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AUTHOR Smith, Robin G.
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ABSTRACT

This study was designed to investigate how a sample of primary student teachers developed their understanding of scientific ideas, their perceptions of the knowledge that they needed to teach the school curriculum, the sources of their learning, and their views on becoming teachers of science. Focus is placed on their own understandings of their learning and any changes in their views about the subject. Seventeen preservice students were interviewed at the end of a 3-year program of primary teacher education at the point when they could look back at their learning and look forward to their first teaching position. Interviews focused on their understandings of the knowledge that they needed for teaching science in primary schools. Evidence from tests and self-audits of their science knowledge undertaken earlier in the program was used to prompt their reflection on what they had learned and how their ideas had changed. Their views were sought on how they had learned and on how well prepared they felt for teaching science in their early careers. Completion of the study coincided with the introduction of national standards in England that all students will have to achieve in order to qualify as teachers. These standards include the specifications of pedagogical and subject knowledge in science. The study has immediate significance for informing the processes whereby students' knowledge can be audited and advanced. It illustrates the tensions between specifying standards for teaching and recognizing individual differences among student teachers not only in their knowledge, but also in their approaches to learning. More generally, the narrowing of teacher education to technical-rational prescriptions is questioned. Attention is given to the personal dimension and the relationship that adult learners have to a subject as they make the transition from students to teachers. (Contains 13 references.) (ASK)

Common standards and personal development: Changing ideas of what you need to know.

Robin G. Smith, Sheffield Hallam University, England

INTRODUCTION

17 preservice students were interviewed at the end of a three year programme of primary teacher education, at the point when they could look back at their learning and forward to their first teaching post. The interviews focused on their understandings of the knowledge that they needed for teaching science in primary schools. Evidence from tests and self-audits of their science knowledge undertaken earlier in the programme was used to prompt their reflection on what they had learnt and how their ideas had changed. Their views were sought on how they had learnt and on how well prepared they felt for teaching science in their early careers.

Completion of the study coincided with the introduction in England of national standards which all students will have to achieve in order to qualify as teachers. These include the specification of pedagogical and subject knowledge in science (TTA, 1998). The study has immediate significance for informing the processes whereby studentsí knowledge can be audited and advanced. It illustrates the tensions between specifying standards for teaching and recognising individual differences among student teachers, not only in their knowledge but also in their approaches to learning. More generally the paper questions the narrowing of teacher education to technical-rational prescriptions. It argues for attention to the personal dimension and to the relationship that adult learners have to a subject as they make the transition from students to teachers.

The study is located in the burgeoning research tradition concerned with the nature of the subject knowledge needed for teaching which was stimulated by Shulman (1987). Parallel policy developments in England have emphasised conceptual and factual knowledge, although the latest standards prescribed for student teachers feature pedagogy and incorporate some pedagogic content knowledge (TTA, 1998). Standards for teaching are now found in many countries but there are some differences in the content, style and view of learning that they emphasise. Kennedy (1998) has recently reviewed the research on maths and science knowledge for teaching in relation to standards and educational reform in the USA. She notes how conceptual, pedagogical, epistemological and attitudinal knowledge are all deemed necessary but that ëwe still know very little about how to foster these kinds of deep understanding and reasoning abilitiesí (p. 260). In several countries studies of primary student teachers have investigated the development of knowledge, confidence and attitudes toward science teaching through preservice programs and into their early years in teaching (e.g., in Australia by Appleton, 1995; Ginns & Watters 1995; Skamp, 1997). These indicate the need to link learning of the subject to personal development as a teacher. In the present study the view taken of the studentsí learning was one which acknowledged the influence of their prior experiences and individual perspectives, and the need to examine how students relate to the subject. In this paper the specific argument for learning to teach science is located in a general argument about what constitutes an appropriate model of professional learning for teachers, one within which the personal dimension is recognised but not prioritised over other aspects (Coldron & Smith, 1998; Smith & Coldron, 1996). This is consistent with the social constructivist view of science teacher development presented by Bell and Gilbert (1996) in which ëconstruction and reconstruction of knowledge is both personal and social Ö learners can reconstruct their knowledge through reflectioní (p. 57). A similar position was adopted by Gunstone et al (1993) who conducted a longitudinal study of secondary science teachers during a preservice program and their early years of teaching; their findings led them to propose that teacher education ëmust take account of, and build on, the individualís content, or task-based attributes and competencies, and the more general elements of intellectual competence and performance (e.g., those related to personal awareness, sense-of-self, or professional purpose).í (p.67).

