the student teacher as a scientist, their background from undergraduate, previous postgraduate and life experiences as well as monitoring changes in their responses to a short questionnaire derived from (McComas, Clough, & Almazroa, 1998). This paper reports on an investigation into any changes in the views of student teachers undertaking a Professional Graduate Diploma in Education (PGDE) course in physics, chemistry or biology.

The Scottish Perspective

Initial teacher education is located in the University sector in Scotland, Souter (2007). This was the result of a series of mergers that took place between April 1993 and December 2001 following funding changes in Higher Education in 1993. The study group were following the standard one year pathway to entering teaching which has been renamed "Professional Graduate Diploma of Education". All pre-service programmes are subject to a process of periodic internal review by the Universities and accreditation by the General Teaching Council for Scotland (2003). The non-statutory requirements for all courses (The Scottish Office, 1998) including the 36 week PGDE determine that programmes must include arrangements for interviewing applicants; that they must include partnerships between the Universities and schools; and must provide a curriculum to include professional studies, subject studies and school experience. Internal review is designed to ensure that robust and rigorous teaching; learning and assessment practices are in place to ensure that the graduates are suitably prepared to meet the Standard for Initial Teacher Education, QAA (2000). GTCS accreditation requires detailed documentation including course reports, self evaluation and supportive evidence to be presented for peer and professional review. The Guidelines also require secondary courses "leading to a Teaching Qualification in physics, chemistry or biology must undertake at least 60 hours of study in general science". This is designed to support the tradition of Integrated Science during the junior years of the Scottish Secondary school. According to HM Inspectors of Schools (1994) "An integrated science course during the first two years of secondary stages remains the norm in most Scottish schools." "Most pupils in S1 (Secondary year 1) and S2 follow versions of the integrated Science course presented in Curriculum Paper 7 , although large sections are clearly identifiable as biology, chemistry or physics." Draft experiences and outcomes for science were published in September 2007 for review during session 2007-08 to describe expectations about learning from ages 3 to 15 as a significant part of the Scottish curricular reforms under the banner of "A Curriculum for Excellence" (CfE). The Memorandum on Entry, SEED (2005), describes the minimum entry requirements for programmes leading to teaching qualifications in Scotland. The PGDE(S) demands a degree and a pass in Higher Grade English or an equivalent qualification.

Literature Review

NOS – the wider picture

The quote from (Abd-El-Khalick, 2005) used in the previous paragraph, highlights NOS As one of the main issues in science education. Earlier work by (Abd-El-Khalick & Lederman, 2000) looked at attempts to help teachers develop their understanding of NOS and concluded that explicit instruction about NOS and the Philosophy of Science (POS) was more effective than trying to develop NOS via implicit instruction. One difference in this study is the impact instruction about POS and NOS had on the student teachers' teaching strategies. This suggests that explicit links should also be made between the student teachers' own learning and their teaching approaches.

The world-wide concern about understandings of NOS among science students, the general public and science teachers before and after initial training is reflected by a large number of authors. For example, (Aikenhead & Ryan, 1992) in Canada; (Aldridge, Taylor, & Chen, 1997) in Western Australia; (Adams *et al.*, 2006) in Colorado and by extension USA; (Chen, 2006) in Taiwan; (Irez, 2006) in Turkey, among others have explored participants views about NOS in different ways.

A further issue is the general lack of agreement about a suitable instrument to investigate NOS understandings. For example Aikenhead and Ryan reported in the development of the Views on Science-Technology-Society (VOSTS) instrument; Aldridge *et al* reported on the development of Beliefs About Science and School Science Questionnaire (BASSSQ); Adams *et al* reported on the development of the Colorado Learning Attitudes about Science Survey (CLASS); Chen reported on the development of Views on Science and Education Questionnaire (VOSE) and Irez used interviews to gather data.

A further issue apart from NOS is what should be taught in schools: Science for Citizens or Science for Specialists? A recent European manifestation of this debate is summarised by (Osborne & Dillon, 2008), who come down on the side of Science for Citizens. This contrasts with the European Commission report, (Gago, 2004), which makes the case for substantially increasing the supply of scientists and engineers in Europe.

Nevertheless, although there is disagreement about what NOS should cover, there is increasing agreement about the core ideas which should be included, even if there is disagreement about peripheral ideas, (McComas *et al.*, 1998).

