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ABSTRACT

The subject knowledge primary teachers have as a basis for their teaching has become a major concern in preservice and inservice teacher education. This paper reports on a study that investigated the science and pedagogical content knowledge of a sample of 42 preservice primary teachers in England. Assignments and questionnaires were used to collect the data. Many students identified particular areas of science in which they felt confident, or more often where they lacked knowledge--most commonly they felt least confident in the physical sciences. Many of the responses to the questionnaires revealed a lack of specific subject knowledge and misconceptions. Many of the students were able to draft suitable plans for teaching significant scientific ideas and to summarize relevant subject knowledge at their own level. However, there were many assignments where the subject and pedagogical knowledge were not tightly linked, for instance some student teachers presented a collection of science facts and concepts about the topic to be taught but did not focus on the key ideas that would require explanation. The results also indicated specific curriculum knowledge and wide use of published teaching resources by the student teachers. Contains 22 references. (JRH)

# "I'd Need To Do A Lot Of Reading Myself Before Teaching This." How Do Primary Student Teachers Know What Science To Teach?

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# "I'D NEED TO DO A LOT OF READING MYSELF BEFORE TEACHING THIS." HOW DO PRIMARY STUDENT TEACHERS KNOW WHAT SCIENCE TO TEACH?

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The subject knowledge primary teachers have as a basis for their teaching has become a major concern in preservice and inservice education. In England the requirements for teacher training courses have increasingly stressed science knowledge. There are differing views among policy makers, teacher educators and student teachers about what primary teachers need to know and how they are best prepared for teaching science. Some students are anxious and wish to be taught substantial scientific content, others acquire confidence faster than they gain understanding. Many students say that when approaching a real teaching situation they would be able to prepare themselves adequately by independent research using published sources. This paper considers what combination of subject and pedagogic knowledge is appropriate for intending primary teachers, drawing on data from a study of student teachers' planning and background knowledge.

## INTRODUCTION

What knowledge do prospective primary teachers need to become effective teachers of science? This question is of practical concern to student teachers, teacher educators and educational policy makers. There seems now to be widespread agreement that subject knowledge is needed and that lack of sound scientific understanding is a problem for many primary teachers The apparent consensus may not be maintained when we ask subsidiary questions such as the following.

"What can be done to improve pupils' learning of science if teachers appear to share many of their pupils' misunderstandings of key scientific concepts?"
"Wouldn't a requirement for all entrants to teacher training to have a higher school qualification in science ensure that they knew enough?"
"What level of scientific understanding is appropriate for teaching this age group?"
"How wide a knowledge of science is needed, b[illegible]mediate topics specified in the curriculum?"
"If it cannot all be learnt in advance is it not better to acquire some general principles - and what should these be?"
"Is more general knowledge of pedagogy and of children's learning not the most useful resource in teaching, whatever the subject?"
"Won't the most significant factor turn out to be the teachers' ability and disposition to learn what is needed when it is needed?"

The questions need both theoretical and empirical examination. In this paper they are approached from the perspective of an investigation into the science and pedagogical content knowledge of a sample of preservice primary teachers.

### National Policies

The argument for primary teachers to acquire subject knowledge as a base for their teaching has been mounted by the inspectorate in England from the time of their 1978 survey of primry education (DES, 1978) up to the present ("Steps need to be taken to enhance the science subject knowledge of teachers, especially those teaching the older Key Stage 2 classes" OFSTED, 1995:5). The requirements for preservice courses have increasingly featured study of at least one of the the subjects to be taught "at a level appropriate to higher education" (DES. 1989:Section 6) and the time all students must spend on science studies directly related to the primary curriculum has grown from 100 hours in 1989 to 150 hours in 1996 (DFE, 1993: para 22). In the USA Project 2061, in its recent Blueprint for Teacher Education recommends all prospective elementary school teachers should have an undergraduate disciplinary major within the context of a broad liberal arts background that includes several science courses: "Because we believe that deep understanding of a discipline is essential to effective teaching at every level." (Floden, Gallagher and Wong, 1995). In Australia the Discipline Review of Teacher Education in Mathematics and Science recommended minimum requirements for science in preservice courses (DEET, 1989).

