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# Changes in perceptions and attitudes of pre-service post-graduate secondary school science teachers

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The article deals with perceptual and attitudinal changes of British post-graduate pre-service secondary science teachers during and following their education and training year at the University of Keele, UK. Specifically, the following aspects were addressed: views about education through science; views about the aims and goals of science education, classroom management, teaching schemes and instructional strategies; their self-concepts as science teachers; their self-confidence concerning a variety of teaching assignments; and their expectations of the PGCE (Post-Graduate Certificate of Education) programme. The influence of gender, age, and science subject background, on their initial views and subsequent changes of perceptions and attitudes, were also investigated. The research was conducted with 39 PGCE students and their five academic tutors. It combined both qualitative (open questionnaire and interviews) and quantitative ('closed' questionnaire) methods. The findings emphasized three characteristics of the pre-service teachers:

(*a*) the progressive ideas which they already possessed and their considerable motivation on entering the teacher education programme;
(*b*) their idiosyncratic nature. Throughout the teaching practice the students passed through a dynamic process of transformation. A meaningful change of perceptions and attitudes occurred for almost all of them in respect to ideas about science education in schools;
(*c*) their narrowly practical viewpoints and learning abilities. The influence of the university tutors was effective only when their ideas provided useful and practical teaching tools. The students could only dimly understand the relevance of many of the theoretical and philosophical ideas presented by their tutors.

It is suggested that these findings might serve as a good beginning for developing more effective pre-service education and training programmes.

## Introduction

The 'Trinity' of Pupil–Curriculum–Teacher is a well-explored area of science education. This paper involves the most important part of this triangle: the teachers who should be the link between the curriculum and the pupils. Specifically, it deals with preconceptions and attitudinal changes of British post-graduate pre-service secondary science teachers during and following their education and training year at the University of Keele.

Whilst research in the 1960s and 1970s was predominantly concerned with curriculum developments, pupils' and teachers' roles have been receiving much more attention throughout the last two decades. Intensive research has been conducted in relation to practising science teachers (Tobin 1987, Tobin *et al.* 1988). In relation to the pupils' cognitive achievements, greater focus has been given to the initial conceptions and beliefs which children have acquired through prior learning

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and life experiences (Nussbaum and Novak 1976, Driver *et al.* 1985, Osborne and Freyberg 1985). This constructivist research has a central role in the development and implementation of learning materials for school students.

The pre-service teacher who comes to the training programme is a learner. Therefore the constructivist approach should be applied to these students as well (Tamir 1991). Surprisingly, an ERIC search for 1982–1993 revealed very little in relation to prior beliefs and views of pre-service secondary science teachers about science education and science teaching, and in relation to changes which occur whilst they undergo their initial teacher education and training. More emphasis has been given to these issues in relation to pre-service primary or elementary school teachers (Young and Kellogg 1993, Westerback 1982). Some studies have been undertaken in relation to general pre-service teachers, but not in relation to intending science teachers (Tamir 1991, Hollingsworth 1989, Lortie 1975).

Certain of these studies (e.g., Hollingsworth 1989, Zeichner and Liston 1987, Lortie 1975) argue that students entering teacher education programmes already posses definite ideas about teaching and learning. Tamir (1991), in contrast, showed that a relatively small proportion of the views and beliefs of pre-service Israeli student teachers were definite. Previous research suggests that the pre-service educational programmes which emphasize school experience tend to perpetuate those preconceptions and attitudes which were formed largely on the basis of their previous school experiences. Hollingsworth (1989), however, described how students' preconceptions and the ideas of the school's teacher mentors can interact to create desirable changes in perceptions and attitudes.

It seems, however, that although some general understanding of pre-service student teachers is available, there is a need for many more intensive studies in the area of secondary pre-service science education. In this context information concerning the nature and origins of students' prior beliefs and views is very much needed. Later it would be helpful to know along which lines and how these views can be changed or sustained by a pre-service education and training programme.

## The purpose of the study

The purpose of the study was to find out the views, beliefs and expectations of British post-graduate pre-service secondary science teachers with respect to a range of matters which are at the heart of science teacher education. Specifically, the following questions were addressed:

1. What are their initial views about education through science?
2. What are their initial views about specific issues related to teaching science: the aims and goals of science education; classroom management; teaching schemes and instructional strategies?
3. What are their initial self-perceptions as science teachers?
4. What is their initial self-confidence concerning teaching assignments in the classroom, the laboratory and out-of-school environments?
5. What are their expectations of the PGCE (Post-Graduate Certificate of Education) programme?
6. What changes of perception and attitude occurred in relation to these domains following the pre-service training programme?
7. Are there gender differences in relation to initial views and subsequent changes?

8. To what extent does the science subject background of students affect their initial views and subsequent changes of perception and attitude?
9. To what extent does the age of students affect their initial views and subsequent changes?
10. To what extent does previous teaching experience affect their attitudes towards different aspects of the programme?

## The pre-service PGCE education and training programme

This course was one academic year, a total of 37 weeks. Each student was a postgraduate who had gained first (and often second) degrees in a wide range of science disciplines, mainly biology, chemistry, earth science and physics.

All major parts of the course—theory (Educational Issues and Perspectives), science methods (Broad Balanced Science and a specialist science subject) and the main teaching practice—were school-based. Two thirds of the time was spent in schools learning how to become professional in a 'real-life' context.

The pattern of the PGCE year is given in Table 1. It is divided into I, P, D, J and S weeks.

The science methods courses are designed to help students to develop a broader role as science teachers, no matter what their original degree course specialism and interests. All PGCE students taking science main methods courses follow the full programme outlined below. It consists of a common course entitled Broad Balanced Science (BBS); one methods course, either biology, chemistry, earth sciences (mainly geology) or physics; a nine-week period when students spend two days each week in schools; and 15 weeks of teaching practice.

The following are common elements of the nine-week period although the details varied from school to school.

1. An introduction to the science department: personnel, facilities, policies (particularly safety procedures) and day-to-day operation.
2. Acquaintance with the schemes of work, syllabuses and resources used in the department.
3. Structured lesson observations, if possible in pairs, of a variety of classes of different ages and abilities.
4. Weekly tutorial sessions with the science mentors.

**Table 1. Pattern of the year in the PGCE Education and Training Course at Keele University in 1992–3.**

| *Designation* | *Type of study* | *Total weeks* |
|---|---|---|
| I week | Induction week at the university | 1·0 |
| P weeks | Work in primary school | 3·0 |
| D weeks | Work in the Education Department at the university | 6·5 |
| J weeks | Work in a secondary school (2 days) and in the Education Department (3 days) | 9·0 |
| S weeks | Work in a secondary school (the main teaching practice) | 17·5 |
| Total | | 37·0 |

5. Working with classes in a supporting role and helping individual pupils or small groups in both practical and non-practical activities.
6. Helping with assessments, particularly where these involve discussions with individual pupils and some marking of pupils' work under the guidance of the teacher.
7. Team-teaching, probably in the form of taking the lead for a short part of a lesson, perhaps preceding, and then helping with, a practical activity.
8. Working with children with special needs.
9. Teaching lessons from lesson plans devised jointly with the teacher.

