Report to SCORE – Science Teacher Education

Special focus on biology

Introduction

Arguably biology has enjoyed a healthy uptake over the years both within compulsory and higher education. When considering Initial Teacher Education, despite a reported decrease in biology applicants onto science PGCE courses between 2001 and 2006 in England and Wales, a healthy increase in acceptances onto such courses was evident across the devolved nations during that time. Scotland in particular almost doubled their figures during this period (The Royal Society, 2007). Although the picture remains buoyant, concern exists regarding the medium to long-term supply of quality biology teachers. Drayston (2009) emphasised the need to enthuse and motivate pupils towards the sciences from the GCSE years; to achieve this a well qualified, enthusiastic and motivated teaching staff needs to be in place. This paper reports on observations regarding the supply of specialist science teachers within the forthcoming years. These observations are substantiated through a small scale scoping survey as preliminary research to a longitudinal study.

This scoping survey has been commissioned by SCORE and involves the collection and processing of data gained from questionnaires and email interviews designed to investigate the current context of Science Education and how this may influence the motivations and intended exit routes of science trainees.

Background

It has been recognised over the past decade that a good supply of high quality science teachers is crucial to achieving results in the classroom. Shortages in teaching staff in science but specifically physical science teachers have been reported and continue to be so (DfES, 2004; Moor, *et al*, 2006, The Royal Society, 2007 and Smithers in Maddern, 2010). Steps have been taken to address this shortage: in 2004 the Government recognised the need for quality continued professional development (CPD) in science education and advocated the value of CPD being recognised as part of a school's success strategy (DfES, 2004). There followed a push to improve quality teaching in science by expanding the professional development scheme and enhancing support for the newly established network of Science Learning Centres. A key emphasis was to eliminate teacher shortages in science. Other success strategies aimed at achieving this included incentives to attract graduates into Initial Teacher Education (ITE), reportedly an increase of 7% on 2002/3 entry figures into ITE were recorded (DfES, 2004). However, the report went on to state that in January 2004, 240 unfilled science teaching posts still existed in England. It is suggested elsewhere (The Royal Society, 2007) that the actual number of science posts advertised by secondary maintained schools at the time, was considerably higher than this figure indicates. What is significant however, is that with the exception of English, science and mathematics (combined) contributed the majority of advertisements across all subjects (ibid, p.70). Government at the time once again encouraged schools to address the problem of science teacher shortage by empowering them to reward their best science teachers as a further recruitment and retention incentive. However Moor *et al* (2006),

following a NFER-funded study, reported that there still remained a significant shortage of physics teachers. They went on to state that 8% of science teachers in England were non-specialists or teachers with other subject specialisms. They defined a specialist teacher as either having a degree in the subject or specialised in that subject whilst undertaking Initial Teacher Education. At the time, Moor *et al* (2006) identified an imbalance in representation of science teacher specialism in English schools:

- 44% of teachers of science held a specialism in biology
- 25% in chemistry
- 19% in physics

Their research posed the question as to what more could be done to increase specialist teaching capacity in shortage subjects in the physical sciences.

Current Position

Four years on from the NFER report, the same question of how to eliminate shortages in teaching of the physical sciences remains a strong policy driver in science education. One possible solution referred by The Royal Society (2007, p.17) and iterated recently (Maddern, 2010) is to encourage science teachers to teach outside their specialism. Enhancement programmes such as the Science Additional Specialism Programme (SASP – introduced in 2008) have been established to support these teachers in physics and chemistry. A participants' financial incentive accompanied this programme. This initiative came at a time when Initial Teacher Education subject knowledge enhancement funding was channelled through the physical sciences, raising concerns that within the medium to long term there could be a potential short fall in quality biology teachers (Lakin, 2009); specialists who have been encouraged to stay within their chosen domain and develop their professionalism within it.

Scoping Survey

The above concerns were based on observation and circumstantial evidence and warranted substantiating through a small scale scoping survey. The survey aimed to achieve the following:

- To identify the intended exit routes of PGCE and final year undergraduate secondary science trainees.
- To ascertain motives for and possible employment outcomes of attendance on the Science Additional Subject Programme (SASP).
- To ascertain whether or not current professional initiatives in the physical sciences could impact on the future supply of specialist biology teachers.
- To inform a longitudinal research study monitoring specialist science teacher status on a national scale.