## Research with Preservice Students

Research responding to Shulman's (1986) call for more attention to the teaching of specific subject matter has accumulated evidence of the difference subject knowledge can make, especially in the way concepts are represented and the structure of a subject is translated for pupils. Implications for preservice education have been reviewed, for instance by McDiarmid, Ball and Anderson (1989) from an American perspective and by McNamara (1991) in England. Much of the earlier work was with secondary teachers of science and other subjects. Subsequent research has included several studies of primary science and preservice teachers. It has also gone beyond the general identification of subject knowledge as a necessary condition for teaching to investigate the issues in more detail. Central to many current studies is a concern with promoting constructivist teaching strategies in schools; some also reflect a parallel concern to adopt a constructivist approach to student teachers' own professional development. (eg in papers at an AERA symposium chaired by Tabachnik,1995).

Studies have been carried out with student teachers in several countries as science has become a more established feature in their primary school curricula ( eg in Korea by Park and Dana, 1995). Those reviewed here are chosen because the research questions, course structures and policy contexts allow fruitful international comparisons with our own research.

Gooday, Payne and Wilson (1993) investigated the scientific backgrounds, attitudes and knowledge of students training as primary teachers on a four year undergraduate course in a Scottish College. All first and fourth year students completed questionnaires and eleven fourth years were interviewed. The results indicated that during their course students acquired greater confidence in their ability to teach science despite limited gains in their own understanding of scientific concepts. The authors noted that the Scottish school curriculum guidelines for ages 5-14 being introduced at that time would increase the demand on primary teachers' conceptual understanding in science. The emphasis of science units in the course those students were following was on pedagogy and science processes. There were some differences in the priorities expressed by the first and fourth year students when they were asked what a science course should provide: increased confidence, curriculum knowledge and practical classroom help featured in both lists but personal scientific knowledge featured less prominently in fourth year students' questionnaire responses. Both year groups identified a need for more information on children's learning in science than the course at that time provided. Almost threequarters of the students had gained some science qualification at school, most commonly in biology, and their secondary school teachers appeared to have played an important part in forming their attitudes to science.

Skamp and Geake (1991) reported an Australian study of the confidence and knowledge of primary student teachers in relation to the content of a primary science and technology syllabus being introduced in NSW. Questionnaires about their confidence and sources of their knowledge were completed by students starting an undergraduate teaching course and by students at the beginning of the third year. At the start of the course more than half the students expressed a lack of confidence in most of the areas of scientific knowledge specified by the new NSW syllabus. Third year students were markedly more confident in almost all areas, although their course had not devoted as much time to their own disciplinary knowledge as was now allocated in a newly introduced unit for first years. Group concept maps and individual assignments were used during that unit to explore the science concepts held by first year students. These suggested that there were gaps or misconceptions in the students' scientific knowledge, even in topics where they felt confident. There are clear parallels with the concern voiced in the Scottish study that the students' growing confidence in their science knowledge as a basis for teaching might be misplaced. Skamp and Geake also analysed the sources which students identified as significant for their confidence, illustrating the complex relationship between the varied experiences of secondary schooling and the curriculum they are preparing to teach. In general there was a shift from attributing confidence to their previous upper secondary school science toward the growing influence of the science units they were taking and of their teaching experiences. Appleton (1995) reports another Australian study in which primary student teachers showed increased confidence following a science education unit that only included a small amount of disciplinary knowledge.The significant gains in students' perceptions of their knowledge and their ability to teach science appeared to derive from the teaching approaches used. Appleton notes that while this effect is significant and welcome "self-confidence should not be confused with competence." (1995:366)

The most substantial study in England, reported in Bennett and Carré (1993), was carrried out as part of a larger investigation into the beliefs and knowledge of graduates who followed a one year teacher education course (the PGCE). Although their background and course is different from students in the present study there are several relevant insights. The subject knowledge of PGCE students was assessed at the start and finish of their course, then related to other features of their professional learning and to their teaching in four lessons. Student teachers in general did not do as well as 'able' 11 year olds on items where comparisons were possible (Bennett and Carré 1993:34). Science and maths graduates performed better on tests of their science knowledge than those with arts degrees. However in some areas even they had similar misunderstandings to pupils. Science graduates gained lower scores for their lesson evaluations and tended to teach in a more didactic style despite the course's emphasis on science as inquiry. Their planning and classroom performance in science lessons was in some ways better than that of non-science graduates. These findings raise questions about the impact of graduate subject study upon the students' understanding of science and the use of that knowledge as teachers. These are significant for courses other than the PGCE where there are discrete units of subject study.