NOS – England and Wales
In England and Wales, interest in what should be included in the school science curriculum fed through into curriculum change after the publication of Beyond 2000: Science education for the future (Millar & Osborne, 1998). The debate about the purpose of science education – science for scientists or science for citizens - also has an impact on the content of the school science curriculum. The Beyond 2000 approach led to the introduction of the Twenty First Century Science GCSE course in some schools in England and Wales from 2003. The fundamental focus is on Science for Citizens via a focus on scientific literacy. This is intended for all school pupils. Pupils who wish to study more specialised Science for Scientists courses are able to do so. http://www.21stcenturyscience.org/ This change in the focus of school science education led to the need for inservice courses for teachers and further consideration of their views of NOS. Halloun (2005) suggests a linkage between views about NOS and the way that teachers present science to their classes.

Part of the reason for the prolonged interest in NOS in pre-service teacher education is disagreement about what should be included in NOS instruction (Ref). (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003) attempted to find a consensus in a British context about which 'ideas-about-science' should be included in school science carrying out a three phase Delphi process with experts from a range of disciplines related to science education. These ideas were compared to the list compiled by (McComas *et al.*, 1998) and a large amount of overlap was found.

(Osborne, 2007) carries these ideas further and argues "that the primary goal of any science education should be to develop scientific literacy". He goes on to discuss what this would mean for Science Education. The strongly argued case for scientific literacy links with changes made to the Science Education Curriculum in England and Wales through the Twenty First Century Science course, (Millar & Osborne, 1998). Some of this debate has filtered through to the school science community through chapters in text such as Harlan and Qualter (2004) Newton (2005) in the primary school sector and Kind and Taber (2005), Newton (2005) and Wellington and Ireson (2008) in the secondary school sector.

NOS - Scotland
The Scottish context for Initial Teacher Education is different. There is little or no published material academic about the role of NOS in school science education in a Scottish context, perhaps because of the worldwide debate. However, there is discussion about what should be included about NOS in the curriculum. Recent curriculum documents such as Learning and Teaching Scotland Guidelines 5-14 (1992) and (2000) discuss what should be included in the primary and lower secondary school and specified developing informed attitudes as one of the strands for science. The Scottish Consultative Council on the Curriculum later discussed the role of scientific capability to emphasise the potential for action as well as developing knowledge, Graham (1996). These ideas were not taken forward. The Scottish Science Consultative Committee (2003) suggested that all pupils not studying science at Higher level (post-16) should take a course on science for citizenship. The development of the science learning outcomes for A Curriculum for Excellence is currently under review, but the documents contain no explicit statements about NOS or what should be taught regarding NOS. The constructivist approach espoused reveals *implicit* values about NOS, but the practical effect of this is likely to be small – see (Abd-El-Khalick & Lederman, 2000).

Methodology

This study involved repeating a questionnaire based on McComas et al (2) prior to the first and second periods of school experience and following the third and final one towards the end of the course. 74 student teachers were in the study group were analysed in relation to several factors including the first or second teaching subject, Biology, Chemistry or Physics; home or overseas, gender, subject combinations and the subject of their degrees and previous postgraduate qualifications.

<u>Calculating a Teaching Score</u>
It was necessary to develop a method to rate the students' progress as they moved through the course and three blocks of teaching practice. A profile is maintained for students after each block of teaching practice. The profile combines the results of assessed tutor visits and the school's summary of the student's progress. This gives a grade in six categories when the

results are combined by tutors at the end of each placement. To give an indication of students' progress through the course, these 18 grades were aggregated into a "teaching score". This was done using the method developed to provide a numerical score for students taking the Joint Honours Science with a Teaching Qualification degree.

The available grades were Not Yet Satisfactory, Satisfactory and Merit. Each grade was given a mark of 5, 10 and 15 respectively. The total for the 18 grades was combined to give a percentage. Most students obtain 18 Satisfactory grades, which would give a teaching score of 60%. A student gaining 18 Merit grades would gain a teaching score of 90%, the maximum possible. A student with any Not Yet Satisfactory grades, not balanced by a Merit grade, would obtain a net teaching score of less than 60%. (The minimum teaching score for a student with 18 NYS grades would be 30%.)

It was decided to use all 18 interim grades to calculate the teaching score rather than the final student profile for a number of reasons. The vast majority of students successfully complete the course with a final profile of 6 Satisfactory grades or better. If there are any Unsatisfactory grades in the final profile, the student is given the option of an Additional Placement to reach the Standard for Initial Registration with the General Teaching Council for Scotland (GTCS). However, each year a number of students who have recorded Not Yet Satisfactory grades in any area(s) successfully achieve Satisfactory grades by the time they complete the course. The overall profile of the 18 grades gives a better indication of the spread of attainment than the final profile alone. The teaching score generally shows an improving trajectory.

<u>Research Questions</u>
What are student science teachers' initial views about NOS?
How do these change over the course of the PGDE programme?
What is the effect of current PGDE teaching about NOS?

