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Trainee teachers' perceptions of the Nature of Science and implications for pre-service teacher training in England

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This paper is an English perspective on the Liang study (2006) into educational contexts for schooling in science; the linkage between teachers' understanding of the Nature of Science (NoS) and their effectiveness as educators. The work reflects on the basic training received by pre-service teachers in secondary science at the University of London (UEL), and a number of interventions introduced to enhance their awareness and discrimination of NoS. The study is a three-year longitudinal design and intended to probe trainee teachers' perceptions of NoS. It explores how these notions may be affected by the training experienced in both the university and school placement in the context of the new Science National Curriculum for Schools (England). The new science curriculum requires pupils to be engaged at a deeper level of conceptual and procedural understanding. It is considered important that trainees have a sound understanding of NoS in order to facilitate learning in this aspect of the curriculum (Bartholomew 2004). The study has informed where to fine-tune the training experience to support trainee teachers in this area. Two successive cohorts of pre-service teachers were given the Student Understanding of Science and Scientific Inquiry (SUSSI) instrument before and after their formal Postgraduate Certificate in Education (PGCE) training. The results at the end of year one informed the interventions introduced through year two. Results indicated that the interventions had a positive effect in some areas, but mixed in others. The project was extended to a third year to extend the dataset to more accurately track developmental trends.

Keywords: Nature of Science (NoS); How Science Works (HSW); Pre-service Teacher Training; Programme Interventions; SUSSI Instrument.

Introduction

Developing trainee teachers' knowledge and understanding with respect to the Nature of Science (NoS) has been considered by a range of authors (eg Liang 2009; Abd-El-Khalick 2005; Liu 2007; Seung 2009). Bartholomew (2004) suggests that the breadth of understanding of NoS influences a teacher's ability to engage with the subject and determines their ability to teach effectively. Authors such as Martin-Diaz (2006) have chronicled the demands for increased understanding of NoS in teacher training programmes and the factors impacting on teacher development in this area. In this respect, Bartholomew identifies the importance of components of NoS as central elements of the science curriculum in England and that a more in-depth investigation into trainee teachers' understanding of NoS offers a means of identifying salient aspects of pedagogy for initial and in-service training.

NoS may be considered to refer to the sociology and philosophy of science and as such has involved much debate, particularly in relation to which aspects of NoS should be incorporated into the school curriculum (Osbourne 2003). Liang et al (2009) suggest a consensus has emerged allowing for broad agreement on the relevance of NoS for the school science curriculum and identify components of NoS that offer a core for knowledge development for teachers. It was with an aim to explore trainee NoS knowledge and understanding and ways in which pre-service training might facilitate development in this area that this longitudinal study was embarked upon.

Approximately 40 pre-service science teachers are trained at the Cass School of Education, UEL for the secondary science UK context each year. Trainees undertake a one-year postgraduate programme that incorporates significant elements of school-based training in addition to university-led pedagogy input. Incoming trainee teachers at this institution come from a range of ethnic and cultural backgrounds with entry qualifications, personal experiences and understanding of science that vary widely. The purpose of this work is to establish students' prior understanding of NoS, evaluate the added value through the whole pre-service training experience and determine the shape and content of any intervention strategies that may become apparent.

Theoretical context

Bartholomew (2004) identifies the importance of the components of NoS as a central element of the school science curriculum in Great Britain. He determines strong links between teachers' depth of understanding of NoS and the ability to effectively teach science. This provides the means of identifying salient aspects of pedagogy for initial and in-service training.

Abd-El-Khalick (2000) assesses the 'effectiveness' of attempts undertaken to improve prospective and practising science teachers' conceptions of NoS. He categorises these into two general approaches: implicit and explicit. *Implicit* attempts utilised science process-skills instruction or engagement in science-based inquiry activities to improve science teachers' conceptions of NoS. He found that to achieve the same goal, *explicit* attempts used instruction geared towards various aspects of NoS and/or instruction that utilised elements from the history and philosophy of science. The explicit approach was relatively more effective in enhancing teachers' views. The relative ineffectiveness of the implicit approach could be attributed to two inherent assumptions. The first is that developing an understanding of NoS is an 'affective', as compared to a 'cognitive', learning outcome. The second ensuing assumption is that learners would *necessarily* develop understandings of NoS as a by-product of engaging in science-related activities. Abd-El-Khalick emphasises that explicitness and reflectiveness should be given prominence in any future attempts aimed at improving teachers' concepts of NoS.