## THE STUDY

### The Students and Course

These student teachers were all in their third year of a four year consecutive undergraduate course. There were 34 female students and 8 male. 17 of them were over 21 years old when they began their course. Only six had gained a science A level qualification, all in biology. Ten had succesfully studied chemistry or physics at a lower level in school.

They were preparing to teach the whole primary school curriculum, with a particular strength in one subject (either English, environmental studies, mathematics or technology). Another group of 16 students studying science as their special subject is referred to briefly in this paper for comparison only; they are involved in a longitudinal research programme (Smith, 1993). The students considered here were all planning to teach pupils in the 7 to 11 age range and they were about to undertake five weeks of teaching practice. The sample consisted of all those students taking the third year unit of Curriculum Science in the first semester (n = 42). Other groups took the unit in the second semester. A parallel unit was run for students specialising in the 5 to 7 age range. All of these groups had already undertaken a science curriculum unit in their first year. Together with experience gained in school these would constitute their preparation for teaching science within the framework of the National Curriculum, wherein science constitutes a 'core subject' along with mathematics and English.

The data were collected as part of the third year unit taught by one of the authors. This involved some 40 hours in class and an equivalent time in private study, largely for the assessed assignment. The unit aimed to increase students' confidence, science knowledge and awareness of teaching approaches. These aims were made explicit to students at the start of the unit when they were also asked to consider their own particular strengths and needs. They prioritised those and handed in individual lists in the next session.

### Assignments

The individual assignments were set early on. These assignments required each student to negotiate with the tutor a science topic where they felt a need to build up their understanding, and over the semester to research teaching ideas and their own scientific knowledge in that topic. At the end oi the unit they submitted plans for a five week sequence of teaching with pupils, supported by the knowledge generated from their research. It thus represented an opportunity to carry out the sort of preparation which many indicated they would do before any teaching, with tutorial support, access to the books and teaching materials in the primary science base, and plenty of time. It was to be presented as a model of the type of preparation needed for their teaching practice plans, but in more depth and more fully documented than would be possible then. The task was also designed to boost confidence in their ability to build up a knowledge base for teaching. Procedural understanding, specific curriculum knowledge and general pedagogical issues such as assessment were also integral to the unit and assignment but the emphasis in this study was on scientific understanding. Assignments were marked according to criteria relating to the production of suitable teaching plans underpinned by sound, relevant scientific knowledge gleaned from their own study. Comments on each students' assignment in relation to the focus of this study were noted separately.

### Questionnaires

A questionnaire which had been piloted with another group was administered in a session towards the end of the unit. The questionnaire had been designed to elicit aspects of students' science knowledge, and their ability to draw upon such knowledge in planning, explaining and handling pupils' questions. It was in two parts.

In the first part there were three items designed to assess specific subject content knowledge. The first item (1a) asked questions about seed germination, the second item (1b) asked about photosynthesis in the context of trees and the atmosphere; items 1a and 1b each had an initial stem question and further extension questions requiring progressively precise scientific details. The third item (1c) was a multiple choice question about the forces acting on a ball as it was rising and falling. The questions were administered separately, with demonstration or visual aids to encourage responses, and to minimise the perception that this was an examination.

For example, item 1a was introduced by giving each student a seed from an ash tree and asking them to think about how this would change if it were to begin growing. The written item included a drawing of the seed and prompts to elicit their knowledge:

> 'If you planted this seed it might eventually begin to grow.
> Write notes to explain what you think would happen inside the seed if it did.
> Include key scientific terms associated with this early stage of its life.
> Draw a picture if it helps you.'

The extension questions in this first item asked students to list the conditions required for this process to happen, to explain what would provide the energy needed for this process at this early stage, to state whether this original source would still be needed when it had grown into a sapling and to explain why.

In the second section there were three items exploring students' ability to apply science knowledge to teaching tasks. The first of these (2a) asked students to outline a plan for teaching pupils the process of germination , the second (2b) to suggest how they could explain photosynthesis to pupils, and in the third (2c) they were required to respond to a pupil's question about how there could be forces without movement . Students' answers to this second set gave evidence of their use of more general pedagogic knowledge as well as specific pedagogical content knowledge.

Students were encouraged to include notes at the end of each item explaining their ideas, expressing any uncertainties and views about the tasks. This produced some insights into their awareness of their own needs and strategies for enhancing their science knowledge.

