



**HAL**  
open science

# A conflict in your head: An exploration of trainee science teachers' subject matter knowledge development and its impact on teacher self-confidence

Vanessa Kind

## ► To cite this version:

Vanessa Kind. A conflict in your head: An exploration of trainee science teachers' subject matter knowledge development and its impact on teacher self-confidence. *International Journal of Science Education*, 2009, 31 (11), pp.1529-1562. 10.1080/09500690802226062 . hal-00516239

**HAL Id: hal-00516239**

**<https://hal.science/hal-00516239>**

Submitted on 9 Sep 2010

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



**A conflict in your head: An exploration of trainee science teachers' subject matter knowledge development and its impact on teacher self-confidence**

Journal:	<i>International Journal of Science Education</i>
Manuscript ID:	TSED-2007-0285.R2
Manuscript Type:	Research Paper
Keywords:	pedagogical content knowledge, pre-service, qualitative research, science education, teacher development
Keywords (user):	subject matter knowledge



## Abstract

Teachers' subject matter knowledge (SMK) is one factor contributing to teaching "successfully", as this provides a basis from which pedagogical content knowledge develops.

UK-based trainee science teachers teach all sciences to age 14 and often up to age 16. Trainees have specialist science knowledge in chemistry, physics or biology, from their degrees. Other sciences may not have been studied since their school days. Thus, trainee science teachers often teach "outside specialism". The extent to which teaching within and outside specialism influences successful teaching, that is, ensuring learning objectives are achieved, was investigated.

The sources 71 trainees use for preparing within and outside specialism science lessons for 11-14s and 11-16s and effects on teacher self-confidence of working in these two domains were probed by questionnaire and interview. All trainees responded to open and closed questions, and Likert scale statements exploring preferences for teaching, self-confidence, ability to handle subject-related questions within and outside specialism, and attitudes towards learning new SMK. A sub-group of 12 participated in individual semi-structured interviews.

Results are counter-intuitive: trainees often teach more successful lessons outside specialism, particularly in the early stages. This relates to using a richer range of SMK sources, including, crucially, advice from experienced colleagues. Within specialism, trainees report an inability to select appropriate knowledge and /or strategies and a sense of conflict in teaching inaccurate information. Some "anxious" trainees rely heavily on extant materials for outside specialism teaching. "Super-confident" trainees able to teach any science focus on selection of appropriate instructional strategies and realise early on the need to transform SMK.

1 A conflict in your head: SMK and trainee science teacher confidence  
2

### 3 **Introduction**

#### 4 **Background, context and literature review**

5  
6  
7  
8 Science teachers working in state-funded secondary schools (for 11-18 year olds) in the UK are  
9 expected to teach all aspects of science to 11-14s and, frequently, 11-16s regardless of the  
10 scientific subject matter knowledge (SMK) that forms the major part of their academic  
11 backgrounds, often referred to as their subject “specialism”. A majority of science graduates  
12 attending teacher education courses (“trainee” science teachers) have backgrounds in biology or  
13 biology-related subjects, and little or no post-16 education in either physics and/or chemistry.  
14 Trainees’ minimum age is 21 so in all cases at least five years and in many ten years have  
15 passed since these sciences were studied. Hence, questions arise about how best to equip  
16 trainee science teachers with the scientific SMK required for teaching, given research evidence  
17 indicating that possession of “good” SMK is a key factor influencing teacher effectiveness  
18 (Geddis, Onslow, Beynon and Oesch, 1993; Lederman, Gess-Newsome and Latz, 1994). This  
19 paper reports a study that investigates sources employed by trainee science teachers to develop  
20 their SMK for teaching, and the potential impact weaknesses in SMK may have on confidence in  
21 relation to their classroom practice. The study thus contributes to discussion of the role SMK  
22 plays in teacher development.  
23  
24  
25  
26

#### 27 **Hypothesis, literature review and research questions**

28  
29 The study is situated in the Shulman paradigm in which SMK is perceived as separate from but  
30 essential to teachers’ pedagogical content knowledge (PCK). Shulman (1986a, b) proposed that  
31 teachers “transform” SMK for their students using PCK, a powerful model that has been re-  
32 interpreted widely (for example, Marks, 1990; Magnusson, Krajcik and Borko, 1999; Carlsen,  
33 1999). This paper takes the view that the ability to transform SMK is significant to trainee  
34 science teachers’ perceptions of their teaching as “successful”. The extent to which trainees  
35 develop SMK for personal “survival” rather than transform SMK for pedagogical practice may be  
36 expected to vary according to whether teaching takes place within and outside subject  
37 specialisms. A reasonable hypothesis is that within specialism teaching, based on high level, or  
38 “good” SMK held at degree level is likely to generate more successful transformation of SMK  
39 than lessons taught outside specialism based on low level “survival” SMK. Also, greater  
40 confidence may arise when trainees teach within their specialism, as they can then focus on  
41 pedagogy rather than learning the SMK required.  
42  
43  
44  
45