Clough (2007) proposes that understanding NoS is critical particularly in respect of misconceptions in science. The significant misunderstandings that both students and teachers hold regarding NoS are particularly damaging to general scientific literacy because they affect students' attitudes toward science and science classes. A better understanding of scientists and the scientific community will enhance an understanding of science's strengths and limitations; interest in science and science classes; social decision-making; instructional delivery; and the learning of science content.

Liu (2007) carried out an international collaborative study of pre-service teachers' views about NoS. This indicated strongly that teachers do not typically possess coherent and informed views of NoS. In particular, different cultures and nationalities may hold quite diverse and distinct perceptions and understanding.

Research design

This work is a longitudinal study based on an inductive–interpretive mixed methods study drawing on the strengths of both positivist and constructivist approaches.

Sample

This study involved two consecutive cohorts of pre-service teachers (n = 35 and n = 40). Trainees ranged in age from 21 to 50, were of both genders, represented a wide range of socio-economic backgrounds, and were drawn from a cross-section of minority ethnic groups in the UK. Educational background varied significantly, from doctorate-level science qualifications to undergraduate degrees with a significant element of science content, to a subset having degrees in other subject areas but having gained heightened subject knowledge through intensive subject-knowledge enhancement programmes prior to commencement in teacher education. All trainees were involved in each stage of the study. Ethical protocols were strictly adhered to, responses were anonymous and data aggregated to indicate trends only.

Instrument

An adapted version of the Student Understanding of Science and Scientific Inquiry (SUSSI) questionnaire was used to gain the views of the participating trainee teachers (Liang 2009). The questionnaire focuses on six themes in NoS. The research team adapted three of the six themes to reflect the UK environment. The adapted instrument provided for investigation of trainee views in the following areas: *Observations and Inferences*; *Nature of Scientific Theories; Scientific Thinking and Technology; Social and Cultural Influences on Science; Imagination and Creativity in Scientific Investigations; and Scientific Investigations.* Each of the six themes contains four questions that drill deeper to test contextual understanding of the section.

The instrument was structured on a five-point Likert scale which allowed the participant to explore, and comment on, issues ranging from 'naive' (strongly disagree) to 'informed' (strongly agree) views about NoS. It is to be noted that there has been significant debate concerning the range of possible responses to NoS and the authors of this paper have used the SUSSI instrument and the presentation of informed and naive views presented in Liang (2009) as the baseline against which responses were measured and graded. This allowed for the datasets from each cohort to be analysed in terms of the trainees' level of alignment with informed views of NoS.

In this paper, discussion is confined to the quantitative data from the Likert-type items and does not consider open-ended responses which form part of the full SUSSI instrument. It is recognised that this limits the validity of the findings, as the open-ended questions do provide the participants with the opportunity to expand upon their rating of the items. Early responses from trainees indicated very limited engagement with the open-ended questions. This together with the sample size of responses was too small to provide significant change to the Likert datasets. The survey tool was used at the start of each training year (across the two years), prior to any significant training input on NoS, other than introduced to the Science National Curriculum. The survey tool was then completed in the final week of the training programme.

Interventions

One of the aims of this project is to determine the overall awareness of NoS among pre-service teachers so that, if necessary, course structure and input can be modified to ensure trainees are best prepared for entry into the teaching profession. In year one, pre- and post-course student awareness was measured with no modifications. Data analysis would reveal the areas of weakness and this in turn would indicate some action and additional input that might be beneficial in improving areas of weakness. This 'additional input' is called an intervention. The process is iterative, with analysis of each year indicating success or failure of a particular intervention and informing the process of further modifications and inputs.

In year one (2008/09), there were no formal interventions other than the normal curriculum and content of the Initial Teacher Training course. In year two (2009/10), additional input was given to trainees in the early part of the course: Thinking skills – two lectures; CASE (Cognitive Acceleration through Science Education) – two lectures; Theoretical input on 'How Science Works' – one lecture; and practical work on How Science Works in the classroom (one taught session).

Discussion

Data were processed and presented in several formats: raw numbers, percentages and histograms showing 'before and after' course comparisons. The SUSSI paper also provided a set of 'correct' answers to each question. These were used as a baseline against which all answers were measured. It is these comparison figures that were used for analysis and interpretation. To make data handling and analysis a little easier, the top two (strongly agree and agree) and bottom two (strongly disagree and disagree) categories on the Likert scale were conflated, which reduced the scale to: disagree – uncertain – agree.