During the 15-week teaching practice, each student was expected to act as a professional teacher. The student teachers enjoyed many of the rights and privileges of full-time staff and were expected to share the administrative, pastoral and extracurricular duties of a class. They taught 50 to 60% of a full timetable under the guidance of a mentor who had been trained at the university and who was responsible for team teaching with the students (at first) and observing, analysing and discussing their lessons (later). Other classroom teachers often offered similar support and wise counsel. Student teachers taught a wide range of pupils of all ages and abilities – 11 to 16 and sometimes 16 to 19. Mentors held weekly tutorials. University tutors visited the students periodically to observe, analyse and evaluate their schemes of work, lessons and general progress. They conferred with mentors with whom they formed an equal partnership with respect to counselling and eventually assessing the students' teaching practice grade.

The summer term which followed the teaching practice was devoted to a variety of obligatory workshops such as data logging and handling, using interactive CD ROM resources, and a residential period at an outdoor education centre. In addition students were required to make a restricted choice from other workshops related to organizing visits to the following locations: an industrial site, a radio telescope, a planetarium or an arboretum; an interactive science centre; a city museum; a local area where a famous scientist once developed his ideas (Darwin: origin of species; origin of soil; the location of igneous dyke rocks).

Assessment of the students' progress and final achievement was the joint responsibility of the school and the university, with the latter being charged with overall evaluation and quality control.

## Methods

### *Sample*

The study involved both the student teachers and their university methods tutors. The student sample consisted of 39 postgraduates who participated in (and completed) a one-year pre-service teacher training programme (PGCE) during 1992/93. This group comprised over 90% of the initial population (42 students) who began the programme.

The distribution of the postgraduates in relation to their scientific backgrounds, e.g. biology, chemistry, earth sciences (mainly geology) and physics, was roughly equal (Table 2).

There were 24 males (61%) and 15 females (39%). The students had obtained their first degrees from universities all over Britain. Their ages ranged from 21 to 39 years; 58% were between 21–25 years (almost all of them with no previous teaching

**Table 2. Population distribution.**

| *Major* | *Number* | (%) | *Male* | *Female* |
|---|---|---|---|---|
| Earth sciences | 8 | 21 | 7 | 1 |
| Biology | 12 | 31 | 4 | 8 |
| Chemistry | 9 | 23 | 5 | 4 |
| Physics | 10 | 25 | 8 | 2 |
| Total | 39 | | 24 (61%) | 15 (39%) |

experience); 26% were between 26–30 years; and 16% were over 31 years old. Fourteen (37%) entered the programme with limited previous teaching experience; only two students (5%) claimed to have a great deal of previous teaching experience. The five methods science tutors were all long-experienced science educators. Four of them had been involved in pre-service educational training for more than 15 years. According to the tutors' judgement the student group in this study was fairly typical of the groups who have participated in the rapidly changing but basically comparable Keele programmes over the last ten years.

### *The instruments and the structure of the research*

The data were collected through questionnaires and interviews conducted both during and at the end of the education and training course. The questionnaire included an 'open' section and a 'closed' Likert-type section.

1. The open section involved views about education through science and included the following question:

   > Besides the importance of pupils being acquainted with various aspects of subject matter, what in your opinion are the most important reasons for including science education in the national curriculum? (Please write short statements).

2. The Likert-type section included 65 items concerning seven categories: the purposes of science education; classroom management; teaching schemes and instructional strategies; their self-concept as a science teacher; their self-confidence in using selected teaching strategies; and their expectations of the PGCE programme.

Each category was rated on a 7-point scale developed from a similar instrument used by Tamir (1991). The validation of the current questionnaire was conducted through the 'expert' judgement of eight science educators in Israel and the United Kingdom who have specialized in pre-service teacher training. The experts were given a list of 94 items concerning the above seven categories and were asked to evaluate the nature and quality of the categories and statements. Following this validation process 65 statements were selected for the final questionnaire (Table 6).

The questionnaires were administered to the postgraduate students before (pre-test) and after (post-test) participating in the education and training programme. The category relating to 'expectations' was modified in the post-test version in order to reveal the students' final judgements.

Towards the end of the programme about 25 students were interviewed individually. The interviews began with a general discussion about the student's experiences and impressions of the programme. At some stage of the conversations the students were asked direct questions about their responses to both the pre- and post-questionnaires. They were provided with their original answer sheets and were asked to explain some of their views. No notes were taken during the interview in order to maintain the informal and open atmosphere of the conversation. However, a brief summary of the main points raised in the interviews and enlightening quotations which were offered, were written up immediately afterwards.

This method of integrating quantitative and qualitative data enabled the researchers to obtain an overview of students' ideas, together with the reasoning which lay behind them, and to overcome the limitations of using only one data collection method.

### *Data analysis*

The analysis of the 'closed' section of the questionnaire included frequency distribution, means and standard deviation, *t*-test and one-way analyses of variance (ANOVA) statistics. For the sake of brevity and clarity the 7-point scale was merged into three categories: Disagree = 1, 2; Not sure = 3, 4, 5; Agree = 6, 7.

The written responses were analysed and classified into categories which later enabled a personal, and we hope non-subjective, pre/post-test comparison. The comparison used four scales of analysis:

(1) No change. The same reasons appeared in both responses.
(2) Minor change. Only one change (in or out) appeared.
(3) Moderate change. Two or three changes were noted (in or out) and the change was less than 50%. If there were only three reasons and two of them were changed then it was counted as a major change, not a moderate one.
(4) Major changes. More than three changes or more than 50% of changes.

The student teachers' interview data is used to justify the findings given later.

## Results

### *Analysis of the 'open' questionnaire*

The analysis of the written text of the pre- and post-questionnaires revealed 35 different sets of statements by the student teachers. These reasons were later reclassified and collapsed into 18 different categories which served as the basis for the comparison of personal changes of opinion (Tables 3, 4 and 5).