The position outlined above had implications for the methodology:

- Each student should be encouraged to voice their views, assisted to reflect upon their personal development, and provided with evidence to stimulate recall of their learning.
- It was necessary to use multiple sources of data. Gunstone et al (1993) make the point that the complexity of individual change in their study meant that a single source, such as their questionnaire, yielded inadequate information and that it was essential to have self-report and interview data.
- It was essential to collect individual studentsí accounts of their experiences and to record their expressed views.

THE STUDY

The study was designed to investigate how a sample of primary student teachers developed their understanding of scientific ideas, their perceptions of the knowledge that they needed to teach the school curriculum, the sources of their learning and their views about becoming teachers of science. We were especially interested in their own understandings of their learning and any changes in their views about the subject.

The BA (Honours) Primary Education followed by these students was a three year programme leading to qualified teacher status. In each year students worked in schools for several weeks, teaching classes and carrying out directed tasks linked with their university-based courses. Those courses covered the primary curriculum subjects, with particular attention to English, maths and science in all three years; general pedagogical skills and knowledge; and in year 3 some work on curriculum leadership and their own specialist subject. Their subject specialisms had been identified when the students applied to enter the program. In addition to the minimum requirements for admission (GCSE level qualifications in English, maths and science; for school leavers normally advanced level qualifications in at least two subjects) applicants were required to have advanced qualifications in one of the special subjects being offered: English, design and technology, geography, maths or science. Although all students were trained to teach throughout

the primary age range they had identified a preference for Key Stage 1 (ages 5-7) or Key Stage 2 (ages 7-11) and their work reflected this.

All 106 students completing in summer 1998 had undertaken two knowledge tests and had carried out two self-audits of their subject knowledge for teaching the science National Curriculum in primary schools. For the audit they reviewed the Programmes of Study for the science National Curriculum (DfE, 1995), checking each of the individual statements that comprise it to see if they felt confident that their personal subject knowledge was sufficient to teach it. They then transferred that checklist to an optical mark sheet. The first audit was done before they began year 2 of the program, after they had gained some experience of teaching and had taken one science course which had familiarised them with the curriculum requirements. For the second audit this process was repeated after they had completed their last science course in year 3. The two tests were carried out after each self-audit; they dealt with science knowledge in aspects of the school curriculum, drawing upon items from national standard assessments set for pupils in schools. Each test covered similar aspects, spanning the main areas of the Programmes of Study, but the items were not the same. Seventeen students were interviewed individually toward the end of their program. The sample students were selected to include features which might influence their views and development, and to represent differences of experience and achievement within the cohort. There were eight students specialising in Key Stage 1, eight specialising in Key Stage 2, and one student who now expressed an equal interest in both. The sample included:

- Students who had come to the programme directly from school and others who had previous work experience.
- Students with children of their own.
- Some of the small group of students who had joined the programme at the start of year 2 because their prior studies or experience had been accredited.
- Students who had gained only the minimum school science qualifications that were required for entry to the programme and others who had advanced school qualifications in science.
- Some students who were taking specialist options in science teaching on the program, and some taking each of the other specialist subjects available (English, geography, maths, technology).
- Students who had improved their scores substantially between the two tests, some who had made limited progress, some who had scored highly from the start. The sample was reviewed to ensure that all items on the tests were represented so there was evidence of knowledge growth in different aspects of the sciences.