46 An exploration of research relating to the precise role played by SMK in teacher development  
47 yields a varied picture. De Jong (2000) and van Driel, de Jong and Verloop (2002) provide  
48 evidence that good SMK helps trainees be more readily aware of students’ difficulties, a key  
49 aspect of Shulman’s model for PCK. In a highly specialised but extremely thorough study, Davis  
50 (2003) indicates that good SMK helps trainees select appropriate instructional strategies, also a  
51 feature of Shulman’s PCK model. Thirdly, Markic, Valanides and Eilks (2006) indicate that SMK  
52 contributes to teachers’ orientations towards teaching and beliefs about science. All these  
53 factors are likely to vary at least to some extent on trainees’ subject specialism – for example,  
54 might a physics specialist teaching biology topics find it more difficult to select appropriate  
55 instructional strategies and be less aware of students’ difficulties than a biologist teaching the  
56  
57  
58  
59  
60

1  
2  
3 same topic? Conversely, what learning outcomes are achieved by biologists teaching physics  
4 topics when they themselves have similar misconceptions to the students they teach?  
5  
6

7 Besides these SMK related issues, other research evidence indicates that specialised support  
8 helps trainee science teachers develop positively (Luft, Roehrig and Patterson, 2003). In the UK  
9 system each trainee teacher is provided with an experienced science teacher who is a “mentor”  
10 assisting them while on teaching practice. Mentors help trainees gain access to additional  
11 support within school science departments, and hold regular (usually weekly) one-to-one  
12 meetings with their trainees. The influence of specialized support on teachers’ confidence or  
13 “efficacy” has been investigated by Hoy and Spero (2005), who showed that positive effects are  
14 seen where this is effective.  
15  
16

17 Hence, this study investigates:  
18

- 19 • What sources do trainee science teachers use for developing their subject matter  
20 knowledge for within and outside specialism teaching while on a ten month postgraduate  
21 teacher education course?  
22  
23
- 24 • To what extent is the confidence of trainee science teachers influenced by teaching within  
25 and outside their specialist subjects?  
26  
27

28 The study presented here forms part of a larger, on-going investigation of trainees’  
29 misconceptions in chemistry, their subject matter knowledge (SMK) and pedagogical content  
30 knowledge (PCK) development. The data collected relate to 71 trainees from the 2005 -2006  
31 and 2006 – 2007 Postgraduate Certificate in Education (PGCE) cohorts at a university, situated  
32 in the North East region of England.  
33  
34

### 35 **Initial Teacher Education programme background, context and content**

36

37 Obtaining a PGCE constitutes the major route into teaching at secondary school level in the UK.  
38 This initial teacher education (ITE) programme is intensive, requiring nine months of full-time  
39 study. The course, effectively one extended academic year running from mid-September – mid-  
40 June, combines school-based (24 weeks) practice and Higher Education Institution (HEI)-based  
41 (12 weeks) sessions. All participants must be graduates with a Bachelor’s degree in a subject  
42 that links closely to a National Curriculum subject. Science trainees are divided into teaching  
43 subject specialisms of chemistry, physics, or biology based on the content of their degrees.  
44 During the PGCE, trainees teach 11-16s and, exceptionally, 16-18s in two different schools on  
45 “teaching practice”. This provides experience of teaching science topics within and outside their  
46 specialist science subject at Key Stage 3 (KS3: 11-14s), Key Stage 4 (KS4: 14 – 16s). Some  
47 trainees also teach their specialist subject at KS5 (16-18s). Schools used are within a 50 mile  
48 (80 km) distance of the university.  
49  
50  
51  
52

53 The UK’s National Curriculum for science (DfES, 2004) stipulates the content of 11-16 science  
54 courses taught in state-funded secondary schools. Pupils’ success is measured by tests taken at  
55 age 14 (Standard Assessment Task, or “SAT”) and 16 (General Certificate of Secondary  
56 Education, or “GCSE”). To deliver the curriculum, school staff choose freely from a wide variety  
57  
58  
59  
60

## A conflict in your head: SMK and trainee science teacher confidence

of published materials and textbooks from which “Schemes of Work” (SoWs), giving precise details of lessons, are produced. Trainees are often expected to follow the school’s defined scheme, but may have freedom to develop their own lessons or parts of lessons.