Questionnaire responses were graded from 0 to 5. If a student gave no answer this was graded 0, and a substantially incorrect answer was graded 1. Grades of 2 to 5 represented increasingly strong answers defined by criteria which had been developed independently by both authors, trialled and then compared to produce a final version. Answers graded 2 or 3 indicated incomplete understanding, 4 or 5 indicated substantial, correct knowledge. Students' written comments supplied further insights - eg where they wrote about their partial understanding or recalled having studied the topic long ago, or provided unsolicited misconceptions. There were many statements about their uncertainty, their need for more understanding of specific topics, and strategies they would use for enhancing that knowledge before teaching it. All of these were transcribed and compared with the student's grade, the tutor's comments on their assignment, and their own initial summary of strengths and needs.

Grades were analysed across each student's profile, within and between items. We highlighted student profiles which were very low or high, or where there were striking discrepancies between an item assessing specific science knowledge (1a,b, or c) and the corresponding item assessing its application (ie items 2a,b,or c respectively).

Details of the questionnaire items, criteria and grades are available in working papers from the authors.

## RESULTS

### Students' perceptions of their needs and strengths

Many students identified particular areas of science in which they felt confident, or more often where they lacked knowledge - most commonly they felt least confident in the physical sciences. Some cited teaching strategies they had practised in school or acquired in their course as a source of confidence; several specified particular needs in this area of general pedagogical knowledge such as managing groups, differentiating and assessing. A few highlighted their own approach to professional development , for instance specifying that they felt able to teach science successfully with appropriate preparation because they were enthusiastic and aware of their needs for knowledge. Thus student 101 identified her strengths as *"Knowing that I need to acquire more knowledge and understanding of certain areas in science. Knowing that with plenty of ideas, the confidence and knowledge and enthusiasm I will hopefully be able to plan and teach sucessful science lessons."*. One or two voiced considerable anxiety or produced long lists of science topics about which they felt unsure.

### Questionnaires

There was wide variation of grades between questions and within questions. Very few responses demonstrated the depth of knowledge necessary to be graded 4 or 5. (These ranged from 0% to 10% across all questions - for the equivalent group of science group students the range was 0% to 64%). Grades of 2 or 3, representing partial understanding, were commonest. Many responses were graded 0 or 1. (These ranged from 2% to 73% across all questions compared with 0% to 40% for the science group).

For many students the score for a teaching application (ie items 2a,b and c which probed pedagogical content knowledge) was lower than that for the equivalent question about scientific knowledge in item 1a, b or c . This was most evident in items 1c and 2c where a slight knowledge of forces demonstrated in the former was often accompanied by a grade of 0 or 1 in the latter. which required students to suggest ways of helping pupils grasp the idea of balanced forces. This was despite the support of an extract from that part of the science National Curriculum featuring this idea, and work done on balanced forces in the curriculum science unit in year 1. Where the teaching application grade did exceed the equivalent knowledge one this was usually in relation to seeds (items 1a and 2a). It appeared that students could generate plans for pupil activities with seeds which were relevant but were not backed up by the knowledge to make the most of those in promoting standard scientific ideas. This might have been because they interpreted the question more loosely as legitimating any activity with germinating seeds or because many could recall a familiar test of conditions required for germination. An incidental finding was that, to our surprise, several students had never grown plants nor germinated seeds. However even some of those who had this experience and who had also studied biology confused the need for light during subsequent growth with the conditions for germination.

There is now a substantial body of work indicating areas where teachers have unscientific ideas or even share the alternative ideas their pupils hold (eg Kruger, Palacio and Summers, 1992). In this paper we do not intend to catalogue the many misconceptions held by student teachers in our sample. We elicited several, notably the confusion between the greenhouse effect and the ozone layer, the belief that plants do not respire, and the well-documented impetus conception of forces. These are a cause for concern of course. So are the many answers which revealed a lack of specific subject knowledge needed to underpin teaching in parts of the required curriculum. However we also need to acknowledge the variety of knowledge they do have, how that can be developed and supported in practice. The overall picture of students' science knowledge was uneven, with many students having peaks and troughs in their profile of grades across questions. This pattern suggests that a generalised coverage of all science ideas for all student teachers is not the solution - even if it were feasible. Although the parallel group of students specialising in science scored higher overall and mostly gave fuller, more appropriate answers there were still errors and gaps in their understanding. Despite studying disciplinary science in their c e there were several questions where they did not achieve a substantially greater number of the top grades. They did score significantly better where they had to give more specific, detailed answers explaining scientific ideas or terms.