<u>Constraints on Survey Instruments</u>
There were a number of practical constraints on this piece of research. The aim was to survey the student teachers' attitudes to science at three points during a year long course. This suggested the use of a short survey instrument. This preference was reinforced by the requirements of course monitoring which require students to complete 2 or 3 surveys at the completion of each of the three blocks of teaching practice. To avoid overloading the students, the additional questionnaire – which would only be completed by volunteers – required to be short.

<u>Choice of Survey Instruments</u>
There are a variety of survey instruments available to explore aspects of the respondents' attitudes towards science, showing current interest in this topic. Many of these instruments are designed to be subject specific rather than generic. The response options vary from forced-choice Likert scales to Contrasting Alternatives Design (CAD) and free response questions. A CAD design requires respondents to choose between a weighted combination of two options. (I. Halloun & Hestenes, 1998). A number of these instruments will be considered and the choice of a suitable instrument discussed. (See Table 1)

A number of the instruments can be rejected immediately because they are aimed at students studying physics or physics and chemistry. This means that the items used are too specific to

be used with biology students. This category includes the Colorado Learning Attitudes about Science Survey, CLASS, (Adams *et al.*, 2006);
Epistemological Beliefs Assessment for Physical Sciences, EBAPS (White, Elby, Frederiksen, & Schwarz, 1999); the Maryland Physics Expectations Survey, MPEX, (Redish, Steinberg, & Saul, 1998); and the Views about Science Survey, VASS, (I. Halloun & Hestenes, 1996).

The Beliefs About Science and School Science Questionnaire, BASSSQ, (Aldridge *et al.*, 1997) was influenced by the context of the teacher respondents thinking. There also seemed to be a confusion between whether answers related to science or school science. Consequently, this was not further considered.

Student Understanding of Science and Scientific Inquiry, SUSSI, (LIANG *et al.*, 2008) was published too late to be considered for this research.

The Thinking about Science Survey Instruments, TSSI, (Cobern, 2000) was initially designed to be used with pre-service elementary teachers. Initial consideration suggested that this may have been useful. Using a survey initially designed for pre-service elementary teachers with pre-service science teachers would require validation. However, Cobern suggested this as a further step in the development of TSSI. Nevertheless, the length of the questionnaire meant that it was not used in this research.

The Views on Science-Technology-Society survey (VOSTS) (Aikenhead, Ryan, & Fleming, 1989) was developed from the views of Canadian high school students and reflects their opinions about NOS among areas. It is likely that the items in the survey reflect a range of views among the public about science, technology and society (STS), and could therefore be used The number of items (114) means that a selection would need to be made for use with the student teachers – assuming that the items would reflect their range of views. However, each item has a large number of responses (often 10 or more). This means that an accurate view of students' beliefs about STS can be obtained, (Aikenhead & Ryan, 1992). Aitkenhead and Ryan argue that this is easier for most high school students than writing a paragraph about what they think and more accurate than completing a Likert scale. VOSTS was not chosen because of the need for three administrations.

The last instrument considered was the Views on the Nature of Science survey VNOS, (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). This instrument was designed to be accessible to all rather than being discipline specific. VNOS is also interested in teachers' views about NOS, (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2001). The open-ended response format allows rich data to be gathered, but each administration of VNOS would take about one hour. Additionally, it is recommended that a follow-up interview be given after answering the questions. The time taken for administration and the follow-up interviews needed make VNOS too time consuming for this research.

Overall most of the instruments discussed above are unsuitable to survey the views of student teachers of science about NOS because they are aimed at Physics students in particular or physical science students. Additionally, some of the instruments ask about the respondents' attitudes to learning physics or physical science, which would be interesting but not relevant to this initial exploration. TSSI would be an interesting option, but contains too many items with too many choices for a test and re-test research design. VOSTS again would be an interesting choice, but contains too many items. VNOS would provide detailed information, but be too time consuming.

Having eliminated the instruments discussed above, it was necessary to find an instrument to explore the student teachers' views about NOS. One view of the common features of NOS is given in (McComas *et al.*, 1998). This view is summarised on page 18 of (Ratcliffe & Grace, 2003), see Appendix 1. Ratcliffe and Grace is a text which is aimed at helping teachers to explore teaching socio-scientific issues with their pupils. This suggested that it would be a useful starting point for this small-scale piece research.

The McComas *et al* summary of the consensus about the nature of science was used to explore the student teachers' views about NOS using a forced-choice 4-point Likert scale. The 14 items in the questionnaire were thought to be sufficiently short to enable testing at three points during the academic year. Previous experience using the questionnaire with a cohort of physics students on one occasion had suggested that there was likely to be a wide range of agreement and disagreement with some of the items used.