To help prepare trainees’ SMK for teaching, everyone participated in forty-five hours of HEI-based sessions on specific science topics that feature commonly in Key Stage 3 and Key Stage 4 SoWs. Topics included electricity, forces, chemical reactions, energy, waves, ecosystems, the genome, Earth and space, substances and investigations. All sessions comprised a mixture of theoretical and practical work and were led by experienced teachers and / or teacher educators. Efforts were made to indicate how best to use the materials in lesson preparation and to discuss children’s difficulties with conceptual ideas. Trainees were also introduced to science education research and well-established research on misconceptions in science, in part through a 3000-word written assignment.

### **Methodology**

Data were collected by questionnaire to all participating trainees supplemented by semi-structured interviews with twelve volunteers (five from 2005 – 2006 and seven from 2006 – 2007). These two approaches permit validation of responses. Analysis of response patterns across the questionnaires and interviews reveals that sub-groups of trainees with specific characteristics are apparent.

#### ***The questionnaire***

Information relating to trainees’ educational backgrounds, personal details and topics taught within and outside specialism at Key Stages 3 and 4 were collected. In addition, trainees responded to three probe types:-

- Open questions: trainees selected, separately, one topic from within specialism teaching and one topic from outside specialism teaching and described the sources of SMK they used in preparing their lessons for these topics. They were asked to comment on differences and similarities in their preparation sources
- Closed questions: invited trainees to list all the topics taught at KS3 and KS4 during their teaching practices. A separate question asked them to rank preferred sources of SMK from a pre-prepared list.
- Eight statements (from the complete set of fourteen) explored trainees’ thinking about SMK and teacher confidence using a five-point Likert scale

#### ***The interviews***

Interviews were conducted using a semi-structured protocol, allowing deeper exploration of specific issues as these arose. Appendix 1 gives the main questions. Issues explored were: sources used to develop SMK needed for teaching within and outside specialism; trainees’ awareness of the impact of their preparation on achievement of intended learning outcomes; and the extent to which their modes of subject matter knowledge acquisition and lesson preparation changed during the PGCE course.

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Questionnaires were administered in April 2006 and April 2007 after completion of all HEI-based sessions and towards the end of the second of two teaching practices. Interviews were conducted in June 2006 and June 2007 when the course was complete.

## Results

Twenty-eight respondents were from the 2005 – 2006 cohort while forty-three were from the 2006 – 2007 cohort. Maxima of forty (2005- 2006) and fifty-two (2006-2007) were possible – absences and fall-out from the course on the day of data collection account for discrepancies. For reporting purposes, all respondents are treated as one group.

### Trainees' backgrounds

Table 1 provides information about the gender distribution, degree class, age and science subject specialism of the respondents.

[Insert Table 1 about here]

The samples were representative of the full cohorts, being skewed approximately 60:40 towards females. The trainees were born mainly in the North East of England and Scotland. Four trainees born outside the UK were classified formally as ethnic minority trainees. Eight participants did not complete the course for different reasons.

Degree subject is the key indicator used to decide trainees' science specialism as physics, chemistry or biology. Trainees' degree subjects are broad-ranging: data indicate that about 55% of respondents were "biology specialists", holding degrees in biology, genetics, ecology, biomedical sciences, aquatic / marine bioscience and physiology. Twenty-four trainees held degrees in chemistry, biochemistry, geology, environmental chemistry or pharmacology. Eight trainees held degrees physics or physics-related subjects, such as astronomy, mechanical engineering and optometry.

Degree class is widely respected as an indicator of the quality of trainees' science specialist knowledge. These trainees are regarded as "academically well-qualified": Table 1 shows that about 54% held Upper Second (2:1) or First Class (1<sup>st</sup>) honours degrees, the two highest degree classifications possible, while a further twenty-one held Lower Second (2:2) class degrees. Thus, overall around 83% of respondents held "good" degrees. Twenty also held Masters or Doctorate qualifications, including one Masters degree in Law. Possession of a "good" degree means in practice that a trainee would be expected to respond correctly to GCSE level questions in their specialism without additional help.

Trainees' average age was 27. Around 58% were in the 21 – 25 band. For this sub-group, teaching is their first career choice. The remainder comprise those changing career, such as post-doctoral scientists, science graduates who have worked in non-science fields and parents returning to work.

A conflict in your head: SMK and trainee science teacher confidence

### Comparing sources of subject matter knowledge for teaching within and outside specialism

Table 2 lists the topics trainees taught at KS3 and KS4, organised by science subject area and ranked in order of the number of trainees citing each topic at KS3.