Before the interview each student was sent a photocopy of two test items in which he or she was judged to have made progress because the second score was much higher. The semistructured interviews were conducted individually by the author or a colleague. During the interview the studentsí tests and audits were available to stimulate recall and comment. A schedule was used by the interviewer to ensure similar questions were posed and for keeping brief notes but students were encouraged to extend the conversation and to offer their own ideas on any issues relating to their learning and teaching of science. The schedule covered studentsí recall of their their initial views about how well their knowledge equipped them to teach science, where they had expected to learn things they needed to know and what sources turned out to be most important, their progress in selected areas on the two tests, and their views about teaching science in their first jobs. Each interview was audiotaped with the studentís permission and subsequently transcribed. Names used below are not the studentsí real ones.

ANALYSIS AND FINDINGS

All transcripts and schedule notes were inspected to identify themes; these were listed on a matrix. Each transcript was then analysed to produce a summary in the matrix, with references to the raw data. Both researchers carried out this process and compared their interpretations. Appendix 1 summarises the responses to the interviews. The overall picture is described below and individual perspectives are presented through the words of three students.

No students reported that at the start of the programme they had felt there was too much knowledge for them to learn, although several recalled being anxious about teaching science. A majority had felt that their existing knowledge was adequate as a starting point but that they would have to do a lot of work in order to build upon it. Students who had previously studied science to an advanced level had felt confident about their personal subject knowledge, apart from a few gaps in topics which they had not covered. All students articulated the need to learn ways of teaching and there was a growing recognition of their need for pedagogic content knowledge, most often expressed as understanding how to explain science to pupils. By the end of the programme students with advanced science qualifications had come to realise that their previous scientific achievements did not guarantee they understood the subject in ways which equipped them to teach it (David: ëto explain it to someone else you have to understand it at a deeper level, and to explain it to kids who donít know any of it you have to understand it inside outí).

There was evidence of growth in knowledge and confidence by all students, and many had systematically tackled the ëgapsí identified by their initial audit and test. Students had learnt from various sources (modelling and instruction by tutors, workshops, reading, assignments, planning and teaching, experience with children). There were differences between individuals in the weighting they gave to these. Initially many students had anticipated that much of their learning would be received from lecturers (14 ranked this as the main source). By the end of the programme although tutors and their taught courses in university were still cited most often as sources of their progress in the identified areas this rarely represented a passive approach. Many articulated how they had come to see active learning through personal study as crucial (Sajida: ëthey just give you a flavour and youíve actually got to go out and research it and go into detailí). Some commented that a standardised approach was inappropriate when learners varied so much (Susan: ëso itís hard when people are coming from different backgrounds to fill in those gaps. I think youíve got to do it yourselfí). Asked how they expected to build up knowledge in their teaching posts, when they would no longer have access to the lecturers and university courses, colleagues and friends were still rated highly, closely followed by books. There was little reference to using systematic professional development through in-service provision and no student volunteered that they would use information technology. All students were positive about teaching science in their first posts, even those who had started with the least knowledge and confidence viewed it as a valued part of their job, and two more confident students actually said ëIíd die if I couldnít teach it!í.

Individual Case Studies

This section presents the views of three students who illustrate some common themes and some individual perspectives.

David was a mature student with experience of child care work who had entered the course at the start of year 2. He was was specialising in maths but was very confident about his personal subject knowledge for teaching science because of his engineering background and advanced level qualifications in physics and chemistry gained at school many years previously. ëI looked at the National Curriculum and thought Iíve done all this and Iíve done O level biology as well and I thought Iíll just be able to when it

comes to doing a lesson, Iíll be able to look it up again and it will all come back.í But he ëhadnít really thought about how to turn scientific knowledge into explanations that kids can understand, thatís the tricky bitî. He had expected to learn this pedagogic content knowledge from a mixture of sources, including tutors and books but mainly through teaching practice. That view had been influenced by a friend who had done a postgraduate teacher training course and who had told him that all his learning had come from teaching practice and not from college. When David was asked to look back at what he himself had learnt about science on the programme he began with his comments that implied revision of inert knowledge (ëyes I do know a little bit more, but itís more been brought back a bit more, because itís 19 years nowí) but went on to reflect upon the nature of knowledge and how it is held

ë also knowledge seems a lot different now, when I was at school it was more fact based and I knew a lot of facts Ö The knowledge was different and I needed to adapt my knowledge a bit I think to a deeper understanding. And other things that I learned but didnít have an understanding of at the time, if I think about them now I start to get an understanding Ö Iíve looked at things afresh and itís deepened my understanding I thinkí.