Methodology

- **Research Design – Scoping Survey/Timing/Site**

This was a small scale scoping survey, whose focus was to investigate the extent, nature and range of issues related to the question of whether the current initiatives in physics and chemistry teaching might lead in the future to a shortage in supply of specialist science teachers, with a specific focus on biology. With this in mind it was decided to focus on a cross-section of science teacher training courses within one institution rather than examining one course across a number of different institutions.

The research took place in the 2009/10 academic year, between September 2009 and August 2010. It was conducted at the University of Cumbria, Lancaster campus where the participants attended their classroom-based learning sessions.

- **Mixed Methods**

A combination of methods was employed to ensure a range of data was gathered and as much detail as possible within the constraints of the study.

Methods of data collection involved questionnaires (Stage 1) and semi-structured email interviews (Stage 2). The interviewees were self-selected from the questionnaire sample.

- **Participants/Sample**

An opportunist sample of teachers and trainee teachers was employed (*n*= 92) drawn from across 3 programmes studied at University of Cumbria. The sample comprised students enrolled on science teacher training courses (undergraduate and postgraduate) and practising science teachers enrolled on the Science Additional Specialism Programme (SASP).

The sample was divided into three cohorts according to the course being studied:

- Science Additional Specialism Programme (SASP) teachers (*n*=26)
- Third Year Secondary Science Specialism QTS Undergraduates (*n*=6)
- PGCE (1 year) Secondary Science Specialism Postgraduates (*n=60)*

- **Materials**

The Questionnaires:

An original questionnaire was designed around the key research areas:

- Subject specialism
- Subject area in which teaching job is based (or if not employed, area in which teaching jobs are sought)
- Motivation to change subject specialism (if relevant)

- Perceptions of levels of subject knowledge (at Key Stage 3[1])
- Perceptions of teaching confidence (at Key Stage 3)

To check the validity of the questions the questionnaire was piloted with a small sample of 4 SASP students. It became evident that the questionnaire needed adapting to reflect the different characteristics of the 3 participant groups. This resulted in the questionnaires having minor differences in structure and in the wording of questions; wherever possible wording and questionnaire structure were consistent to allow for comparability across the 3 groups.

The final question on all questionnaires invited respondents to take part in a focus group to discuss the issues arising from the questionnaire.

The Email Interviews:
The original intention was to follow-up the questionnaire stage with focus groups, to examine in greater depth the responses elicited by the questionnaires. This approach had to be revised due to a number of problems encountered at this stage of the study:

- participants dropping out due to high pressure teaching workloads,
- communication problems, and
- time availability

It was apparent that it would not be feasible to continue with the focus group approach, therefore a decision was made to change to the use of email interviews.

As with the questionnaires the structure and wording of the email interview questions varied slightly to reflect the particular characteristics of each of the 3 participant groups.

Ethical Issues:

Questionnaire Respondents:
Prior to completing the questionnaires participants were provided with a brief description of the nature of the study, they were assured that their participation was voluntary and would in no way impact on the assessment of their academic work and that their responses would remain anonymous unless they chose to provide their contact details and if they did so, their personal details would be maintained confidentially.

Email Interview Respondents:
Written consent was gained from participants in the second stage of the study. A letter of invitation describing the study and a consent form were sent to all questionnaire respondents who had indicated their willingness to participate in this stage of the study. The consent form reiterated the voluntary nature of participation and asked the respondent to sign indicating their consent to their anonymised information being used for the purposes of the study and any relevant publications and conference presentations.

[1] The questions which related to teaching knowledge and teaching confidence were focussed solely on teaching at Key Stage 3 because on all ITE science courses students are trained to teach across the curriculum at KS3 before they are able to specialise for Key Stage 4 and post 16.

Results

- **Response Rate**

Response to the questionnaires in Stage 1 was generally good, with the exception of the PGCE cohort. The response rate for the Stage 2 email interviews was, for a variety of reasons, extremely poor in comparison with Stage 1.

- **Questionnaire Responses:**

Cohort	Total (n)	Actual (n)
SASP	26	21
PGCE	60	11
Undergraduate	6	5

- **Email Interview Responses:**

Cohort	Total volunteered (n)	Actual (n)
SASP	4	0
PGCE	3	1
Undergraduate	6	3

The poor response rate to the Stage 2 email interviews can be largely explained by the following factors:

- Reliance on a third party to administer Stage 1 questionnaire
- Despite several SASP respondents volunteering to participate in Stage 2 of the study, after numerous attempts at communication with these respondents and the offer of alternative options to participate, a nil return from this group was received.
- PGCE students' failure to respond to the Stage 2 email interviews despite having volunteered to take part.