The following comparisons can be made:

(1) Initially the students mentioned a wide spectrum of reasons. This spectrum was enlarged in the responses offered after the programme had finished.
(2) Only one of the reasons for studying science in schools, the important 'role of science in our daily world', was mentioned by the majority of the students (about 60% in the pre-test and about 75% in the post-test).
(3) Almost all of the students changed their views about science education and most of them exhibited major changes. They acquired new ideas and set aside old ones. This changing pattern exemplified the heterogeneity of the group and the different and opposing changes which each experienced in relation to their counterparts. At a macro scale, only a small change can be detected

**Table 3. Examples of analysing the extent of changes in students' reasons for including science in the National Curriculum.**

| *Pre* | *Post* | *Change effect* |
|---|---|---|
| 1. It explains much of the world around us – the basics of life. | 1. It enables children to understand how the world around them operates. | No change |
| 1. A good science background is essential for employment in many modern industries<br>2. A nation's prosperity may well be placed in jeopardy should it not pay heed to the importance of encouraging and nurturing its prospective scientists and technicians. | 1. Science opens people's eyes to the world in which they live.<br>2. The teaching of science is crucial to a nation's success and prosperity as it encourages prospective scientists to persist in making it their career; new blood increases creativity in industry. | Minor change |
| 1. To enable pupils to find out and enquire about nature.<br>2. To discover properties of materials, of the world.<br>3. To use logic in order to relate science to demands and experiences of the working world. | 1. To create an awareness of and interest in the natural world around us.<br>2. To develop essential skills: decision making, hypothesis making, investigations, questioning etc. | Moderate change |
| 1. Science applies to the world in which children live and therefore it is important that they understand how things work, etc.<br>2. Industry and other careers are aided by science education.<br>3. An understanding of the world in a scientific manner will lead to a respect for environmental issues. | 1. Practical science lessons create good discipline and practice for other practical activities.<br>2. The pupils learn self control when using chemical apparatus, etc. | Major change |

**Table 4. Pre- post-comparison of the reasons for teaching science in schools written by the same students (one to one) and a comparison with the tutors' reasons and their distribution.**

| *List of reasons* | *Pre* | *Post* | *No change* | *Change* | | *Tutors' views* (%) |
|---|---|---|---|---|---|---|
| | | | | *In* | *Out* | |
| 1. The role of science in our surroundings: the world we live in, everyday (real) life, common objects and our personal bodies | 23 (61%) | 28 (74%) | 18 | 10 | 5 | 80 |
| 2. Development of cognitive skills | 21 (55%) | 16 (42%) | 10 | 6 | 11 | 60 |
| 3. The role of science in society aspects: environmental and/or technological awareness | 15 (39%) | 18 (47%) | 7 | 11 | 8 | 80 |
| 4. Development of practical investigative skills | 13 (34%) | 9 (24%) | 3 | 6 | 10 | 40 |
| 5. Progress and advancement of world/nation/humankind/industry | 11 (29%) | 5 (13%) | 5 | | 6 | |
| 6. Influence on future study and career | 9 (24%) | 5 (13%) | 3 | 2 | 6 | |
| 7. Enquiring state of mind | 6 (16%) | 5 (13%) | 1 | 4 | 5 | 20 |
| 8. To provide basic education | 4 (11%) | 3 (8%) | | 3 | 4 | 20 |
| 9. The natural world | 8 (21%) | 6 (16%) | 3 | 3 | 5 | 40 |
| 10. Affective aspect: fun, enjoyment, interest | 4 (10%) | 5 (13%) | 1 | 4 | 3 | 20 |
| 11. Social aspect: team work, co-operation | 3 (8%) | 1 (3%) | 1 | 3 | 20 | |
| 12. Truth and objectivity | 2 (5%) | 2 (5%) | 1 | 1 | 1 | |
| 13. Foster creativity | | 2 (5%) | | 2 | | |
| 14. Tool to involve all pupils in the lessons | | 1 (3%) | | 1 | | |
| 15. Knowledge of historical development in science | | 1 (3%) | | 1 | | |
| 16. To develop good discipline | | 1 (3%) | | 1 | | |
| 17. To develop self control | | 1 (3%) | | 1 | | |
| 18. Study skills | | 1 (3%) | | 1 | | |
| Total | | | = 53 | +57 | −63 | |

No change: same reasons given in both questionnaires.
In: reasons appeared only in the post-test.
Out: reasons appeared only in the pre-test.

since the overall average of the pre- and post-tests results is quite similar, but there were many swings of opinion in both directions at the personal level.

(4) Although the changes were mainly in the individual domain it is possible to detect certain general changes:

(*a*) Students' views about the importance of the role of science in daily life and in society generally tended to increase.

(*b*) The importance of the following categories tended to decrease:

- the role of science education in the development of skills;
- the importance of studying science for future studies and a career;

**Table 5. Amount of change in ideas about education through science revealed by the personal comparison of the pre/post questionnaires.**

| *Criterion* | *Number of students* | *Percentage of students* |
|---|---|---|
| No change | 1 | 3 |
| Minor | 3 | 8 |
| Moderate | 10 | 26 |
| Major | 24 | 63 |
| Total | 38* | 100 |

No change: Same reasons given in both questionnaires.
Minor: Only one change (in or out).
Moderate: Two or three changes (in or out); change less than 50%. (If there were only three reasons and two of them were changed then it was counted as a major change and not as a moderate one.)
Major: More than three changes or more than 50% of changes.
*One student did not write of his reasons in the post test.

- the influence of science on the progress of each nation and the world in general;
- science in basic education;
- science as a study of the natural world.

In summary, these findings indicate that the group should be best described as a group of individuals. They exhibited a wide range of views upon entering the programme and an even greater range when leaving it. Their ideas about education through science were significantly changed or reshaped following the course, but again the changes took place at the individual level; no general pattern was observable.

These findings raise immediate questions such as, What is the mechanism of these perpetual and attitudinal changes? From whence did the new ideas emerge: the university courses? the classroom experience? or both? Did ideas which are not mentioned by the students in the post-test disappear or merely cease to have immediate importance?

The preceding questions, along with others, were also included in the interviews. Their responses revealed the following:

1. Many were not aware of their perceptual and attitudinal changes and were quite surprised to see their original written statements.
2. None of the students ignored the statements which he/she mentioned only in the pre-questionnaire. They all explained that they just did not consider them to be as important as they first thought.
3. All mentioned that the changes occurred mainly as a result of their teaching practice:

> I adopted the idea of teaching science in a relation to daily life experiences, since I found that the children liked this approach.

> My teaching practice was a kind of 'trial and error' process ... I adopted ideas which I found useful with the children and deleted those which I did not find very helpful.

> I found many of the ideas which were introduced to us in the university course were irrelevant, since I could not find any relationship between them and my teaching experience in the school.