25 students spontaneously wrote comments on their own knowledge, 12 stating that they needed to do a lot of reading before being able to teach one or more of the topics. A few of those spelt out in more detail the strategy they would use: *"If I had to teach this* (germination) *I'd read about it in as many children's books as I could alongside studying it at my own level to give me an adequate background understanding"* (Student 212, who scored very low in most items).

So were students able to identify what they needed to know and to equip themselves with this knowledge through personal reading and research? The assignments provided answers to those questions.

## Assignments

Generalisations about student knowledge here are dangerous since they were being assessed on assignments which were required to be good discriminators, and all the usual distractions of student life and other course work may have affected the quality of the assignments they produced. However there were patterns which related to the key requirements of the assignment and the questions in this paper.

Many of the students were able to draft suitable plans for teaching significant scientific ideas and to summarise relevant subject knowledge at their own level to underpin such teaching. A few of of these had begun with very low levels of knowledge and confidence in the chosen science topic and ended with a sense of achievement based upon extensive private study and consultation with the tutor. They demonstrated real understanding of key ideas which was reflected in their teaching plans. Those plans outlined a learning sequence to foster children's understanding of scientific ideas selected to match the National Curriculum. For instance two mature students, 215 and 219, got to grips with ideas about colour and space, respectively, and translated their understanding into teaching plans. Their extensive use of books for teachers and curriculum materials was reflected in detailed lesson plans and proposals for how they would explain ideas to children.

However there were many assignments where the subject and pedagogical kn›wledge were not tightly linked, for instance where students presented a collection of science facts and concepts about the topic to be taught but did not focus on the key ideas that would require explanation. In other cases the student had not acquired the depth of understanding needed to make curriculum decisions - eg in a topic on light where additive and subtractive colour mixing were confused and the confusion was passed on to pupils because of a poor combination of activities. Some extensive reports of apparently well synthesised science knowledge were associated with plans for too many loosely connected pupil activities. More often the research at their own level led students to propose teaching plans overloaded with content which relied heavily on didactic teaching. Some rose to the challenge of incorporating scientific investigation that would assist pupils' understanding, but many struggled with this requirement in the assignment.

Specific curriculum knowledge and wide use of published teaching resources was well in evidence. Some students had evidently gone beyond the stage of picking activities out of curriculum packages and were adapting tasks to translate difficult concepts for children. These students vindicated the claim that they could "read it up before teaching". By so doing they were establishing a repertoire of pedagogical content knowledge and the depth of science understanding needed to teach flexibly. They also appeared to know what it was they needed to know in order to teach the topic.

A few students sadly still failed to demonstrate that understanding in these ideal conditions - they may have achieved greater confidence in the topic, maybe even done the sor ·ᶠ reading and research they claimed they would do before any teaching, but had still not p: · red themself with the pedagogical content knowledge. Or perhaps their grasp of what was needed was weak.

## DISCUSSION

We return now to examine the questions posed in the introduction in the light of the literature and our study.

"What can be done to improve pupils' learning of science if teachers appear to share many of their pupils' misunderstandings of key scientific concepts?"

Such misconceptions are certainly common. The lesson many teacher educators have drawn is that we need to work with student teachers in the way that we advocate they work with pupils to foster conceptual change. There is evidence that under such conditions significant understanding may be achieved, eg as illustrated for changes of state in the water by cycle by Stoddart, Connell, Stofflett and Peck (1993). In their first year curriculum science unit the tutors had worked in this way with the students in our study to build their understanding of balanced forces through activities on floating and in falling. However in year three several needed to revisit this. Newly acquired standard scientific ideas may not become well established as personal knowledge. There is not time to tackle all necessary scientific ideas in such depth, so it will be important to identify priorities. Some concepts are particularly resistant to change and may need more intensive teaching than others (Smith and Peacock, 1993). It may be that in many areas students can build their knowledge in other, less time consuming ways, including direct teaching, individual reading and subsequent support from curriculum materials.

While tutors need to be discriminating in their choice of teaching strategies students need to become aware of their needs and optimum learning strategies.

"Wouldn't a requirement for all entrants to primary teacher training to have a higher school qualification in science ensure that they knew enough?"