Table 1 Survey Instruments used to Investigate Students' Views about the Nature of Science

Survey Name	Author(s)	Area(s) covered	Target Audience	Response type
BASSSQ - Beliefs About Science and School Science Questionnaire	Aldridge *et al* (1997)	Attitudes to teaching and learning science	School pupils or teachers	40 Likert type questions
CLASS – Colorado Learning Attitudes about Science Survey	Adams *et al* (2006)	"beliefs about physics and about learning physics"	Physics students	42 questions Likert-scale
EBAPS – Epistemological Beliefs Assessment for Physical Sciences	White *et al* (1999)	Structure of scientific knowledge Nature of knowing and learning. Real-life applicability Evolving knowledge Source of ability to learn	Physical science students at high school or college – taking algebraic courses	Multiple choice 5-point scale
MPEX - Maryland Physics Expectations Survey	Redish *et al* (1998)	"Student attitudes, beliefs, and assumptions about physics"	Physics students at university	34 questions Likert-scale
SUSSI - Student Understanding of Science and Scientific Inquiry	Liang *et al* (2008)	"students views on the nature of scientific knowledge development"	Pre-service elementary teachers	Likert-type items and related open-ended questions
TSSI - Thinking about Science Survey Instruments	Cobern (2000)	"quantitative instrument for assessing socio-cultural resistance to, and support for, science"	Pre-service elementary teachers	60 questions Likert-scale

Table 1 Continued.

Survey Name	Author(s)	Area(s) covered	Target Audience	Response type
VASS Views about Science Survey	Halloun and Hestenes (1996)	"Student views about physics and physics learning"	Physics students	Contrasting alternative design (CAD) (choosing between combinations of two options)
VNOS - Views on the Nature of Science	Lederman *et al* (2002)	Various aspects of NOS	All students	Open-ended questions and follow-up interviews
VOSE - Views on Science and Education Questionnaire – based on VOSTS	Chen (2006)	"concepts of the nature of science (NOS) and relevant teaching attitudes"	Teachers	15 questions – copy not available
VOSTS - Views on Science-Technology-Society	Aikenhead *et al* (1989)	Based on views of Canadian High School students about STS	All students	114 multiple choice questions Many responses

<u>Use with Student Teachers</u>

Once an instrument was chosen, it was used with the student teachers on three occasions. The questionnaire was administered to students during the first week of the course to establish baseline data before any tutor input or school experience. The questionnaire was also administered on the day the students returned from their third and final block of teaching practice. This was the last day that all the students would be present together. The second test was administered halfway between these two points when the first eight weeks of teaching practice had been undertaken and approximately two thirds of the classroom input from tutors.

Participants

The study group were 74 students enrolled in the one-year preservice Professional Graduate Diploma of Education (Secondary) in 2007. Quotas for funded places on the PGDE(S) are established annually by the Scottish Funding Council in response to the Scottish Government's projections on teacher supply that are derived from annual statistical analysis. Teaching subjects are broadly categorised into areas of priority and each University determines the balance of student numbers. The registered student numbers and gender following each subject as a first teaching subject is indicated in table 2.

Table 2 Student numbers by subject and gender at the start of the course

	Female	Male
Biology	23	2
Chemistry	22	5
Physics	7	15

The biology class included 2 female students who were following chemistry, and one who was following PE, as a second teaching subject. Overseas female students came from Canada (2) and Nigeria (1). The chemistry class included 3 female students who were following biology as a second teaching subject and one who was following a part time pathway. Two overseas students, both women, came from the United States and from Tunisia. The physics class included two women from overseas (India) and 1 female student who was following chemistry as second teaching subject, as well a qualified teacher from Africa.

Data collection
For each of the student teachers, three administrations of a questionnaire with fourteen items gives a maximum of 42 data points per person. The results were examined for student teachers taking only one subject or a first teaching subject in biology, chemistry or physics and then for all the student teachers combined. The final numbers are slightly less than the figures quoted in Table 2 because of withdrawals from the course.

Overview of results
Table 3 shows the overall average score for each item for physics, chemistry and biology student teachers as well as the overall average scores and the average score for each group. The results assume that the Likert scale can be treated as an equal interval scale. A score of 1.0 would indicate complete agreement with the statements about NOS. A score of 4 would indicate complete disagreement. Since a score of 2.0 indicates agreement with the statement, anything more than 2.0 indicates some level of disagreement with the statement.

In most cases, the students agree rather than disagree with the statement they were evaluating. Making a cut-off at 2.0 to select the statements the student teachers disagree most with, still gives a low level of disagreement.