From this analysis of their written statements and interviews, it seems that almost all the students reshaped or developed new ideas about education through science. The perceptual and attitudinal changes which took place might indicate a general tendency to adopt more practical views and less naïve or idealistic views. It seems that the process of understanding, development and change occurred mainly through the 'concrete' experience gained on school practice. This experience was the 'road test' for their own ideas and for the range of additional ones that were offered by the tutors. If an idea was found to incorporate a useful teaching and learning tool, and was within the competence of a beginner, the idea was adopted; it 'passed' the test. An idea which only achieved partial results or 'failed' the test was rated of lower importance.

It should be stressed that each of the students was exposed to a varied and different sample of university tutors, school mentors and school settings; each of them processed these stimuli individually according to her/his own personality, competence and stage of development. Hence different persons displayed different and sometimes even opposite changes of viewpoint. The students entered the course as a heterogeneous group of individuals and they reshaped their ideas individually and in unique ways.

### *Analysis of the 'closed' questionnaire*

Table 6 presents the frequency distribution and means of both pre- and post-test data of the whole sample, together with a *t*-test comparison. In addition, the table records statements relating to prominent differences which were found between the frequencies or means of the views of the student teachers and those of their professional tutors.

### *Students' opinions and characteristics upon entering the course*

The majority of the students (at least 60%) entered the course with uncertainty of viewpoint in relation to 65% of the statements. This uncertainty is apparent in their responses to all seven categories but mainly in those relating to 'Teaching schemes and instructional strategies' and 'Self concept'. Where students' views were found to be more definite they provided quite an encouraging picture of their characteristics, as the following illustrate:

- They chose to enter the programme for 'positive' or 'right' reasons (challenge and satisfaction);
- They held a pupil-oriented approach in relation to the purposes of teaching science and the management skills which they imagined would be needed;
- They did not display gender bias or show preferences for the more able students;
- They held progressive ideas about questioning the nature, origin and future workings of our world through science education;
- They believed that external examinations should have a marginal influence on the purposes of science education;
- They displayed progressive ideas in relation to classroom management, e.g. the importance of extensive feedback, and in relation to using a variety of learning environments including both the laboratory and the outdoors.

Their expectations of the programme were practically oriented. As intending

**Table 6. Students' frequency distribution, means and standard deviation of the pre- and post-questionnaires t = test comparison. Pr = Pre, Po = Post. The 7-point scale was merged into three categories: Disagree = 1, 2; Not sure = 3, 4, 5; Agree = 6, 7.**

| | Frequency (%) | | | | | | $\chi$ (SD) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Agree | | Not sure | | Disagree | | | | | |
| Statement and category | Pr | **Po** | Pr | **Po** | Pr | **Po** | Pr | **Po** | $t$ | $P$ |
| *Views on teaching science* | | | | | | | | | | |
| 1. Teaching separate sciences up to 16 is best. | 36 | **24** | 46 | **54** | 18 | **22** | 4·5 (1·7) | **4·0** (1·6) | 0·5 | NS |
| 2. Teaching science today is not very different from the way it was taught when I was a pupil. | 20 | **24** | 49 | **19** | 31 | **57** | 3·8 (1·8) | **3·2** (1·9) | 1·8 | NS |
| 3. Teaching science could be very stressful for me. | 13 | **14** | 38 | **50** | 49 | **36** | 3·1 (1·6) | **3·1** (1·8) | 0·9 | NS |
| 4. Less able pupils should be taught less science than the more able ones. | 15 | **14** | 23 | **40** | 62 | **46** | 2·9 (1·8) | **3·1** (1·7) | 1·0 | NS |
| 5. Teaching broad balanced science is a greater challenge than teaching single science. | 56 | **68** | 39 | **23** | 5 | **9** | 5·3 (1·4) | **5·5** (1·5) | 0·8 | NS |
| 6. I expect more challenge and satisfaction in teaching science than in other jobs. | 79 | **68** | 21 | **27** | — | **5** | 6·0 (0·8) | **5·5** (1·4) | 1·7 | NS |
| 7. Girls will be more difficult to teach than boys in science. | 3 | **3** | 25 | **13** | 72 | **84** | 2·2 (1·8) | **2·0** (1·2) | 0·2 | NS |
| *Aims, goals and objectives (High–Low scale)* | | | | | | | | | | |
| 8. The purposes of science education should be derived from the needs of society. | 25 | **32** | 65 | **62** | 10 | **6** | 4·6 (1·3) | **4·9** (1·3) | 1·2 | NS |
| 9. The purposes of science education should be derived from a knowledge of ideas pupils already possess. | 13 | **35** | 67 | **54** | 20 | **11** | 3·7 (1·3) | **4·7** (1·5) | 2·9 | 0·006 |
| 10. The purposes of science education should be derived from the methodology and philosophy of science. | 15 | **22** | 77 | **70** | 8 | **8** | 4·4 (1·3) | **4·2** (1·4) | 0·9 | NS |
| 11. The purposes of science education should be derived from the questions of the examination papers. | 2 | **12** | 26 | **24** | 72 | **64** | 2·2 (1·3) | **2·5** (1·6) | 0·8 | NS |