[Insert Table 2 about here]

A wide range of science areas was addressed. Topics taught by twenty or more of the group include chemical reactions, fitness and health, forces, energy, electricity and the Solar System. Table 2 indicates that trainees are expected to possess very broad SMK: science teachers would teach all topics listed at KS3 at some point. Topic titles vary because school science departments develop documentation for delivering the National Curriculum specifically for their own use. The frequency of KS4 teaching is lower than that for KS3: in England and Wales, the dominance of assessment has contributed to school staff reducing availability of KS4 classes to trainee science teachers, due to anxiety about possible detrimental effects on examination results. Nevertheless, all trainees experienced some specialist subject teaching at KS4, with many also teaching outside specialism at KS4. At KS3, all trainees taught science topics within and outside their specialisms.

Trainees chose one topic each from within and outside their specialisms that they had taught. They described how they prepared the SMK required for teaching. Table 3 summarises the sources cited.

[Insert Table 3 about here]

Four main sources of SMK were used for within specialism teaching: the internet, textbooks, knowledge from their degree or previous job and formal documentation, such as exam papers, the National Curriculum or school Schemes of Work. Comments emphasised trainees' sense of "already knowing" the topic, implying little work was needed to "prepare":-

"Microbes and Disease – nothing particular as had the knowledge" (Biologist)

"Genetics – quick recap on genetic diseases" (Biologist)

"I knew it and only had to skip through the KS3 revision book, ie. 5 mins" (Chemist)

"Forces – looked at QCA<sup>1</sup>, school and exploring science SoWs and tests to come up with learning objectives and teaching scheme... otherwise did not need to think about own subject knowledge" (Physicist)

Three trainees explicitly stated that they had consulted no additional sources of SMK, relying entirely on their prior knowledge.

<sup>1</sup> QCA Qualifications and Curriculum Authority, organisation responsible for setting examination standards. The QCA has produced a non-compulsory scheme of work for teaching KS3 used by some schools. [www.qca.org.uk](http://www.qca.org.uk)

1  
2  
3  
4 Most trainees citing “school” or “own textbooks”, regarded these as low level material, justifying  
5 choice of this source by the description “background reading”, or “refreshing knowledge”:-  
6  
7

8 “Cells. Background reading which brought back what I already knew ... I already felt  
9 quite confident with the topic” (Biologist)  
10

11 “Active body.... I read the chapter in biology textbook to refresh.” (Biologist)  
12

13  
14 Others used school textbooks to check the level of knowledge required by their students, for  
15 example:-  
16

17 “Cells. Main problem was making sure I wasn't going over their heads! – had to  
18 carefully check... “ (Biologist)  
19

20  
21 “Light – I used subject revision guides to establish what the content should be. My  
22 subject knowledge was already adequate” (Physicist)  
23

24  
25 Several trainees noted that they believed they had the necessary subject knowledge, but wanted  
26 to find good resources or explanations to use in teaching:-  
27

28 “Acids and alkalis – [I] looked at how to describe ideas using simple vocabulary”  
29 (Chemist)  
30

31 “Variation - I.... researched for novel activities....” (Biologist)  
32  
33

34 These trainees are stating explicitly that they were aware of transforming SMK to pedagogical  
35 content knowledge (PCK).  
36

37  
38 Table 3 indicates that few trainees prepared for within specialism teaching by seeking  
39 colleagues' advice, consulting misconceptions or science education research literature or testing  
40 out practical experiments prior to lessons.  
41

42 Sources of SMK used for outside specialism preparation shows a more intense pattern of  
43 sources, with school colleagues and textbooks each being consulted by about half of  
44 respondents. The internet is popular, together with formal documentation. Inspection of  
45 individual responses shows that three or more different sources of SMK were frequently  
46 consulted; a biologist trainee who taught the *periodic table*, for example, cited four. The range of  
47 resources reflected trainees' awareness of their SMK weaknesses and perceived need for more  
48 detailed preparation, for example:-  
49  
50

51  
52 “Electromagnetic spectrum – [I] read around the subject and to a higher level than I  
53 was required to teach. [I] prepared an extensive lesson plan with difficult concepts  
54 fully written out” (Biologist)  
55  
56  
57  
58  
59  
60

1 A conflict in your head: SMK and trainee science teacher confidence

2  
3 The role of school colleagues and the respect they gained in helping trainees prepare for outside  
4 specialism teaching is apparent, for example:-

5  
6  
7 “Environments – had long conversations with other teachers...” (Physicist)

8  
9 “Radiation – [I] spoke to the physics teacher (he knows everything)” (Biologist)

10  
11 “Gravity and Space - ....Teachers at school and technicians were very helpful” (Chemist)

12  
13  
14 Trainees using textbooks did so to learn the information necessary, rather than to check the  
15 level of understanding required, for example:-

16  
17 “Paints and pigments – [I] read over student textbook then looked in A level book to  
18 improve higher knowledge then researched on internet” (Biologist)

19  
20  
21 The increase in “Other” sources for outside specialism SMK arises from more trainees stating  
22 that they practiced experiments before lessons, or asked for help in setting up equipment.