Setting a cut-off of 2.0 for statements, only 2 statements showed some level of disagreement and all three groups disagreed with only one statement. In all three cases, the level of disagreement is very slight. Only the chemistry student teachers disagreed with Statement 12 that “science is part of social and cultural traditions.” Both physics and chemistry student teachers disagreed with the Statement 2 that “Scientific knowledge is durable, but tentative.” It is difficult to know if they disagreed with the durable part of the statement or the tentative part of the statement or both.

Statement 7 that observations are theory-laden is the only one with a high level of disagreement across all the groups. Statement 2 that scientific knowledge is durable but tentative is not supported strongly by the physics and chemistry groups. The chemistry cohort also slightly disagrees with statement 12 about science being part of social and cultural traditions.

Table 3 Combined results for all items and all groups of student teachers at the end of the course.

Item	Average score for Physics	Average score for Chemistry	Average score for Biology	Average score for all student teachers
Q1	1.4	1.7	1.6	1.6
Q2	2	2.1	1.8	1.9
Q3	1.4	1.4	1.4	1.4
Q4	1.8	1.9	1.8	1.8
Q5	1.4	1.3	1.3	1.4
Q6	1.3	1.2	1.2	1.2
Q7	2.5	2.2	2.1	2.3
Q8	1.6	1.5	1.6	1.6
Q9	1.4	1.4	1.3	1.4
Q10	1.6	1.6	1.6	1.6
Q11	1.5	1.8	1.7	1.7
Q12	1.8	2.1	1.8	1.9
Q13	1.3	1.5	1.5	1.4
Q14	1.8	1.8	1.8	1.8
Average score for each group	1.6	1.7	1.6	1.6

Table 4 looks at the statements order of agreement by the entire cohort of student teachers.

Table 4 Statements ordered by level of agreement of all student teachers

Item	Statement	Average Score
Q6	Scientists require accurate record-keeping, peer review and replicability.	1.2
Q5	New knowledge must be reported clearly and openly.	1.4
Q9	People from all cultures contribute to science.	1.4
Q3	Scientific knowledge relies heavily on observation, experimental evidence, rational arguments and scepticism.	1.4
Q13	Science and technology impact on each other.	1.4
Q8	There is no one way to do science.	1.6
Q1	Science is an attempt to explain natural phenomena.	1.6
Q10	Scientists are creative.	1.6
Q11	The history of science reveals both an evolutionary and a revolutionary character.	1.7
Q14	Scientific ideas are affected by the social and historical milieu.	1.8
Q4	Laws and theories have different roles in science.	1.8
Q12	Science is part of social and cultural traditions.	1.9
Q2	Scientific knowledge is durable, but tentative.	1.9
Q7	Observations are theory-laden.	2.3