*(continued overleaf)*

**Table 6 (*continued*).**

| Statement and category | *Frequency (%)* Agree | | Not sure | | Disagree | | χ (SD) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pr | Po | Pr | Po | Pr | Po | Pr | Po | *t* | *P* |
| 12. The job of science teachers should be to encourage pupils to question the natural world around them. | 100 | **89** | — | **11** | — | — | 6·5 (0·5) | **6·4** (0·7) | 0·4 | NS |
| 13. The job of science teachers should be to respond to the needs of society. | 41 | **35** | 46 | **57** | 13 | **8** | 4·8 (1·5) | **4·8** (1·3) | 0·1 | NS |
| 14. The job of science teachers should be to satisfy the needs of the pupils. | 64 | **68** | 28 | **29** | 8 | **3** | 5·5 (1·6) | **5·5** (1·1) | 0·2 | NS |
| 15. The job of science teachers should be to produce a life-long interest in science in the pupils. | 82 | **78** | 13 | **17** | 5 | **5** | 5·9 (1·3) | **5·9** (1·3) | 0·3 | NS |
| *Management skills* | | | | | | | | | | |
| 16. The teacher should avoid grouping students by abilities. | 18 | **8** | 44 | **38** | 38 | **54** | 3·5 (1·6) | **3·0** (1·6) | 1·3 | NS |
| 17. Developing a disciplinary role and the use of sanctions are very important. | 51 | **83** | 41 | **17** | 8 | — | 5·2 (1·4) | **6·2** (0·8) | 3·7 | 0·0007 |
| 18. There should be separate classes for pupils of different abilities. | 43 | **63** | 44 | **32** | 13 | **5** | 4·8 (1·7) | **5·4** (1·4) | 2·7 | 0·01 |
| 19. As a teacher I would give encouragement to each of my pupils. | 97 | **97** | 3 | **3** | — | — | 6·7 (0·5) | **6·8** (0·5) | 0·2 | NS |
| 20. Gaining extensive feedback from many sources on the results of teaching is vital. | 94 | **81** | 3 | **16** | 3 | **3** | 6·4 (0·9) | **6·2** (1·1) | 1·0 | NS |
| 21. Laboratory activities are not essential for teaching science. | 3 | **5** | 5 | **11** | 92 | **84** | 1·5 (1·1) | **2·0** (1·3) | 1·3 | NS |
| 22. The computer is a vital educational tool for teaching science. | 41 | **27** | 49 | **57** | 10 | **16** | 4·9 (1·5) | **4·5** (1·5) | 1·2 | NS |
| 23. I could teach science properly without even going outdoors. | 13 | **8** | 21 | **38** | 66 | **54** | 2·7 (1·7) | **2·9** (1·6) | 0·4 | NS |
| 24. Pupils should get homework regularly in order to develop independent learning skills. | 67 | **81** | 25 | **16** | 8 | **3** | 5·5 (1·4) | **5·9** (1·0) | 1·3 | NS |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *My self concept as a science teachers* | | | | | | | | | | |
| 25. I am confident in myself as a science teacher. | 48 | **94** | 49 | **6** | 3 | — | 5·3 (1·2) | **6·1** (0·6) | 3·1 | 0·004 |
| 26. I think I 'know my stuff' and will have few problems with teaching content/concepts. | 20 | **68** | 72 | **27** | 8 | **5** | 4·8 (1·3) | **5·6** (1·2) | 2·3 | 0·03 |
| 27. I will have few disciplinary problems with my pupils. | 8 | **37** | 79 | **49** | 13 | **14** | 3·9 (1·1) | **4·8** (1·5) | 2·6 | 0·01 |
| 28. A specialist science teacher is better respected than a general science teacher. | 13 | **24** | 43 | **41** | 44 | **35** | 3·5 (1·8) | **3·8** (1·8) | 0·7 | NS |
| 29. Teaching science will be life-long career for me. | 44 | **46** | 53 | **46** | 3 | **8** | 5·2 (1·2) | **4·9** (1·5) | 1·6 | NS |
| 30. I am apprehensive about developing appropriate relationships with science classes. | 31 | — | 41 | **38** | 28 | **62** | 4·2 (1·7) | **2·5** (1·3) | 4·4 | 0·0001 |
| 31. I am apprehensive about developing sound personal relationships with every student. | 18 | **11** | 51 | **35** | 31 | **54** | 3·9 (1·7) | **3·0** (1·6) | 2·6 | 0·01 |
| 32. I will be able to act out the role of the best science teacher who taught me. | 15 | **19** | 60 | **43** | 25 | **38** | 4·0 (1·6) | **3·5** (1·7) | 1·3 | NS |
| 33. I expect to have to earn the respect of my pupils. | 100 | **83** | — | **12** | — | **5** | 6·4 (0·5) | **6·0** (1·3) | 1·3 | NS |
| *Teaching scheme and instructional strategies* | | | | | | | | | | |
| 34. Individual teachers should decide the teaching scheme for each science class. | 15 | **17** | 62 | **49** | 23 | **32** | 4·0 (1·6) | **3·5** (1·6) | 1·9 | NS |
| 35. Teachers must cover all the topics in the science syllabus. | 44 | **46** | 48 | **46** | 8 | **8** | 5·1 (1·5) | **4·9** (1·4) | 0·6 | NS |
| 36. Heads of science should control the curriculum which is taught by individual science staff. | 23 | **40** | 64 | **49** | 13 | **11** | 4·5 (1·4) | **4·8** (1·5) | 0·9 | NS |
| 37. The external examination in practice determines the course of science which is taught. | 64 | **51** | 33 | **39** | 3 | **11** | 5·6 (1·2) | **5·1** (1·4) | 1·3 | NS |
| 38. The needs of the industry and other influencing bodies should be reflected in what is taught. | 46 | **62** | 44 | **35** | 10 | **3** | 5·1 (1·4) | **5·5** (0·9) | 1·7 | NS |
| 39. Teachers should not spend much time on development of teaching materials; there are good materials to buy. | 8 | **6** | 43 | **40** | 49 | **54** | 2·9 (1·5) | **2·9** (1·5) | 0·1 | NS |
| 40. What is taught should be chosen for its potential to interest students. | 33 | **29** | 54 | **60** | 13 | **11** | 4·4 (1·6) | **4·7** (1·4) | 0·9 | NS |
| 41. Individual teachers should decide how to teach each topic in the science syllabus. | 62 | **60** | 35 | **26** | 3 | **14** | 5·5 (1·1) | **5·2** (1·7) | 0·1 | NS |

(*continued overleaf*)