23  
24  
25 Trainees were clearly aware of differences in their approach to SMK for lesson preparation:-

26  
27 “My biology topics are fairly clear in my mind and so I do not need to look at basic  
28 knowledge ... with Chemistry I am not sure of my basic knowledge and must look  
29 at the topic as though I am teaching myself.” (Biologist)

30  
31  
32 “I needed to make sure I was prepared for any additional questions students may  
33 ask” (Biologist)

34  
35 Some trainees indicated that outside specialist subject lessons were sometimes “easier”, for  
36 example:-

37  
38 “Non-specialism takes longer [to prepare] but is sometimes easier to teach as  
39 you don’t have the same extent of knowledge” (Biologist)

40  
41  
42 This response, found also at interview (see below, p 15) suggests that possession of too  
43 much subject matter knowledge was regarded as problematic. Outside specialism teaching  
44 meant that trainees could only teach as much as they themselves could learn: this  
45 sometimes resulted in better, more clearly focused lessons than those taught within  
46 specialism.

47  
48  
49 Other issues relating to outside specialism teaching included:-

50  
51 [Outside specialism] – emphasis on accuracy and avoidance of misconception  
52 perpetration” (Biologist)

53  
54  
55 “[I did] far more preparation for the physics topic to feel more secure and confident”  
56 (Biologist)

1  
2  
3  
4  
5 Some trainees clearly needed to enhance their confidence prior to teaching, as well as ensuring  
6 that their own misconceptions were addressed.  
7

8 Several trainees who used the same sources in both cases did so by choice, stating, for  
9 example, that they had devised a method that worked for them and stuck to it:-  
10

11 “I used similar strategies as I find them most effective to refresh my knowledge and  
12 ensure my understanding” (Biologist)  
13  
14

15 Around half of the trainees use a richer and more comprehensive range of SMK sources for  
16 preparing outside specialism teaching, a significant number actively seeking colleagues’ advice.  
17 SMK preparation for within specialism teaching is characterised by trainees relying heavily on  
18 prior knowledge and not seeking advice or testing experiments prior to teaching.  
19  
20

### 21 **Preferred sources of subject matter knowledge for teaching**

  
22

23 Trainees ranked SMK sources they preferred from a list of ten possibilities. Table 4 shows the  
24 rankings from 1 – 10, where 1 is highest and 10 lowest.  
25  
26

27 [Insert Table 4 about here]  
28

29 These data show strong preference for school-based or school-oriented material, reliance on  
30 note-taking and reading. University-based teaching sessions, misconceptions and science  
31 education research literature receive very low rankings. Possible reasons for these choices and  
32 their significance are considered in discussion.  
33  
34

### 35 **The extent to which trainees’ confidence for teaching relies on subject matter knowledge**

  
36

37 Trainees’ responses to eight statements scored using a five-point Likert scale are summarised in  
38 table 5.  
39  
40

41 [Insert Table 5 about here]  
42  
43  
44

45 The statements, drawn from a questionnaire comprising fourteen statements in total, were  
46 paired to permit exploration for consistencies in response patterns: one pair each investigates  
47 trainees’ **preference** for teaching within and outside specialism; their **confidence** for teaching;  
48 the extent to which trainees believe they can handle students’ **questions**; and trainees’  
49 **attitudes** towards learning new SMK.  
50  
51

52 Detailed data relating to combinations of responses are presented below. For this purpose, the  
53 scale has been summarised to three points by adding “strongly agree” to “slightly agree” and  
54 “strongly disagree” to “slightly disagree”, with neutral in the centre. The words “agree” and  
55 “disagree” are used to express extremes. One “no response” was recorded to one statement.  
56  
57  
58  
59  
60

A conflict in your head: SMK and trainee science teacher confidence

### ***Preferences for within and outside specialism teaching***

Two statements, “I prefer to teach topics in my specialism” (“prefer specialism”) and “I am pleased to teach topics in all areas of science” (“all science”) assessed trainees’ preferences. A trainee preferring in-specialism teaching may respond positively (strongly agree/ agree) to the first statement and negatively (disagree/ strongly disagree) to the second; vice versa for a trainee pleased to teach all sciences.