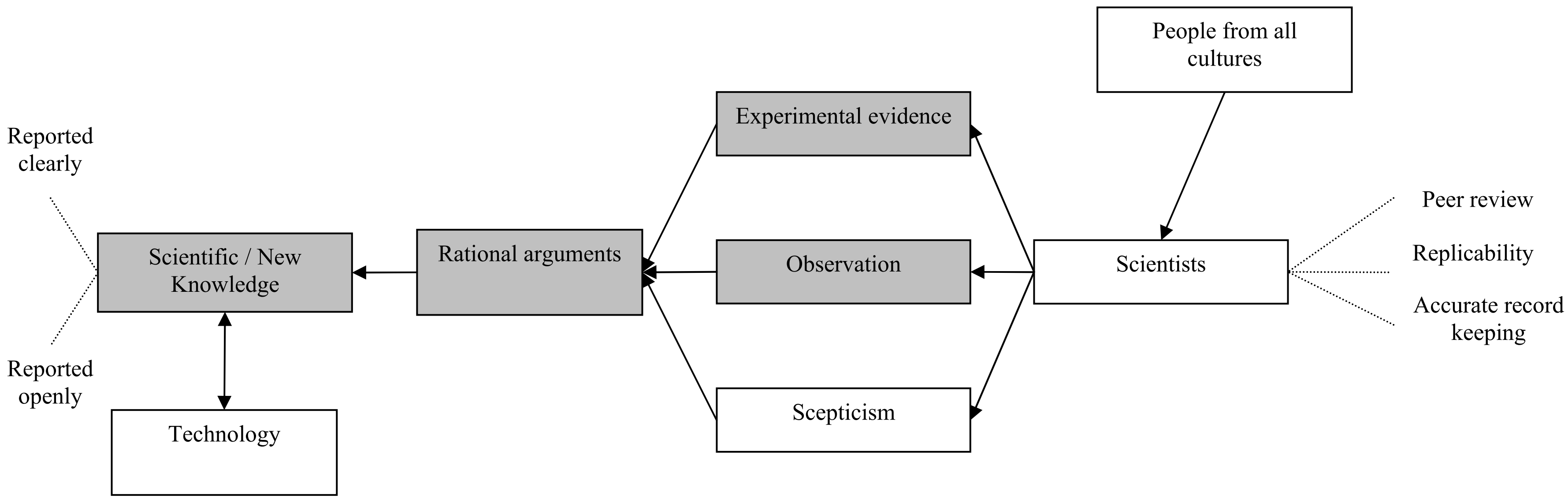

Figure 1 **Student teachers' views of NOS drawn from their top five responses. The shaded boxes show overlap with the "caricature" view of NOS drawn from Chalmers (1999).**

All three groups of student teachers disagreed with Statement 7 that "observations are theory-laden." The idea that observations are straightforward and are not influenced by theory is a common misconception about science among non-scientists, Chalmers (1999), and science graduates with no training in NOS or philosophy of science, Halloun (2001).

Table 4 shows the statements given to the student teachers in descending order of agreement. The strongest agreement (score less than 1.5) is for the first five statements. These statements were used to develop a tentative core model for the student teachers' views about science, shown in Figure 1. This is compared to a core model of non-scientists view of science taken from chapter 1 of Chalmers (1999) in figure 2.

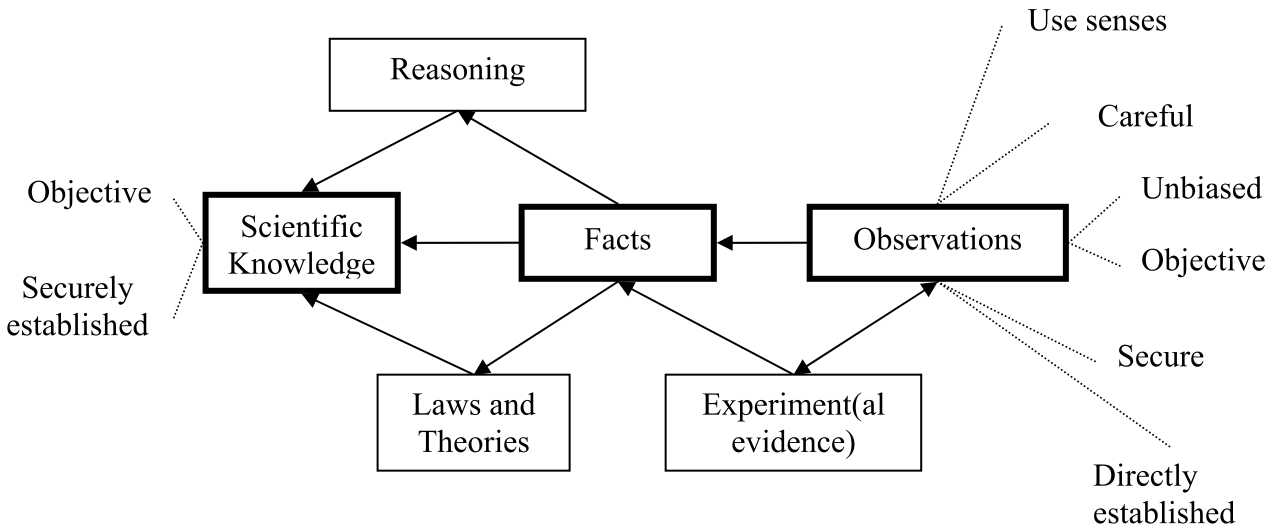

Figure 2 Interpretation of Chalmers's (1999) "caricature" view of science

The student teachers' core model shows similarities with the "caricature" view of science identified in Chalmers. More interestingly, it also shows a common model of doing science which contrasts with the sixth statement in Table 4 that "there is no one way to do science."

Changes of opinion

The results did not show any systematic trend in the development of student teachers' ideas about NOS within or between subjects. The overall change of mind about NOS was +0.1 for each group. Table 5 shows the number of changes of opinion for a particular question broken down by subject and given as percentages to allow for comparison.

Table 5 Number of students who changed their answers for a particular item.