A requirement for a science qualification equivalent to that already specified for English and maths is in fact being introduced in England. This would appear logical given the equivalent status of the three subjects in the National Curriculum. It is likely to be helpful, but the evidence from studies such as Bennett and Carré's (1993) and from our parallel investigation with the science specialists is that students have some misconceptions despite extended study of science at school or on a degree. The specificity of curriculum knowledge, the variety of particular scientific subjects students may have taken suggest that this requirement, "whilst welcome, can only be described as of marginal utiltity in improving the quality of science teaching in the medium term." (Huggins, 1994). Whether or not entrants to any preservice course have similar mimimum qualifications in science they will still have individual strengths and needs which ideally require some differentiated provision within a shared experience.

The next two questions focus on the depth and breadth of knowledge students will have when they complete their course and join experienced teachers - for whom the questions also apply.
"What level of scientific understanding is appropriate for teaching this age group?"
"How wide a knowledge of science is needed, beyond the immediate topics specified in the curriculum?"

The simplest answer is "A bit more than the pupils." Early discussions relating to teaching the National Curriculum were often of this form, concerned with how many levels above their pupils teachers needed to be. Some of our students take the same view, especially in the parallel groups preparing to teach younger children. There are areas of that prescribed school curriculum where the next stage does give some indication of the knowledge needed to teach the earlier levels effectively. However in many cases the teacher needs to know other related ideas, to have a deeper understanding of where it leads, and to be alert to the simplification represented in a school curriculum. One of our science specialist students explained how knowing the subject (sound and waves in his case) in much more depth made him aware of the potential of teaching activities and able to respond to the ideas pupils expressed, rather than limited to prescribed tasks and prespecified answers.

At the start of their careers new teachers should have the framework and a deeper knowledge in a few areas to establish confidence as well as to illustrate what is necessary. Some of those areas will be well-established features of any curriculum - dealing with growth or changes of state for instance. The emphasis on others will vary from country to country and time to time. Student teachers may find it less demanding where there is a closely specified curriculum with standard school textbooks that can also be referred to in their preservice training, as in Singapore. However as teachers they will need to use new ideas which may not be current at the time of their initial training. Thus the extent of knowledge needed to deal with pupils' questions about genetics is escalating rapidly, and the explanation of climate change or pollution will demand more detailed understanding than many of our students demonstrated.

"If it cannot all be learnt in advance is it not better to acquire some general principles - and what should these be?"

We need to give new teachers sources of background knowledge and a basic map of the territory, whether that be via direct teaching, print or IT. But we should not equate teachers' science with that to be acquired by a practising scientist. They share common ground, but each has a distinctive character. In general terms it is desirable that teachers have a grasp of key scientific concepts, a feel for the substance and syntax of the subject, an understanding of the procedures of science as well as the skills needed to carry out investigations, awareness of social dimensions, specific curricular knowledge, a repertoire of strategies for teaching and assessing learning in the subject, and insights into evidence about children's thinking. Even with more time allocated for science careful structuring of a course will be required to achieve this in concert with all the other learning that primary student teachers have to do. At present research literature suggests that the high expectations teacher educators, teachers and other professionals share for new primary teachers are not always achieved in practice (Reynolds, 1995).

"Is more general knowledge of pedagogy and of children's learning not the most useful resource in teaching, whatever the subject?"

Such more general professional understanding should be a shared aim of units in any programme of teacher education. It can also be a more powerful influence on students' grasp of how specific subject matter can be taught, especially if suitable practical teaching experiences are provided and evaluated. Some students in our study appeared to work from a strong general sense of pedagogy or insights into how young children learn, others from subject specific knowledge. A few were integrating them proficiently, in several cases they appeared to be distinct items yet to be combined in a personal teaching repertoire. The task of teacher educators is to provide students with the elements and assist them toward such integration. There are many ways to design a programme for these aims - one powerful entry point is via close examination of children's learning and thinking in science.

"Won't the most significant factor turn out to be the teachers' ability and disposition to learn what is needed when it is needed?"