## Table 6 (*continued*).

| Statement and category | Frequency (%) Agree Pr | Agree Po | Not sure Pr | Not sure Po | Disagree Pr | Disagree Po | χ (SD) Pr | χ (SD) Po | *t* | *P* |
|---|---|---|---|---|---|---|---|---|---|---|
| 42. Few behavioural and safety problems arise when teachers direct learning closely. | 26 | **26** | 66 | **62** | 8 | **12** | 4·5 (1·1) | **4·5** (1·3) | 0·4 | NS |
| 43. Chalk-and-talk is still the best way of teaching science. | 10 | — | 41 | **33** | 49 | **67** | 3·1 (1·6) | **2·4** (1·1) | 1·4 | NS |
| 44. Small group practicals are better than individualized practicals. | 38 | **41** | 52 | **51** | 10 | **8** | 4·8 (1·5) | **4·9** (1·4) | 0·1 | NS |
| 45. Individualized learning tasks, monitored by the teacher, should be commonplace. | 28 | **43** | 67 | **52** | 5 | **5** | 4·8 (1·1) | **5·0** (1·4) | 0·3 | NS |
| 46. Students learn best if they have to work out things for themselves rather than being told or shown what to do. | 38 | **68** | 54 | **29** | 8 | **3** | 4·9 (1·5) | **5·6** (1·2) | 2·2 | 0·04 |
| 47. When working with slow learners, teachers should focus on developing minimum competences. | 10 | **19** | 59 | **63** | 31 | **18** | 3·5 (1·5) | **4·2** (1·4) | 3·3 | 0·002 |
| *Expectations of the preservice programme* | | | | | | | | | | |
| 48. The science methods course (will be)* was the most important one for me this year. | 18 | **30** | 69 | **45** | 13 | **25** | 4·3 (1·3) | **4·4** (1·8) | 0·1 | NS |
| 49. (I expect that) The programme (will)* supplied me with all skills needed to become a competent science teacher. | 20 | **14** | 60 | **48** | 20 | **38** | 4·2 (1·6) | **3·4** (1·7) | 2·2 | 0·03 |
| 50. I believe that my ideas about education (will)* changed significantly during the programme. | 46 | **30** | 51 | **43** | 3 | **27** | 5·1 (1·3) | **4·2** (1·7) | 2·2 | 0·03 |
| 51. I (expect to find)* found the teaching profession to be enthusiastic. | 46 | **44** | 46 | **29** | 8 | **27** | 5·1 (1·3) | **4·5** (1·8) | 1·6 | NS |
| 52. The training programme should be based on experience in schools which is complemented by work in the university. | 90 | **86** | 10 | **14** | — | — | 6·3 (0·7) | **6·3** (0·8) | 0·0 | NS |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 53. Developing a worthwhile science educational philosophy (will be)* was an important task of my postgraduate year. | 61 | **59** | 31 | **38** | 8 | **3** | 5·4(1·3) | **5·4**(1·2) | 0·3 | NS |
| 54. The teaching practices (will be)* was the most important part of the training programme. | 79 | **92** | 28 | **8** | 3 | — | 6·0(1·1) | **6·5**(0·8) | 2·4 | 0·02 |
| 55. The course on educational issues (history, philosophy, sociology and organization of teaching) (will be)* was very important to me as a science teacher. | 54 | **13** | 36 | **68** | 10 | **19** | 5·1(1·5) | **3·8**(1·6) | 4·1 | 0·0002 |
| *Extent of confidence in teaching (High–Low scale)* | | | | | | | | | | |
| 56. Introducing a topic by interactive discussion. | 49 | **71** | 51 | **29** | — | — | 5·4(1·1) | **5·9**(0·9) | 1·7 | NS |
| 57. Running a practical. | 54 | **67** | 38 | **33** | 8 | — | 5·3(1·4) | **5·9**(0·8) | 1·9 | NS |
| 58. Discussing and interpreting the results of a practical. | 69 | **70** | 31 | **30** | — | — | 5·7(0·9) | **5·9**(1·0) | 0·2 | NS |
| 59. Helping pupils to plan an investigation of their own. | 38 | **66** | 62 | **34** | — | — | 5·2(0·9) | **5·8**(0·9) | 2·3 | 0·03 |
| 60. Helping pupils to create hypotheses/conjectures to test. | 36 | **48** | 61 | **52** | 3 | — | 5·1(1·1) | **5·5**(0·9) | 1·3 | NS |
| 61. Helping pupils to control variables. | 59 | **65** | 41 | **35** | — | — | 5·5(1·0) | **5·7**(0·9) | 1·1 | NS |
| 62. Using audio-visual aids. | 72 | **79** | 28 | **21** | — | — | 5·9(0·9) | **6·0**(0·9) | 0·4 | NS |
| 63. Organizing and introducing a museum visit. | 64 | **24** | 36 | **65** | — | **8** | 5·5(1·2) | **4·6**(1·3) | 4·1 | 0·0003 |
| 64. Organizing and introducing an industrial visit. | 64 | **21** | 36 | **67** | — | **11** | 5·5(1·2) | **4·5**(1·3) | 3·6 | 0·001 |
| 65. Organizing and introducing a field experience in a natural setting. | 54 | **38** | 43 | **48** | 3 | **14** | 5·4(1·4) | **4·8**(1·6) | 2·1 | 0·04 |

* In parentheses the version of the pre-questionnaire.

school teachers they expected that their school experiences would be the most important part of the course, but they also expected to find a close relationship between their school experience and their university courses. Initially they showed over-confidence in relation to their own teaching abilities. This may have reflected an underestimation of the difficulties of acquiring the complex range of skills needed to be successful in the science teaching profession.

A profile of a student teacher in the United Kingdom upon entry to her/his PGCE course might include the following characteristics: considerable motivation; practical expectations; a pupil-oriented approach; a questioning outlook towards studying the natural world; a wish to use variety of learning environments; over-confidence and an underestimation of the complexity of the skills needed in the teaching profession.

### *Students' opinions and characteristics upon leaving the course*

The results of the post-questionnaires indicate that the student teachers left the course with a considerably lower level of uncertainty than when they had entered it. The degree of change, however, was quite small since the majority of the students (at least 60%) left in an uncertain mind in relation to about half of the statements. With respect to some items the level of uncertainty was reduced following the course but with others it was increased.

*Teaching science*: No significant differences were found in pre- and post-test results but a change in the frequency distribution indicates a greater degree of uncertainty in relation to giving equal emphasis to the less and more able students in learning science.

*Aims and goals*: A significant positive statistical change was found in relation to students' recognition of the importance of scientific knowledge and the ideas which pupils already possess when they come to school. Thus, a constructivist pupil-oriented approach was strengthened following the course. With respect to all the other statements there were only small changes (up to 10%) in the students.

*Management skills*: One significant change occurred with respect to classroom management. The students replaced their more 'progressive' attitudes with a more 'practical' approach. In the end they preferred disciplined homogeneous classes rather than boisterous mixed-ability classes, and they advocated setting more homework for the students. In all the other aspects, minor changes (up to 10%) were noted and the changes were all towards the 'not sure' area.

*Self concept*: There was a significant increase in students' confidence in general and even in specific areas such as teaching content and the management of discipline. They also acquired a significant confidence in their ability to develop appropriate relationships with whole classes and sound personal relationships with individual pupils.

About 50% of the students were still not sure if teaching science would be a life-long career. This finding is quite interesting in the light of two facts: most of the students believed initially that the teaching profession would provide them with more satisfaction and challenge than other jobs; and their initial great confidence in their own teaching abilities.

*Teaching schemes and instructional strategies*: Although significant statistical changes were found only in relation to two statements, there are at least four more statements where 15% change can be seen in the frequency distribution patterns. The changes indicate that certain 'progressive' ideas were developed, mainly in terms of a pupil-oriented approach, the use of a greater variety of teaching strategies and the acceptance of more science–society interrelationships in their teaching schemes. By contrast, a significant change (regression?) was found in relation to their confidence and their interest in working with slow learners.

*Students' expectations and their fulfilment*: It seems that the practical expectations of the school practice were fulfiled and students found this experience even more important than they expected; it proved to be the most important part of the whole programme. They did not find the contribution of the university courses to be as satisfactory as they hoped; the problem lay mainly with the course which related to the more theoretical issues of education, e.g. those where there were substantial inputs from philosophy, sociology and history. Only 14% believed that the overall programme provided them with all the skills needed to become a competent teacher.