Data analysis

Questionnaire Data: All data was subject to descriptive statistical analysis using the SPSS statistical package, to highlight trends within and across groups. The data of the SASP and PGCE groups was analysed using the Mann Whitney test of difference but the Undergraduate group alone, was too small for any statistically meaningful analysis. The analysis focussed on the following areas:

- **PGCE & Undergraduate Groups:**
  Exit Routes and the relationship between subject specialism and subject area in which teaching job is based or applied for.

- **SASP group:**
  Relationship between subject specialism and SASP course subject area
  Motivating factors for taking SASP course

- **Across all groups:**

  Relationship between subject specialism and perceived knowledge and confidence levels regarding Key Stage 3 requirements for teaching Biology

Email Interview Data: A thematic analysis approach was used to analyse the data generated from the email interviews in the second stage of the study. Discursive patterns which occurred within and across each question area were identified and over-arching themes and sub-themes drawn out.

Findings:

PGCE & Undergraduate Groups:

- **Exit Routes and relationship between subject specialism and subject area in which teaching job is based or applied for.**

PGCE Group: (*Number of respondents: n=11*)

Subject Specialism
The subject specialism breakdown of this group is as follows:

Specialism	% of total
Biologists	27.27%
Physicists	9.09%
Chemists	36.36%
Other*	27.27%

(* 18.18% had studied undergraduate courses which included a large biology component)

Attendance on SKE Course
Within the total PGCE respondents (n=11), 27.27% took the SKE course. Within this SKE sub-group, the breakdown of subject specialism is as follows:

Original Specialism of respondent	% of total attending SKE
Biology	9.09%
Other	18.18% *

(*9.08% had an undergraduate degree with a significant biology component).

Specialism on SKE

SKE Specialism	% of total attending SKE
Physics	9.09%
Chemistry	18.18%

Employment
27.27% of the overall PGCE cohort had secured teaching positions and 18.18% of this sub-group were participants who had taken the SKE course.

	% Secured Employment	% taken SKE
PGCE Cohort (n=11)	27.27%	18.18%

Physics specialists were under-represented on the course in terms of numbers (18.18% in total comprising 9.09% with an undergraduate degree in Physics and 9.09% with a non-science specialist degree who took the Physics SKE course) but proportionally over-represented in terms of having secured jobs (100% of the Physics specialists had secured jobs in comparison to 0% of Biologists and Chemists).

The strategy employed by Biology and Chemistry specialists in this group who had not yet secured a teaching position appeared to be to apply for the broadest range of science teaching positions to enhance their chances of securing a post. All participants in this group except one (Chemistry specialist) indicated that they were applying for General Science or Biology/Chemistry jobs rather than positions solely in their subject area. This contrasts with the Physics specialists who had all secured positions in their specialist subject area.

Undergraduate Group: (*Number of respondents: n= 5*)

Subject Specialism
The subject specialism breakdown of this group is as follows:

Specialism	% of Total
Biologists	60%
Physicists	40%
Chemists	0%

Employment

	% Secured Employment
UG total (n = 5)	80%

Breakdown by subject specialism

	Own Specialism	General Science	Non-QTS
Physics	100%		
Biology	0%	60%	20%*

(* These respondents dropped the QTS element of the course and were therefore unable to apply for teaching positions).

It is of interest to the study that the Biology participant who had chosen to drop the QTS element of the course described having had to teach "a lot of Physics which is my weakest Science" (P3:2) whilst on school placement and also indicated in his email interview that he had chosen not to pursue QTS because he felt that science teaching had become "the main political tool for governments to change and dictate in as they wish" (P3:3) and could see no positive future for biology teaching, describing it as "Dead in the water" (P3:4).

SASP group:

- **Relationship between subject specialism and SASP course subject area**

Subject Specialism (*Number of respondents: n= 21*)

The original subject specialism breakdown of this group is as follows:

Specialism	**% of total**
Biology	42.85%
Physics	4.76%
Chemistry	28.58%
Other	23.81%

Specialism on SASP

SKE Specialism	**% of cohort attending SASP**
Physics	71.43%
Chemistry	28.57%

SASP subject studied by sub-group of biologists

SKE Specialism	**% of biologist sub-group**
Physics	55.5%
Chemistry	44.5%

The above figures illustrate that Biologists represented by far the highest proportion of teachers on the SASP course, which suggests that this group feel most in need of increasing/broadening their subject specialist skills. Physicists were by far the lowest proportion of teachers on the course and physics was by far the most popular choice of subject specialism for participants, including amongst Biologists, when it could be said that their natural allegiance would be more likely to lie with Chemistry. These findings could indicate that existing science teachers have greatest confidence in the opportunities offered by acquiring an enhanced knowledge and qualification in physics.