Table 5 shows that around 56% (strongly agree / agree) of respondents prefer to teach their specialism, while over 80% (strongly agree / agree) do not mind teaching all aspects of science. Closer inspection of response combinations indicates four clear patterns:-

- Trainees agreeing with both statements 32 (45%)
- Trainees disagreeing with “prefer specialism” and agreeing with “all science” 15 (21%)
- Trainees neutral to “prefer specialism” and agree with “all science” 12 (17%)
- Trainees agreeing with “all science” and disagreeing or are neutral to “prefer specialism” 8 (11%)

Four trainees’ responses did not fit these categories.

Those agreeing with both statements are not necessarily inconsistent – they may be saying that although they prefer to teach within specialism, they are also pleased to teach all topics. They can work on SMK and may enjoy doing this. Around 21% claim preference for teaching all science topics. This group could be described as “generalist” in outlook. The twelve trainees neutral to the “I prefer to teach...” statement could also be “generalist”, although they express their preference less strongly. Finally, a small sub-group of “specialists” exists, as a few trainees express strong preference for within specialism teaching.

### ***Confidence for teaching***

The statement pair exploring trainees’ confidence for teaching was “I am less confident teaching outside my specialism” (“less confident outside”) and “I do not need to teach my specialism to feel confident as a teacher” (“don’t need specialism”). A trainee with good self-confidence may respond negatively to the first statement (strongly disagree or disagree) and positively to the second. A more anxious trainee may state the reverse.

Table 5 shows that 53% respond “strongly agree/ agree” to “less confident outside”, while twelve disagree. This significant minority express confidence in their ability to teach outside specialism. However, in a seemingly contradictory fashion, about two-thirds agree or strongly agree with “Don’t need specialism”, implying that they can teach anything. Closer inspection of combination responses reveals these pairings:-

- 1
- 2
- 3
- 4 • Trainees disagreeing with “less confident outside” and agreeing with or are neutral to  
5 “don’t need specialism” 14 (21%)
- 6 • Trainees who are neutral to “less confident outside” and agree with “don’t need  
7 specialism” 9 (12%)
- 8 • Trainees who agree with both statements 25 (35%)
- 9 • Trainees who agree with “less confident outside” and disagree with “don’t need  
10 specialism” 5 (7%)
- 11 • Trainees who agree with “less confident outside” and are neutral to “don’t need  
12 specialism” 7 (10%)
- 13
- 14

15 Eleven trainees’ responses did not fit into these categories.

16

17

18 The disagree / agree sub-group (14, 21%) could be labelled “super-confident”, as they state that  
19 outside specialism teaching does not affect their confidence. Examining these trainees’  
20 background characteristics shows that just over half (seven out of thirteen) have degrees in the  
21 highest two classes (1<sup>st</sup> or 2:1) or hold a higher degree, while four of this sub-group are male.  
22 The average age is 31: six are aged 30 or over. Tentatively, “super-confident” trainees could be  
23 academically well-qualified females older than the average age of the cohort.

24

25

26 Those agreeing with both statements (25, 35%) may indicate that despite feeling less confident  
27 teaching outside their specialism, this can be handled by putting in the necessary work on SMK,  
28 hence, they can respond positively to “I do not need to teach my specialism...”. This sub-group  
29 could be labelled “working-confident”.

30

31

32 Twelve trainees agreeing with “less confident outside” could be described as “anxious”. These  
33 split 50:50 by gender and degree class, with six possessing 1<sup>st</sup> or 2:1 degrees. Eight of this sub-  
34 group are male. The average age is 25, below that of the whole group, although four trainees  
35 were aged 30 or over. Reasons for trainees’ lack of confidence are unclear, but their background  
36 characteristics differ from those “super-confident” and “working-confident” trainees.

### 37 **Handling SMK-related questions**

38

39

40

41 Statements investigating trainees’ feelings about handling SMK-related questions were: “I can  
42 handle the situation if I am asked difficult questions outside my specialist area” (“I can handle”)  
43 and “I am nervous that I will be asked a question I cannot answer” (“I am nervous”). Anecdotally,  
44 handling subject-related questions causes anxiety among many science trainees, particularly in  
45 the early stages. A trainee able to cope with these may respond positively (strongly agree /  
46 agree) to the first statement and negatively (strongly disagree/ disagree) to the second. A more  
47 nervous trainee may respond oppositely.

48

49

50

51 Table 5 shows thirty-two trainees felt nervous about being asked a question they could not  
52 answer (strongly agree /agree), while fifty agreed or strongly agreed with “I can handle”. Overall,  
53 a majority of respondents appear confident about difficult questions, perhaps accepting that  
54 nerves are to be expected. Response combinations were:-

55

56

57

58

59

60

## A conflict in your head: SMK and trainee science teacher confidence

- Trainees agreeing with “I can handle” and disagreeing or are neutral to “I am nervous” 34 (48%)
- Trainees agreeing with both statements 17 (24%)
- Trainees agreeing with “I am nervous” and disagreeing or are neutral to “I can handle” 15 (22%)

Five trainees disagreed with “I am nervous”.