Item	Number of changes per item for Physics (n = 21)	Percentage change per item for Physics	Number of changes per item for Chemistry (n = 23)	Percentage change per item for Chemistry	Number of changes per item for Biology (n = 22)	Percentage change per item for Biology
Q1	7	33%	7	30%	11	50%
Q2	6	29%	8	35%	7	32%
Q3	5	24%	9	39%	12	55%
Q4	12	57%	8	35%	10	45%
Q5	7	33%	7	30%	6	27%
Q6	8	38%	7	30%	5	23%
Q7	5	24%	11	48%	9	41%
Q8	9	43%	7	30%	8	36%
Q9	10	48%	8	35%	10	45%
Q10	9	43%	9	39%	6	27%
Q11	10	48%	9	39%	8	36%
Q12	7	33%	6	26%	10	45%
Q13	4	19%	8	35%	11	50%
Q14	12	57%	10	43%	6	27%
Total changes / percentages	111	38	114	35	119	40

Although there is no overall change of opinion, just over a third of the questions had students strengthening, weakening or reversing their positions. This indicates that there are some changes of mind over the course of the year.

Strengthening or weakening opinions

There is no clear pattern in the changes of opinion where, for example, agreement strengthen or weakened but remained agreement. For the physics student teachers, changes of opinion were most likely to happen (> 50%) for statement 4 that laws and theories have different roles; statement 9 that people from all cultures contribute to science; statement 11 that the history of science reveals an evolutionary as well as revolutionary character; and statement 14 that scientific ideas are affected by the social and cultural milieu. Generally agreement strengthened for statements 4 and 14 and remained about the same for statements 9 and 11.

The chemistry student teachers did not have a high likelihood of changing opinions for any of the statements.

For the biology student teachers, changes of opinion were most likely to happen for statement 1 that science is an attempt to explain natural phenomena; statement 3 about the qualities needed for scientific knowledge; and statement 13 that science and technology impact on one another. The changes for statements 1 and 13 were approximately the same. However, there was strengthening of agreement about the evidential base for scientific knowledge.

Reversals of opinion

There is perhaps a clearer pattern for reversals of opinion – changing from agreement to disagreement or vice versa. The physics and chemistry student teachers strengthened their views about science being part of social and cultural traditions. All three groups of student teachers strengthened their agreement with the statement about observations being theory laden.

Using the Teaching Score to Predict Attitudes to Science

There is absolutely **no** correlation between teaching score and the students' view of the nature of science obtained from the McComas *et al* questionnaire. Given that (I. A. Halloun, 2001) suggests that such a correlation is common among American and Lebanese students, it would be expected that such a correlation would be found among British students. The lack of correlation` suggests that the questionnaire was not the correct instrument to explore the students' views about NOS.

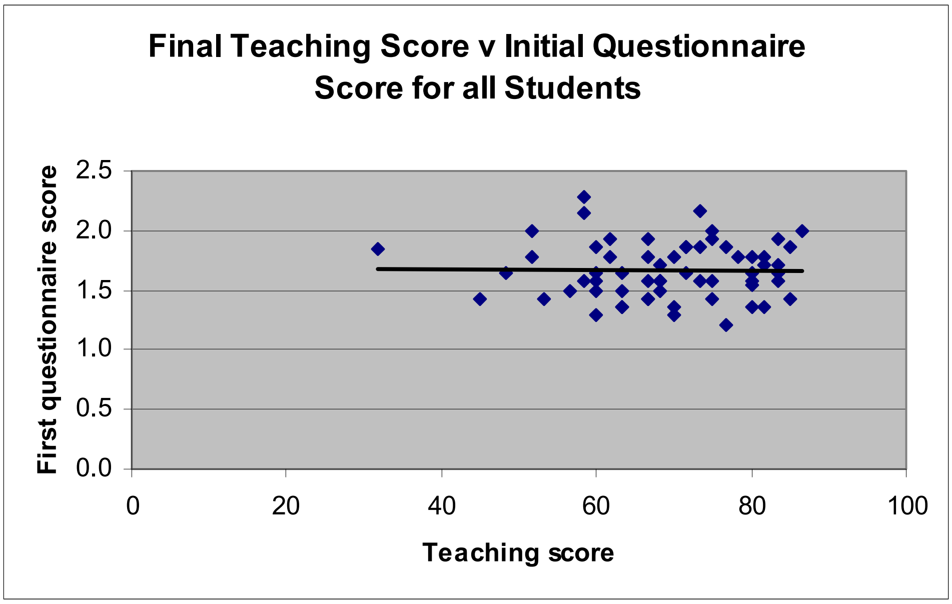

Figure 3 Correlation between student teachers' teaching scores and their initial average score on the NOS questionnaire shows no correlation, R =

The results show no correlation between the students' initial views about NOS and their final teaching scores, $R^2 = 0.0049$. Given that the literature suggests that most studies find a relationship, it suggests that the questionnaire used was not an appropriate instrument. Experience with an earlier cohort of physics students suggested that the questionnaire did succeed in provoking discussion among physics students, particularly about the theory-laden nature of observations. In view of the comments made about the different instruments, what is the next step forward?