Motivating factors for taking SASP course

The respondents were invited to tick as many options as they felt were relevant.

Motivation Response	**% of total SASP cohort (n = 21)**	**Breakdown of responses by subject specialism**			
		Biologists (n = 10)	**Physicists (n=1)**	**Chemists (n=6)**	**Other (n=4)**
To further career prospects	76%	90%	0%	66.6%	75%
Gap in teaching resources in present school	28.57%	30%	100%	33.33%	20%
Instructed by Head of Dept	0%	0%	0%	0%	0%
Loss of interest in main subject area	20%	10%	0%	0%	25%
Vacant Post	14.28%	30%	0%	0%	0%
Other*	9.52%	20%	0%	0%	0%

*Two respondents stated their 'Other' reasons as: "To improve my own understanding of physics" "To enhance my teaching of physics"

The suggestion above, that existing science teachers may be looking to physics as the key to future employment opportunities is given further weight by the response pattern to the set of questions designed to assess motivating factors for taking the SASP course. 'To further career prospects' was overwhelmingly the most popular reason chosen by respondents. Again Biologists were the group most likely to select this factor. Interestingly, however, it was not chosen by the Physicist in the cohort. Also, whilst a vacant post did not appear to be a significant motivating factor for participants, those participants who selected this option were all Biologists.

Knowledge and Confidence ratings in relation to Key Stage 3 biology topic areas :

All 3 groups were asked to rate their knowledge confidence and teaching confidence across all of the major Key Stage 3 Biology topics. The mean scores and range scores were calculated across the cohort groups and within each group by subject specialism.

Undergraduate Group:

Question Area	Mean Average Score for entire undergraduate cohort group (n=5) (score out of possible 30)	Mean Average Scores of Subject Specialist Sub-groups (score out of possible 30)	
		Biologists (n =3)	Physicists (n= 2)
Knowledge	21 (Range = 11)	22.33 (Range= 6)	19 (Range= 11)
Confidence	21 (Range= 17)	22 (Range =13)	19.5 (Range = 12)

PGCE Group:

Question Area	Mean Average Score for entire PGCE cohort group (n=11) (score out of possible 30)	Mean Average Scores of Subject Specialist Sub-groups (score out of possible 30)			
		Biologists (n =3)	Physicists (n= 1)	Chemists (n=4)	Other (n= 3)
Knowledge	22.8 (Range = 25)	28.6 (Range=5)	6 (Range=0)	23.75 (Range = 12)	21.3 (Range =8)
Confidence	22 (Range=18)	22 (Range =16)	20 (Range =0)	23.5 (Range =13)	20.6 (Range =2)

SASP Group:

Question Area	Mean Average Score for entire SASP cohort group (n=21) (score out of possible 30)	Mean Average Scores of Subject Specialist Sub-groups (score out of possible 30)			
		Biologists (n =9)	Physicists (n= 1)	Chemists (n=6)	Other (n=4*)
Knowledge	23.52 (Range = 19)	24.4 (Range= 8)	12 (Range=0)	22.5 (Range =13)	26 (Range =9)
Confidence	22.57 (Range= 25)	26.6 (Range =7)	12 (Range =0)	21.5 (Range =25)	26.25 (Range =9)

*One participant from this group failed to respond to this part of the questionnaire.

Across all 3 cohorts:

There is a slight trend that cannot be supported by statistical analysis with any confidence due to the size and unequal group sizes of the sample, however it is apparent that the mean average scores for the undergraduate cohort were lower than those of both PGCE and SASP participants in all areas of knowledge confidence, the only exception being plants and photosynthesis which was a topic area which all participants rated their knowledge and teaching confidence highly.

Across all 3 cohorts the relationship between teaching confidence and knowledge confidence was found to be highly significant statistically.

A Mann Whitney 'u' analysis of difference test revealed that there was no difference between the PGCE and SASP cohorts in their overall knowledge confidence or their teaching confidence. This suggests that both groups rated themselves in a similar manner with respect to their knowledge and teaching confidence across all Key Stage 3 Biology topic areas. The Undergraduate group were too small for statistically meaningful analysis.