The two cohorts could be considered broadly typical intakes for this provision. In terms of age and ethnicity the profiles were similar; however, the gender balance was different. The 2008/09 cohort was 1:2 male/female; the 2009/10 group was 1:1 male/female.

Analysis of the initial pre-course survey for both groups again showed broadly similar perceptions at the outset of their course, with the second cohort a little closer to the correct answers in some categories. For the purpose of this shortened paper, discussion is limited to general average responses, indicators and implications.

Looking at the results at aggregate level, the overall conclusion is one of mixed outcomes. The data do not indicate consistent improvements pre- and post-training; before and after intervention. In the first year, the year without intervention, the results showed a general improvement across many of the categories and no improvement in others. In the second year, the year with the intervention, results gave quite mixed outcomes. There were a few areas of improvement, but many showed no improvement and some showed regression from the correct answers. The lack of improvement and the move into negative correlation has proven difficult to explain. End-of-course questionnaires and focus group feedback has helped to suggest possible reasons.

Trainees found input on How Science Works (HSW) confusing. The principles and underlying concepts were implicit and not clearly understood by trainees. This was then reflected in the practical session that followed where the hands-on experience was much enjoyed, but trainees failed to make the links to the underlying principles of HSW. Critical thinking and CASE sessions were also much appreciated in their own right, but again, on reflection, trainees found that they did not obviously associate these inputs with the conceptual understanding and awareness of NoS. The notion and relevance of NoS in the school placement science departments was absent.

This situation reflects the perception put forward by Abd-El-Khalick (2000), that the engagement with NoS should be explicit and reflective and is a cognitive rather than an affective process. It would appear that trainees had experienced the more implicit approach where learners would develop the necessary understandings of NoS as a by-product of engaging in science-related activities rather than by a process of direct intervention. In view of these conclusions, it was considered appropriate to extend the project for a third year and restructure the interventions to make them more specific and direct.

The data have identified three areas of strong deviation from the correct answers and therefore of specific focus for the restructured interventions. There are areas that diverged consistently by 40–60% from the correct answers across both cohorts. The place of *creativity and imagination* in scientific investigations was clearly an area that caused considerable perplexity for trainees. There was a strong polarisation between those who considered imagination and creativity as having no part to play in scientific work and those who considered it an essential ingredient. The implications are that both the interventions and experience in schools continue to give the strong message that science and scientists are not open to imagination and creativeness in their work. Science is a serious business and requires fixed, systematic and dogmatic methodologies in order to ensure the gravitas and integrity of such work, with no place for emotive and intuitive approaches. The idea that *cultural values and expectations* determined the work undertaken by scientists and how they approached their work also generated a strong polarisation, with the inference that the rigour of the scientific method transcends any cultural values. The implications here are that despite the very diverse trainee profile, issues of cultural influence in scientific work are either not encountered or are positively engaged with during their training. The third area where trainees expressed a wide spectrum of opinions concerned the *place and validity of the scientific method.* The perception is that the scientific method defines the absolute rigour of investigations and holds true under all circumstances. The implication, again, is that the focus of intervention and the school experiences reinforce the idea of rigid, prescribed approaches to scientific method and a continuing strong impression of its absolute factual accuracy. These three areas will become the particular focus of the third year of this longitudinal study.

There were, however, areas where the overall experiences of the training and intervention had a positive effect on pre-service teachers' perceptions of NoS. Students developed strongly informed ideas about the *nature of scientific theories*. Trainees also developed a good understanding of the place of *scientific thinking* and how natural phenomena are described through laws and theories and subsequently linked to developing technologies. Much of the subject work at university and subsequently in schools is based on developing theories, making observations and collecting evidence; all of which help to develop understanding of scientific theories and how they are developed and modified.

Scientific investigations also showed a generally positive response. As with scientific theories above, trainees are exposed to considerable teaching engaging in practical work in the laboratory. This gives them security in a methodical approach and accurate working.

Conclusion

This study has enabled the researchers to focus on a particularly challenging area of the science teacher training curriculum and has provided a way to measure the effectiveness of training and the impact of planned interventions to improve understanding of the Nature of Science. It ties directly to the needs of new teachers in delivering effective teaching of How Science Works in the science curriculum for schools. Our incoming trainees have a wide range of backgrounds, as befitting a successful widening-participation institution, but this can pose challenges for those less well equipped to go on to a teaching career with a weaker background in NoS, and may be considered to be of significance in the process of engaging children and young people in science. The project has been extended to a third year in order to extend the data sample with the aim of clarifying some of the more perplexing results of year two.

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