Studies over the years, from Moore and Piper (1977) to Appleton (1995), have reported a variety of inputs which have improved preservice students' attitudes to science teaching or increased their confidence in teaching it. Certainly these attitudes are necessary, but not sufficient as the studies analysed in this paper indicate. Appleton notes that although "a science education unit with particular characteristics can have dramatic effects on students' self-confidence to teach science and technology, self-confidence should not be confused with competence." (1995:366). Thus student 216 wrote at the start of the unit in our study *"I enjoy science as a subject as it allows me to work along with children and learn with them."* and wrote on her questionnaire about her need to know more at her own level. However she failed the assignment, taking information from books about health education but appearing neither to internalise it nor use it to support a restricted set of pupil activities. We need to promote students' positive attitudes and confidence but also the knowledge and competence so this confidence is justified. We have to help them see what knowledge they need for teaching and develop the skills to build that. More science knowledge, more confidence and more self-knowledge should be mutually reinforcing.

## REFERENCES


Appleton, K. (1995) Student teachers' confidence to teach science: is more science knowledge necessaary to improve self-confidence? *International Journal of Science Education, 17*(3), 357-369

Bennett, N. and Carre, C (Eds.) (1993). *Learning to Teach*. London: Routledge

Department of Employment, Education and Training (DEET) (1989) *Discipline Review of Teacher Education in Mathematics and Science.* Canberra: Australian Printing Service

DES (1978) *Primary Education in England: A Survey by HM Inspectors of Schools.* London: HMSO

DES (1989) *Circular No 24/89. Initial Teacher Training: Approval of Courses.* London: DES

DFE (1993) *Circular No 14/93: The Initial Training of Primary School Teachers: New Criteria for Courses* London: DFE

Floden, R., Gallagher, J and Wong, D. (1995) *Project 2061 Blueprint for Teacher Education. A Symposium Presentation.* Paper presented at the Annual Conference of the National Association for Research in Science Teaching, San Francisco, April 1995

Gooday, M., Payne, F. and Wilson, J (1993) *Primary Student Teachers' Scientific Knowledge and their Attitudes Towards Science.* Aberdeen: Northern College

Huggins, M (1995) A science GCSE before initial teacher training? *School Science Review, 76* (275), 99-103

Kruger, C., Palacio, D. and Summers, M. (1992) Surveys of English Primary school teachers' conceptions of force, energy and materials. *Science Education, 76*(4), 339-351

Moore, K.D. and Piper, M.K. (1977), Factors underlying student teachers' attitudes toward science in a preservice elementary program, in Piper, M.K. and Moore, K.D. (Eds.) *Attitudes Toward Science: Investigations* Columbus, Ohio: SMEAC

McDiarmid, G.W., Ball, D.L. and Anderson, C.W. (1989) Why staying one chapter ahead doesn't really work: subject specific pedagogy, in Reynold M.C. (Ed.) *Knowledge Base for the Beginning Teacher.* New York: Pergamon

McNamara, D. (1991) Subject knowledge and its application: problems and possibilities for teacher educators. *Journal of Education for Teaching, 17*(2), 113-127

OFSTED (1995) *Science: A Review of Inspection Findings 1993/94. A report from the Office of Her Majesty's Chief Inspector of Schools.* London:HMSO

Park, S.H. and Dana, T. (1995) *Preparing Elementary Science Teachers in Korea.* Paper presented at the Annual Conference of the National Association for Research in Science Teaching, San Francisco, April 1995

Reynolds, A. (1995) The knowledge base for beginning teachers: Education professionals' expectations versus research findings on learning to teach. *Elementary School Journal, 95*(3), 199-221.

Shulman, L.S. (1986) Those who understand: knowledge growth in teaching. *Educational Researcher, 15,* 4-14

Skamp, K. and Geake, J. (1991) *Preservice Primary Teachers and the New Science and Technology (K-6) Syllabus.* Paper presented at the NSW Science Teachers Associaztion Annual Conference, University of NSW, September 1991

Smith, R.G. (1993) *The Development by Student Teachers of a Repertoire of Subject Knowledge in Primary Science.* Paper presented at the International Conference on Teacher Education, Tel Aviv, June1993

Smith, R.G. and Peacock, G.A. (1992) Tackling contradictions in teachers' understandings of gravity and air resistance. *Evaluation and Research in Education, 6*(2&3), 113-128

Stoddart, T., Connell, M., Stofflet, R. and Peck, D. (1993) reconstructing elementary teacher candidates' understanding of mathematics and science content. *Teacher and Teacher Education, 9*(3), 229-241

Tabachnik, B.R. (1995) *First Year Elementary and Secondary Teachers of Biology and their Preparation in a Constructivist Teacher-Education Program*. A Symposium at the Annual Conference of the American Educational Research Association, San Francisco, April 1995