Discussion

Choice of Survey Instrument

The wide range of survey instruments available to investigate views about NOS means that care has to be taken when choosing an appropriate instrument for a particular purpose. The (McComas et al., 1998) summary of the nature of science was useful in provoking debate, but did not discriminate sufficiently between the views of the students. This meant that in-depth changes of view could not be tracked and suggests that a different instrument would have been better.

Table 1 gives information about ten instruments which could be used to assess attitudes towards NOS. SUSSI (Student Understanding of the Science and Scientific Inquiry) was not used in this investigation because it was not fully available until 2008. However, it would seem to be a suitable choice for future work with PGDE student teachers. The instrument has been validated and reliability and Generalisability considered. The combination of Likert scale items and written responses to explain choices would give more insight into students' thinking. In terms of testing and retesting, the authors state that most students can complete the survey within 30 minutes. SUSSI may be a suitable instrument to investigate the effects of future teaching about NOS.

Overview of Results

Previous experience with PGDE physics students suggested that using McComas *et al* to stimulated discussion produced a wide range of views. Using the questionnaire with all the science students produced fairly strong agreement with most of the statements. It is worth trying to explore the reasons for these differences. Students were asked to put their names on the questionnaire so that their response could be tracked over the course of the academic year, even though and reports of results would be anonymous. The first administration of the questionnaire was on the first day that the students had a Curriculum and Pedagogy input for their particular science subject. It is possible that a combination of lack of anonymity and a desire to be seen to give the "correct" answer could have biased the students' answers in a positive direction.

The results as a whole do not show that the PGDE physics, chemistry and biology programmes had an affect on the overall view of student teachers. The overall lack of change hides the fact that some students moved from disagreeing with many of the statements to a more positive view, and necessarily vice versa because of the overall lack of change of position. This supports (Abd-El-Khalick, 2005)'s assertion that explicit teaching about the nature of science is necessary to change learners' conceptions: implicit instruction when discussing pedagogy is not sufficient.

All PGDE courses undergo periodic review as part of the quality assurance programme of the Teacher Education Institutions (TEIs). The next review of the PGDE gives an opportunity for the science team to consider what teaching and learning about NOS should occur and how this could be incorporated into the next iteration of the course. The wider debate within

Scotland about whether the school (science) curriculum should include science for citizens or science for scientists is ongoing.

In the shorter term, there are opportunities to include more explicit instruction about NOS within the TEI science teacher modules. For instance, (Friedrichsen & Dana, 2003)'s card-sort task could be used to encourage student teachers to begin to reflect on their beliefs about NOS and how this will impact on their teaching strategies in the classroom. Plus ref "How do we know that we know what we know"

<u>Questions with the most and least positive responses</u>
The statement with the least agreement is that observations are theory-laden, with a score of 2.3. The naïve view of science discussed in Chalmers (1999) holds that observation is unproblematic and that the link between theory and observation is also unproblematic. Several researchers have found that student teachers of science also hold similar views about the nature of observation. It is possible that the student teachers surveyed here hold a similarly naïve view about the nature and role of observations in science. This may also be reflected in the relatively low level of agreement given to the statements that science is part of social and cultural traditions and that scientific knowledge is durable but tentative. These statements also tend to be problematic for people with little knowledge of NOS, Halloun (2001).

The statements with the highest level of agreement were used to construct a possible model of the student teachers' views about NOS. This model shows a fair level of agreement with the naïve model of NOS constricted from (Chalmers, 1999).

Taken together, this suggests the possibility that although the student teachers appear to hold generally positive views about NOS, they may in practice hold a more naïve view than the results of the questionnaire may suggest. However, the evidence for this is indirect and tentative. They may in fact hold coherent and positive views about NOS.

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Appendix 1 Questionnaire used with PGDE Science Students

Statement Number	Statement	Strongly agree	Agree	Disagree	Strongly disagree
Q1	Science is an attempt to explain natural phenomena.				
Q2	Scientific knowledge is durable, but tentative.				
Q3	Scientific knowledge relies heavily on observation, experimental evidence, rational arguments and scepticism.				
Q4	Laws and theories have different roles in science.				
Q5	New knowledge must be reported clearly and openly.				
Q6	Scientists require accurate record-keeping, peer review and replicability.				
Q7	Observations are theory-laden.				
Q8	There is no one way to do science.				
Q9	People from all cultures contribute to science.				
Q10	Scientists are creative.				
Q11	The history of science reveals both an evolutionary and a revolutionary character.				
Q12	Science is part of social and cultural traditions.				
Q13	Science and technology impact on each other.				
Q14	Scientific ideas are affected by the social and historical milieu.				