By revisiting his sedimented knowledge, learnt previously for school and exams, with a new perspective as a primary teacher he appeared to have amended his view of subject knowledge as well as developing pedagogic content knowledge. He said that this had been helped by seminars on the programme.

ëgoing through things like air resistance and rotation, how to explain them to pupils, it really simplified things and made me think about them again, it just helped me to think things through better. I mean I had formulas in my head that I could apply to things and then I thought "oh, but what does it all mean?" I had to start thinking things through a lot moreí.

Davidís preferred age range was Key Stage 2 whereas Susan, who was specialising in design and technology, was more interested in teaching younger children at Key Stage 1. She also had less science background from her schooling. Both these influences featured in her initial perceptions of the subject knowledge that she needed and how she felt about teaching science. . Before coming on the course she had been ëQuite scared really, because Iíd only done biology at school so I was very apprehensive about itî. However there appeared to be some tension between her concern over having to teach science and her view of how much knowledge a teacher of young children needs She reported that, when doing her self-audit before starting year 2,

ëI was thinking "well, Iíve only got to teach it to five and six year olds" and I wasnít really aware of the knowledge that I needed, my background knowledge needed to be better in order to teach it better. I think I thought I could get away with skimming over the surfaceí.

Susan had identified the areas where she needed to learn more with those subjects which she had not previously studied in school (ësort of chemistry type things, electricity and physicsí) and ëjust thought I would get it from the course, that they would teach me what I needed to know in order to teachî. Although the taught courses did turn out to be a significant source for some of her learning she stressed how important self-study had become: ëI knew we were having another (audit and test) and I knew Iíd done very badly in that one, and in order to be able to teach it I needed to be a lot more confident. So I bought one of the books that Tricia (a tutor) had recommended and I read it from cover to coverî. At first her motivation may have come from the test results and anticipation of a further audit but increasingly it reflected the value that she saw in personal understanding of subject knowledge for herself as well as for her teaching.

ëI think my basic knowledge is a lot sounder than it was, and I really enjoyed doing it, I thought I was doing it because I had to but then I started to enjoy it because it was things Iíd missed in my own education. But I think in school if I knew that I was going to be doing electricity I would read up on it again to make sure I knew itî.

Mark was an English specialist who preferred teaching at Key Stage 2. His position on science was in some ways midway between Susanís and Davidís. He came directly from school, where two years previously he had studied all three sciences leading to a dual award GCSE qualification, which was the commonest science background among the school leavers joining the programme. Because of that background he felt ëOKí about the prospect of teaching science, although he ëdidnít know how far the course would want me to progress my knowledge to teach Key Stage 2î. When he did his first self-audit he looked through the National Curriculum and thought to himself ëwell I understand it, so I would probably be able to teach it to childreníî. Where he identified gaps he thought the university teaching would be the first source of help but he also expected to learn from teaching practice, his own reading and from fellow students as well. His descriptions of how he did in fact augment his knowledge also featured a combination of sources, prompted by a need identified in the test and by a commitment to developing a personal knowledge base for teaching.

ëI knew I didnít do well on it Ö so I remember asking other people about it Öwe had a module about this at college, about candles and changes that happen, and I learned a lot from thatí Ö but I did touch on this in my teaching practice just gone, so that would have helped Ö Because before I teach about anything obviously I make sure that all my knowledge is in the right place for what Iím going to teach.í

Mark made several comments about acquiring knowledge in preparation for teaching but they all referred to subject content knowledge. He only touched on pedagogic content knowledge when the interviewer probed about it.

I ëDo you find it easy to translate information at your level to kidís level?

M No

I So where are you going to get the help to Ö how do you then make that shift from your understanding o making a child understand?

M I think some of the books that are out there at the moment help you do that. Ö But I would say that it is part of being a good teacher that I am able to take my own knowledge and make it accessible for children, itís a quality thatís good in me to make me a good teacher, and itís a quality that I think youíve got to have anywayí.