Across all 3 cohorts the Biologists sub- groups have higher mean average confidence and knowledge scores than those of the other subject specialist groups. This is perhaps to be expected given that the questions here relate to their specialist subject area and thus serves to highlight the nature of science specialist knowledge. The scores of the Physicist sub-groups in the PGCE and SASP cohorts stand out as being very low in comparison to the other groups ; this cannot however be interpreted as an indicator of any potential trends due to the comparatively small sample number.

The ranges calculated for the PGCE and SASP groups are generally high, demonstrating a large degree of variability in the scores of participants overall and within subject specialist sub-groups. The cause in both of these cases can be attributed to a small number of participants from the Chemists and Physicists sub-groups who scored very low across the topic areas in both knowledge and confidence. If these scores were removed from the sample the effect would be far less pronounced.

Discussion and conclusions:

This small scale scoping survey aimed to address the following areas:

- To identify the intended exit routes of PGCE and final year undergraduate secondary science trainees.
- To ascertain motives for and possible employment outcomes of attendance on the Science Additional Subject Programme (SASP).
- To ascertain whether or not current professional initiatives in the physical sciences could impact on the future supply of specialist biology teachers.

- To inform a longitudinal research study monitoring specialist science teacher status on a national scale.

Owing to the nature and size of the survey generalisations cannot be drawn; however the findings give an insight into the experiences and views of the participants, warranting attention and further consideration. All aims have been met to a greater or lesser degree with three key areas arising from the findings. These are summarised as follows:

- There is an assumption that teachers well-qualified in one science specialism can teach effectively in another area of science (i.e. biologists teaching physics or chemistry).
- That the ability to 'teach well' directly correlates with a sound knowledge and understanding of the subject area.
- Student teachers and some practicing teachers are strategic in their approach to personal learning and their application for employment.

Existing documentation (DfES, 2004; Moor *et* al, 2006, The Royal Society, 2007 and Maddern, 2010) suggest that a major political driver within education is the elimination of the shortage of specialist teachers. This applies across the curriculum but specifically in science education; within the physical sciences. Several initiatives have been introduced to address this issue with the introduction of the incentivised Science Additional Subject Programme (SASP) and the Subject Knowledge Enhancement programmes. The aims of these programmes, whether directly or indirectly relate to the shortage of specialist teachers in physics and chemistry. Findings from this scoping survey suggest that the majority of participants on these programmes are biologists (especially on the SASP) with 'furthering their career prospects' as a prominent reason for attending. The perceived view that a specialist in one area of science can teach equally effectively in another was born out by the survey trainee participants on several occasions reporting that whilst on their first placement they were expected to teach outside their specialism. This is not an unreasonable expectation, indeed all trainees are expected to teach across the science curriculum at Key Stage 3, however feedback from the participants suggested it was frequently the case that a trainee would teach outside rather within their specialist area i.e. biologists teaching physics or chemistry, with limited opportunity to teach biology. The view that this can be extended beyond Key Stage 3 was inadvertently reinforced by Professor Smithers in a recent report concerning recruitment into teacher training. He stated that "Poor teachers are bad news, but is it better for physics to be taught by a well-qualified biologist than someone who has studied the subject at university even without much success?" (Maddern, 2010). It could be argued (Ofsted, 1998) that continuously teaching outside ones specialism could undermine a teacher's quality of and enthusiasm for teaching, as was the case with one biology participant from the scoping survey. However, having a background knowledge across the sciences should afford a more balanced and integrated view of science and the inter-relatedness of the disciplines, which can only serve to enhance teaching the subject.

Later in his report, Smithers goes on to state that "Improving quality [teaching] depends on attracting sufficient applicants [into teacher training] to be able to choose those who can make subjects come alive." (Maddern, 2010). Indications from the scoping survey suggest that equating the ability to teach well predicates a sound knowledge and understanding of the subject area. The importance of a thorough command of the subject and its relationship with quality teaching was

identified by Ofsted (1998) and born out in this scoping survey by a physics specialist who felt he could only 'bring the subject alive' when it was the subject he had a deep understanding of and interest in:

'My placements confirmed that I wanted a pure physics post rather than a general science post as I feel I have a lot more to offer students from a physics aspect. Also, I feel that a school which uses subject specialists for science must give science a higher value than those that don't.' Final year UG: Physicist