These figures suggest that about 48% express confidence in their ability to handle questions outside their specialist area and feel little or no nerves about being asked questions they cannot answer. About one-quarter (24%) seem to regard nerves as “part of the game”, responding positively to both statements. About 22% seem to have a more “anxious” disposition, admitting to feeling nervous and not being able to handle difficult questions. Background information shows sixteen of the thirty-four trainees (47%) feeling most confident at handling questions are male, skewing this sub-group away from the cohort’s 60:40 split. Twelve of the fifteen trainees (75%) feeling least confident were female, a skew in the opposite direction.

### Attitudes to SMK

The statements exploring trainees’ attitudes to SMK were “I find it difficult to develop my subject knowledge outside my specialist area” (“I find it difficult”) and “I enjoy learning new subject knowledge outside my specialist area” (“I enjoy learning”). A trainee with a positive attitude towards outside specialism teaching may respond negatively (strongly disagree / disagree) to the first statement and positively (strongly agree / agree) to the second. A trainee feeling uncomfortable learning new SMK may respond oppositely.

Table 5 shows highly polarised responses to these statements. About 79% strongly disagree / disagree with the first and 83% strongly agree / agree with the second. Although this is a strong indication that the majority of respondents have positive attitudes towards acquiring new SMK, small sub-groups showing slight variations exist:-

- Trainees agreeing with “I enjoy learning” and disagreeing with “I find it difficult” 50 (70%)
- Trainees who are neutral to “I enjoy learning” and are neutral to or disagree with “I find it difficult” 10 (14%)
- Trainees agreeing with both statements 3
- Trainees who neutral to “I enjoy learning” and agree with “I find it difficult” 2

Six trainees’ responses did not fit into these categories.

Most interesting here are the five trainees whose responses suggest they find learning new SMK is difficult: three were females aged over 30 and three held 2:2 degrees, while the remaining two held 2:1s. Further exploration with individuals may reveal specific reasons.

### Semi-structured interview data

Interviews indicated the impact perceived by trainees of SMK on their teaching, as well as validating responses found in the questionnaires. The sub-group was atypical, being more skewed towards males (6/12) and biologists (7/12) than the whole group. Three were chemists and two were physicists. Names used are pseudonyms. Interviews explored how trainees perceived their SMK and confidence as a teacher impacted on students' learning. Verification of questionnaire responses emerged naturally during discussion. Trainees' voices are reported verbatim, although colloquial and dialectical expressions have been modified to ease comprehension. Worth noting is that all trainees completed the PGCE course successfully but with differing teaching abilities.

#### *Views about teaching outside specialism*

Three main viewpoints corresponding to questionnaire categories (p 11-12) were apparent. Matthew, an "anxious" trainee according to his confidence responses, said this about teaching outside specialism :-

"In physics when I felt the kids weren't grasping it [the topic] I could tackle it from a different angle by thinking myself, 'How's the best way to put this across?' and going down a different route. That was very limited for me with biology ....I wouldn't have had the knowledge to do that. If it had happened, I would have had to extend into a different lesson, and gone away, thought about it and brought it back in another lesson." (Matthew, physicist)

Daniel and Mary reported differences in the ease with which they prepared for teaching in the two domains. Their confidence responses corresponded to the "working confident" category:-

"I felt I could prepare resources for my specialism much easier, and I was a lot less confident at trying new things, so for chemistry I stuck exactly to what the Scheme of Work gave me ... with biology [when I thought] "I don't agree with that", it was much easier to change things." (Mary, biologist)

"I was a lot less creative with biology and physics – that went down to confidence in the material... I went down traditional lines... I didn't tend to [experiment] unlike my chemistry where I liked to [be] more creative."  
("Daniel", chemist)

These trainees connect their lack of confidence in their subject matter knowledge for an outside specialism topic to their ability to develop their own ideas for lessons. "Sticking to the scheme" enabled them to feel safe and secure.