DISCUSSION

The students were working within an increasingly tightly framed curriculum for schools and for teacher education so the contexts for their learning were very similar even if they had a variety of school experiences. Some of the common features which emerged from all the interviews were the commitment of students to enhancing their subject knowledge in order to become better equipped for teaching, their use of the programme and other resources to achieve this, and their increased confidence and knowledge after three

years. However there were many differences among the group. Some students came on the programme straight from school, others had experience of work or parenting. Despite minimum entry requirements the depth and range of their initial scientific knowledge varied, as did their perception of what they understood and needed to know for teaching young children. Although most were confident that, with work, they could achieve a sufficient knowledge base some students came to hold different views of what this entailed. For some the task remained ëfilling gapsí in knowledge that was listed in the primary school curriculum but which they had not previously studied so that, in Markís phrase, their ëknowledge was in the right placeí. In several cases it was revisiting topics, such as forces or electricity, that they had learnt for exams at school but never really understood. A few students saw their subject knowledge in a new light, as in Davidís move from formulae to meaning, or Susanís move from ëhaving to do it to starting to enjoy it because it was things Iíd missed in my own educationí. There were some whose exploration of pedagogic content knowledge made them reassess their personal relationship with the scientific ideas; this was mainly students who began with good qualifications and confident in their knowledge such as Laura, a science specialist, who said ëwhat I had to do was get inside my knowledge to be able to teach the childrení.

The self-audits and tests had been used to provide feedback to students as well as for the purposes of this study. They were not part of any official assessment on the programme, although some students spoke of how they saw their test results as summative judgements rather than as formative. Many students did use the initial audits and tests to diagnose personal needs. The programme featured personal profiles which students maintained, and it provided some initial structure to support this. The test and audit results were used to inform teaching on the course. However there had only been limited help with individual science knowledge action plans, mainly with the science specialists in the final year when explicit reference was made to subject and pedagogic content knowledge. Since this study was completed a national curriculum has been introduced for primary student teachers which specifies, inter alia, science content and requires this to be audited (TTA, 1998). This standardised requirement has generated a plethora of procedures among teacher educators, ranging from exploration by groups of students of their conceptual understanding to batteries of testing and auditing. National tests or procedures to achieve greater standardisation are being mooted. A spectrum of motives is evident among the different stakeholders in teacher education:

- control and measurement in pursuit of minimum standards
- an inspectorial mechanism to judge teacher education providers as well as new teachers
- a desire to catalogue and to improve the specific subject knowledge which teachers need for

  effective teaching of the school curriculum

- a belief that deep understanding of a subject goes hand in hand with its teaching
- a commitment to personal professional development by teachers as the engine for improving learning in schools.

The political climate is likely to determine what happens in the next few years but there are enduring questions to tackle. Central to the debate is a view about the nature of knowledge for teaching. That being promulgated by government is essentially impersonal and atomistic: a subject curriculum can specify items which can be delivered through effective teaching so the knowledge needed by teachers to do this can be specified in the same way and tested to ensure they possess it. Gaps and deficits and misconceptions in teachersí knowledge are evidence of the need for this. However this view ignores the individual relationship with knowledge evident in the present study, the complexity of knowledge growth and the links between different types of knowledge in a teachersí repertoire.

Self-assessment and review of knowledge is valuable for student teachers for several reasons. Firstly it requires them to be specific and to make explicit what is known and what is to be learnt; secondly it provides a basis for action by themselves and those with whom they work (peers, tutors, teacher-mentors); thirdly it may help them judge their progress and demonstrate it to others; fourthly it underlines the personal responsibility for learning and sets a precedent for continuing professional development. However students need some common framework and some referents for this review process. In the present study the results of studentsí first self-audits were poorly correlated with the results of their tests, although in the interview sample several individuals across the range of scores clearly had a realistic picture of their strengths and needs. The poor correlations may have reflected on weaknesses in the instruments as much as the students, of course, but other research has also shown a poor match between studentsí confidence or self-assessment and independent tests of their knowledge (Appleton, 1995; Gooday and Wilson, 1996; Smith & Lloyd, 1997). The conclusion should not be to rely simply on tests, with all their limitations, but to provide complementary perspectives and systematic feedback to students on their knowledge for teaching science. Teacher education programmes should also develop their metacognitive skills for assessing their needs and addressing them. Student teachers need to be provided with structures and resources which enable them to exercise those skills. They need maps to locate themselves and through which they can begin to see how distinct features, such as pedagogy and subjects, are related in a wider landscape.