Several underlying messages emerged from the scoping survey but perhaps the most poignant was to do with employment and employability both from the political and the teachers' perspective: findings, particularly from the trainee teachers, suggest they place greater emphasis on their ability to teach, than on their subject knowledge. The drive by the trainee teacher to teach within their specialism appeared second to the importance of gaining employment. The participants from across the survey cohorts appeared unanimous in their strategic approach to employment. This was stated clearly by the physicist cited above when he explained …

'I decided I was only applying for physics posts within 10 miles of home as I didn't want a long commute – as it happens I got the first job I applied for, which at just over 1 mile from home came well within my criteria'. Final year UG: Physicist

Evidence from the survey suggests that the employment situation was more challenging for biologists who either elected or were pressurised to 're-train' within the physical sciences to 'further their career prospects'. The outcome of this situation was captured by a biologist who opted to qualify without QTS because he was unable to teach within his specialist subject and felt that biology was 'dead in the water'. He puts the blame firmly in the seat of government, emphasising the political agenda that drives the situation …

'I am sure the new government will again have new ideas with changes to A Levels already being mentioned. I came into education thinking it was all about teaching children but this seems to be a very minor part in it. Along with health, it seems to be the main political tool for governments to change and dictate[ing] as they wish; with teachers being the puppets on the end of the political strings.' Final year UG: Biologist.

Scoping Survey Limitations and evaluation:

Poor response rate: The number of responses returned by the Undergraduate group was too small to undertake any powerful statistical tests and therefore the trends identified could not be supported with any confidence by statistical analysis.

Limitations of Email interviews: Data elicited although interesting and relevant was not as rich and descriptive as that obtained thought the context of a focus group. Responses given to questions in the email interview were generally limited to one or two sentences or very short paragraphs. There were also instances where participants had misunderstood or misinterpreted the question and therefore the answer provided was not directly relevant to the intended meaning of the question. In face-to-face interview or focus group such differences in interpretation could have been challenged.

Conclusions:

This small scale scoping survey aimed to address the following areas:

- To identify the intended exit routes of PGCE and final year undergraduate secondary science trainees.

  Exits routes for both cohorts of trainee teachers were ascertained, with physical scientists seeking only physical science posts, frequently only in their subject specialism. Biologists were more flexible in the job market, using the SKE award to widen their field of employment. Gaining employment was generally more important to biologists than teaching within their specialism.

- To ascertain motives for and possible employment outcomes of attendance on the Science Additional Subject Programme (SASP).

  The majority of participants on the SASP were biologists seeking to further their career prospects by improving their knowledge of the physical sciences.

- To ascertain whether or not current professional initiatives in the physical sciences could impact on the future supply of specialist biology teachers.

  Professional initiatives in the physical sciences, such as the SASP and SKE programmes appear to attract specialist biology teachers wishing to broaden their knowledge-base within the sciences. This can only be commended however the driver behind this is often to improve their employability within science education. This potentially introduces a 'knowledge and expertise-dilution factor' as they transfer their teaching from biology to other specialist areas in science at Key Stage 4 and especially post-16. There is evidence to suggest that biology specialists are seeking teaching posts out with biology as a specialism. These two factors *could* impact on the future supply of quality biology teachers.

- To inform a longitudinal research study monitoring specialist science teacher status on a national scale.

  Opportunities for further related research are outlined below.

  - Employment and employability:
    Further exploration with regard influencing and deciding factors contributing to the employment process within science education
  - Engagement of student teachers and teachers on in-service programme:
    Investigate the impact continued professional development has in terms of quality teaching and learning in science education
  - Assess representation of 'specialist science teachers' across the three science disciplines and assess the impact of teaching out with their specialism, both on the teacher and the pupils.
  - Explore further the perceived relationship between quality teaching, teacher confidence and teacher subject knowledge and understanding.

Recommendations:

- A clear definition of the term subject specialism and how this is represented within science education is required. Existing discrepancy of definitions across documentation has been

recognised elsewhere (The Royal Society, 2007) and steps are in place to address this, i.e. the existence of the SCORE Specialist Teacher Group.

- Greater clarification of teaching expectations across the sciences when on placement i.e. the expectation to teach across the sciences at Key Stage 3 and possibly at Key Stage 4.
- More guidance and clarification for ITE students to take responsibility for their own learning and subject knowledge in science, with an emphasis on developing their specialist knowledge whilst establishing a firm grounding in the three sciences.

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