*Confidence in teaching*: The students left the course with a high level of confidence in their indoor science teaching abilities, but with a much lower level of confidence in their outdoor teaching abilities. These findings reflect the low emphasis on outdoor science education both in the schools where they conducted their teaching practice and in the present education and training programmes. There was almost no significant increase in the students' confidence in their indoor science teaching abilities. However, since they came with over confidence, the degree of confidence shown at the end of the course reflects a genuine situation.

In summary, it is suggested that there is an overall pattern in the changes which were observed in the different sections of the inquiry. This pattern is consistent with the direction of change which was noted in the open questionnaires, namely the development of very practical views based on school experiences. In particular, students emphasized issues which make the work of a science teacher in the classroom more effective and perhaps easier: the development of a strong pupil-oriented constructivist approach; a greater emphasis on disciplinary rules and sanctions; a tendency to prefer homogeneous classes and to prefer teaching more able students. The students are leaving the course with a high level of confidence in their indoor science teaching abilities, but with a much lower confidence in their outdoor teaching abilities. These findings probably reflect the low profile of the outdoor learning and teaching environment in schools and in all but the earth science parts of the science teacher education and training programme.

### *A comparison of the professional tutors' responses*

The university tutors were asked to fill in only those statements in the questionnaire which referred to general issues (the teaching abilities and the self concept assessment) not to the course programme (Table 4). Agreement amongst all the five tutors was found only in relation to 12 statements out of 35 (34%); agreement amongst four tutors only was found in relation to seven other statements (20%). Generally, the tutors' range of responses and their distribution patterns were quite similar to those shown by the student teachers in their responses at the end of the course. This similarity was found both in their agreed views and in the areas of uncertainty. In many cases the 'uncertainty' emerged from the holding of very contrasting views: some of the tutors definitely agreed with a specific statement and others definitely disagreed. Thus, it might be suggested that the high level of uncertainty indicated both by the tutors and the student teachers, was mainly related to the many-sided value judgements which need to be made with respect to most educational issues.

In the following six items (17% of the statements) a strong difference of opinion was found between the tutors' and the students' views:

1. All the tutors think that the aims, goals and objectives of science education should be derived in part from a knowledge of the ideas which pupils already possess (the constructivist approach).
2. Almost all the tutors think that the purposes of science education should be derived in part from the methodologies and philosophies of science.
3. Most of the tutors think that the less able and the more able school pupils should be taught the same science in similar but not identical ways.
4. Almost all the tutors are uncertain about having separate classes for students showing apparently different abilities and levels of achievement. With respect to the same issues, the pre-service teachers generally prefer to segregate pupils into sets of differing ability.
5. All the tutors agree that the head of science should decide what is taught in her/his department.
6. All the tutors agree that the individual teacher should decide how to teach each topic.

These differences, or at least the first four, suggest that the influence of the tutors on the student teachers' views at the end of the course was quite limited. Only in one area, with respect to the constructivist approach, did the students' post-experience attitudes approach those of the tutors, while in the other three the students' post-experience views became even more distant. This finding supports the notion that the student teachers reshaped their ideas following their school experiences; the ideas which were presented to them by their tutors during the university courses were accepted only if they passed the 'real life' test of their classroom teaching. There is a real tug of war here between introducing desirable educational ideals, e.g. incorporating the methodologies and philosophies of science (on the part of the tutors), and only attempting what works easily in schools under often hostile circumstances (on the part of the students).

*Interviews*

Interviews were conducted with 18 students in relation to augmenting their responses to the different questionnaires. One of them was a student who entered the programme with a few years' teaching experience. His responses revealed a high level of satisfaction from the university courses. All but one of the others were students who had entered the programme without any earlier teaching experience or with only limited experience. Their post-experience attitudes reflected a certain amount of dissatisfaction with the university part of the programme. Most of the more or less unsatisfied students used the term 'irrelevance' to describe their critique of the university courses. By using this expression they meant that in their opinion many parts of these courses were not relevant to their school practice. Some of them were specific and inevitable:

> For example, we did those A-level* exercises, but in school we did not teach A-level.

* This is a reference to the Advanced Level courses in England and Wales which are normally followed at ages 16 to 19 by the ablest students who stay on at school after the compulsory leaving age. The courses are academically demanding and are required for university entrance.

> I expected that the methods course would prepare me to teach the same topics I had to teach later with my classes, but instead they just gave us broad ideas and some examples, but they were not concrete enough.

Some students could give only a general opinion:

> I don't know exactly ... but sometimes I couldn't follow them (the tutors), they spoke on too high a level for me ... I couldn't detect the relevance of their ideas for my school teaching.

In response to a question about what specifically they missed in the course, ten different answers were received from the 17 students. The common denominator related to practical needs such as: more practical guidance about how to teach a specific topic; more micro-teaching exercises; more content enrichment in specific topics; and how to work with pupils with special needs. One of the students said:

> I want options; there were too many things that were not relevant for me or that I already knew ... I know my interests and the areas where I need to strengthen myself ... I want to have the option to choose my focuses in relation to my weaknesses and my interests.

These findings support two notions which have been stressed earlier:

(*a*) The narrow practical point of view of the students. Many viewed only their immediate relation to their immediate requirements in their immediate classroom teaching. Everything which was not related to, did not fulfil these immediate needs was classified as irrelevant.

(*b*) The fact that the student group is actually a set of individuals not a group with corporate needs. Although the narrow practical point of view was common for many of the students, each of them had her/his own needs in relation to background, personality and the specific teaching practice experience. They did not have group needs to the extent the tutors may have supposed.

The interview with a student teacher who entered the programme after a few years of school teaching revealed a totally different picture. He used the term 'gold' in order to express his feeling about the methods course. For him it was the highlight of all the programme.

> I remember at the beginning one lesson about classroom management ... For me it was gold, every example of common mistakes that the tutor raised, I used to do as a teacher ... After the lesson I was very excited and went to thank the tutor ... The others, just sat there with bored expressions ... they had no idea what I was so excited about ... What I learned here in one year, I couldn't learn even in ten years of school teaching.

It is suggested that the huge difference between the two sets of experiences presented above illustrates the paradox of any pre-service teaching training course. On the one hand, in order to develop *educators* rather than 'teaching technicians', university courses tend to emphasize the theoretical and philosophical aspects of education and teaching. On the other hand the student teachers cannot understand, at this stage, the relevance of these aspects. They are looking for concrete practices, in some cases 'tips for teachers', which they can immediately implement in the classroom.

These findings, in turn, suggest that amongst serving teachers there will occur (after a certain period of initial experience) a ripening time during which they will be particularly responsive to opportunities to reflect on the teaching strategies and styles they have developed to far. The importance of providing statutory leave for professional needs to be fulfilled by appropriate in-service education (rather than just training) is obvious.