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APPENDIX 1

Summary of Interviews with 17 students

1. "Do you remember when you started the course, before you had a science unit.

At that stage how did you feel about tackling the teaching of science?"

A wide range of backgrounds and feelings were reported, from ëfrighteningí to ëconfidentí.

Which of the following statements would best describe your view then:

1. You knew most of the things but had a few gaps to fill 5

1.2. Your knowledge was OK as a starting point but you had a lot to work on 11

1.3. There was too much for you to learn. 0

1.4. Other? One student said she needed help across all the knowledge sections of NC

2a. "At the beginning of year 2 you checked your profile against the NC programme. You identified those areas where you felt confident about your knowledge and areas where you did not feel you yet had the knowledge to teach that part of the programme. Why did you identify those specific areas?"

Most had based their judgements upon previous formal study of science content, some now felt that they had been overconfident as a result of assuming that advanced study at school had equipped them with the knowledge base they would need in order to teach.

2b. "At that stage where did you think you would learn most of the things you needed to know?"

2.1. Youíd be told by the tutors 14

2.2. youíd pick it up yourself when you needed 0

2.3. teaching practice would lead you to find out 7

2.4. assignments 1

2.5. reading 10

2.6. fellow students 2

2.7. teachers 1

3. "Can we look now at a specific area on the tests you did in science - we sent you a copy of those to remind you. You seem to have got a better score on the second test for this item.

Do you think you made progress in this area so you now have a better understanding of the science you need to know in order to teach this topic?"

Yes 13

No 4

"Where did you learn it/how did you build up your knowledge in this area?"

3.1. you were taught by the tutors/it was part of the taught course 7

3.2. you set out to study it yourself when you found you needed it 4

3.3. teaching practice preparation led you to find out 4

3.4. you did it for a course assignment 2

3.5. reading 5

3.6. fellow students 1

3.7. teachers 1

Did you have any opportunity to teach this area in school? 11 Yes/ 6 No

Did you teach science on all three teaching practices? 13 Yes/ 4 No

4. "Is there another area of science where you feel you made progress/your ideas have changed/youíve learned some science that you can use for teaching - maybe it didnít show upon the test but it illustrates your development?

Tell me about it.

Where did you learn it, how did you build up your knowledge?"

4.1. you were taught by the tutors/it was part of the taught course 14

4.2. you set out to study it yourself when you found you needed it 3

4.3. teaching practice preparation led you to find out 5

4.4. you did it for a course assignment 3

4.5. reading 6

4.6. fellow students 1

4.7. teachers 1

5. "You may not feel confident in all areas of science you would have to teach - not many people do. So how do you think you would build up your knowledge after youíve left the course/ what sources would you use to help?"

8 cited books or libraries, 7 said other teachers (2 of them specified a science coordinator), 4 cited friends (not clear if those might be teachers or scientists), 2 mentioned the content or approach of assignments done on their course, 1 mentioned ëresearchí, 1 spoke of INSET and 1 of a visiting lecturer. None referred to ICT.

6. "What would be the most difficult areas for you - can you identify up to 3 items on the profile (or in NC) - are there any particular items which you think the course should have spent more time on to help students gain subject knowledge?"

Half (9) mentioned aspects of physical processes, a few (4) identified biological topics, 1 identified aspects of materials, 1 needed ëmore information all roundí, 3 did not identify any items.

7. Finally we want you to have this opportunity to express your own views on how you see yourself in relation to science teaching - for example would you choose to teach science as part of your work if the school you were in decided not everyone had to and it went in for more specialist teaching

None said they would avoid teaching science, reasons given for choosing positively to teach it emphasised childrensí responses, active ëhands-oní nature of primary science and personal enjoyment.

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