### *Differences in relation to the heterogeneous nature of the sample*

The sample was heterogeneous in relation to gender, scientific background and age. Only two students possessed a meaningful previous teaching experience.

The *t*-test and the ANOVA statistical analysis revealed few differences in the pre-test and post-test surveys in relation to gender, scientific background and age. The differences which were found indicate that:

- Males hold significantly higher positive attitudes towards the inclusion of such topics as 'the purposes of science education' and 'the science teacher in relation to the needs of society'.
- At the end of the programme the earth science teachers showed higher confidence in teaching science in non-school settings (museums, industrial sites, planetaria, the natural environment). Their confidence was significantly higher than that of the chemistry and physics students.
- The students of the middle-age groups (25 to 30) entered the programme and left it with significantly diminished attitudes about teaching science as life-long career. This age group included students who had turned to teaching as a second career and some who had not found better possibilities elsewhere. The interviews revealed that some of them were still hoping to find a more profitable profession. This might also explain the finding that although most of the students found a lot of satisfaction and many worthwhile challenges, about 50% of them were still not sure that science teaching would be a life-long career for them.

No difference was found between those students who came with no previous teaching experience and those who came with limited experience. Since the experienced group comprised only two students, a statistical analysis between them and the other groups is inappropriate, but it is important to notice that while the mean of the responses of the two other groups in relation to the item 'The programme supplied me with all the skills I needed.' was 3·2, the mean of the experienced students was 6·5. While the mean of experienced students in relation to the item 'The teaching practice was the most important part (of the course)' was 4·5, the mean of the rest of the group was conversely 6·6.

## Discussion and conclusions

Tamir (1991), working in Israel, suggested that student teachers enter pre-service teacher education programmes with a high level of uncertainty. This was in contrast to earlier studies conducted in the USA (e.g. Hollingsworth 1989) which asserted that students entering teacher education programmes possessed definite ideas about teaching and learning. Our findings suggest that this group of British postgraduate student teachers entered the PGCE programme uncertain about most aspects of science education and the practical teaching of science, but with some definite ideas in these areas as well. However, it was also found that students possessed the same amount of uncertainty in most of these aspects *after* participating in the pre-service programme. Following the analysis of the tutors' responses, it is suggested that the uncertainty expressed by the students at the end of the programme reflects the general ambiguity of all concerned about many of the issues under investigation. This ambiguity is mainly derived from two sources:

(*a*) The complexity of the educational setting. There are no clear solutions and more often than not there is more than one way of doing things.

(*b*) The holding of different points of view. Different people may interpret the same situation differently and hold very definite but opposite points of view. Thus, it is suggested that the discussion of such issues and the holding of uncertain attitudes with respect to many problems in education is a desirable outcome, provided, of course, that the students are adaptable, and aware of the complexity of the issues. They need to be provided with an arsenal of different skills and teaching strategies to try out in response to the many different situations.

This last condition was exactly the main aim of the programme under investigation and this is likely to be so for many other pre-service programmes of this kind as well. However, our findings, collected from many sources, suggest that objectives related to this aim do not correspond well with the immediate needs of student teachers and, even more importantly, with their tenderfoot learning abilities. The student teachers enter the course as a group of individuals who possess only one predominant common characteristic – a narrow practical view of the course as teacher training rather than teacher education. Their attention is mainly focused on developing the ability to stand in front of a class of pupils with confidence and conviction. As a learner in the teaching profession, the 'real world' for them consists of a school, a classroom, a laboratory and a group of pupils. There, in the 'real world', they test their own preconceptions and the new ideas they received from their tutors.

Tamir (1991: 239) has written that 'previous research has shown that most pre-service education programmes ... tend to perpetuate the beliefs that pre-service teachers bring with them'. Our findings strongly refute this and suggest that throughout the teaching practice the students passed through a dynamic process of transformation and that meaningful perceptual and attitudinal changes occurred for almost all of them. This process was, however, totally idiosyncratic and the influence of the university tutors was effective only to the extent that the students found that their ideas provided them with useful and practical teaching tools. Furthermore, ideas which were not found useful did not register and were classified as 'irrelevant'.

Our conclusion, that student teachers change their perceptions and attitudes in idiosyncratic ways mainly due to their teaching experiences whilst on the PGCE course, needs to be tested more broadly, ideally using control groups where a variety of teacher education and training systems exist within one culture in any one year.

The high degree of appreciation that the university courses received from the two students who came with previous teaching experience endorses the high quality of these courses, but at the same time emphasizes the paradox of the pre-service training programme. There is no doubt that in order to produce educators rather than 'teaching technicians' student teachers should be introduced both to the practical and to the theoretical and philosophical aspects of education. Nevertheless, they are only able to dimly understand the relevance of many of these ideas. By analogy with the development theory of Piaget, the students may be said to be still in the concrete stage of development. In this stage they have a narrow practical orientation and most are barely open to dealing with the more abstract theoretical and philosophical aspects of education and teaching.

This paradox might lead to the conclusion that pre-service teacher training should be conducted only in schools as is being advocated increasingly by central government in the UK. But this solution could work only in a system which consists of model teachers who could be given the time to learn new strategies and techniques in order to pass on all their practical skills, techniques and wider visions as they supervise the pre-service teachers. However, this utopian state of affairs costs time and money which governments and head teachers are not likely to provide.

In these circumstances, to rely only or predominantly on school-based teacher education and training will serve merely to perpetuate the day-to-day classroom management aspects of the teaching profession.

The basis of a way forward might come from the science educators. While proposing a constructivist approach in teaching school pupils, it might be useful to attempt such an approach in our pre-service teaching programmes. It is suggested that the findings from this study – the progressive ideas which pre-service teachers already possess and their considerable motivation on entering the teacher education programme; the idiosyncratic nature of the student teachers; and their narrowly practical viewpoints and learning abilities – might serve as a good beginning.

The findings presented here are based on a one-year study of a relatively small group of pre-service students. However, according to the students' tutors, this group is quite typical in relation to other groups who have participated in the Keele programmes over the last ten years. Since the nature of the PGCE programme is increasingly dictated by government guidelines, it is suggested that these findings might be generalized in relation to other PGCE programmes in England and Wales.

Inevitably, this study suggests that more research in needed. For example:

(*a*) A closer study should be conducted of the students' learning during their teaching practice.

(*b*) An examination should be made of the possible influences of school mentors on the student teachers and the ways in which these influences are exerted.

(*c*) A long-term study of newly qualified teachers should be made in order to determine the influence of their PGCE programme on their development as teachers.

(*d*) A study of how other pre-service programmes and other cultures influence secondary science student teachers' initial views and how they relate to the beliefs and perceptual-attitudinal changes which follow.

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