Another approach to teaching outside specialism was expressed by physicist George also a "working-confident":-

1 A conflict in your head: SMK and trainee science teacher confidence  
2

3 “I think I just don’t do enough for biology...you’re always looking at your notes  
4 checking you’ve spelt [words] right, whereas in physics you can go off at a tangent  
5 because you know you haven’t got a problem explaining something...” (George,  
6 physicist)  
7

8  
9 In contrast, Simon expressed confidence in his ability to teach outside specialism:-  
10

11 “...as long as I’d prepared I felt confident teaching the subject, I was quite  
12 comfortable, if you said I was teaching physics top set [highest ability], I would go  
13 away... do my research and then I’d be pretty comfortable, you might always get a  
14 question where someone might pull you up, but then you just say to them I’ll have to  
15 go and look at that.” (Simon, chemist)  
16  
17

18  
19 Simon’s confidence responses correspond to the “super-confident” category.  
20

21 These views show that trainees perceived differences in confidence for within and outside  
22 specialism teaching, and were able to articulate reasons for these that corresponded with their  
23 questionnaire responses.  
24

### 25 ***Views about teaching within specialism*** 26

27  
28 Some interviewees thought that learning objectives were achieved more easily when teaching  
29 outside specialism. This is counter-intuitive to expectations, supporting questionnaire data  
30 reported above (p 9). John, Mary and Matthew were among those realizing that initially they  
31 knew too much and failed to select information effectively. They found a much lower knowledge  
32 level than expected was required:-  
33

34  
35 “In the beginning I probably did better physics or chemistry lessons than biology,  
36 because my subject knowledge in biology is so much better. I think when I was  
37 trying to teach [biology] ... I was pitching it far too high because of my  
38 enthusiasm.... Because my subject knowledge in physics at the time was so much  
39 lower, it made the lessons much more successful.” (John, biologist)  
40

41  
42 “...at the start, [with my KS4 biology class] I didn’t think [the learning objectives]  
43 were all met. They were a “Gifted and Talented” [high ability] class...I was going  
44 quite quickly ... and I really enjoyed it. I don’t think they were keeping up with me  
45 as well as I thought they would do....Towards the end things were better and I  
46 would say yes, the learning objectives were being met. In chemistry I would say  
47 yes, they were met, because I was sticking so closely to the Scheme [of Work]”  
48 (Mary, biologist)  
49

50  
51  
52 “I feel that teaching outside specialism is better because to a certain extent I ‘m  
53 learning as the children are, so I can see [the topic] from their angle, and there is no  
54 confusion about what they need to know... With physics it's different ... there were  
55 times that I knew I was thinking [about] quite high level stuff and then dumbing it  
56 down to something they would understand, and that sometimes made my job a bit  
57  
58  
59  
60

1  
2  
3 harder ...[I didn't have] enough experience teaching low level things" (Matthew,  
4 physicist)  
5

6  
7 The frustrating feeling of having to "dumb down", or condense one's specialist subject matter  
8 knowledge was expressed well by John as a "conflict": his comment contributes to this paper's  
9 title:-  
10

11 "[In chemistry and physics lessons] I could explain things at the level [they]  
12 should be explained at. For a biology concept you've got all this [knowledge] in  
13 your mind overriding what you're telling them. [You know what you say is]  
14 almost a white lie, it should be in much more depth, or there are things that you  
15 know need to be accompanied with it [that are] not part of the curriculum, its not  
16 part of what they need to know. There is a conflict in your head" (John,  
17 biologist)  
18  
19

20  
21 Belief in possession of good SMK and enthusiasm seems to create an instinctive desire to show  
22 off, indicated by Martin, who admitted to being side-tracked by questions in within specialism  
23 lessons:-  
24

25  
26 "In biology I could go off track a lot more... In my year 10 [KS4] group they could  
27 question me and we could off track and talk about different things. "  
28 (Martin, biologist)  
29

30  
31 None of the interviewees whose early teaching was more successful outside specialism  
32 connected variation in success explicitly to strategies for preparation, although several noted  
33 differences in their strategies. John, for example, in this extract, shows how he relied on his prior  
34 learning in school as preparation for within specialism teaching, whereas he more actively  
35 prepared for physics and chemistry lessons:-  
36

37 I: How did you prepare the subject knowledge you needed?  
38

39  
40 J: For biology I already had an idea of what I'd already done in school myself...  
41 I did think about what I'd learned and I did find it easier to remember the biology  
42 related lessons ... so planning biology lessons, I think I'd already thought about  
43 it before coming on the course...  
44

45  
46 With regard to chemistry and physics ...there was a lot more preparation,  
47 relearning things ...[for example] I haven't touched on any physics ... since  
48 GCSE. I did quite a big module on chemistry in my 1<sup>st</sup> year at university, [so] it  
49 wasn't as bad... but for physics definitely, there was a lot more preparation, I  
50 used colleagues in school, speaking to other physics teachers, and other  
51 people on the course, getting their advice...  
52

53  
54 I: So when you were preparing you were more aware of spending time on  
55 outside specialism?  
56  
57  
58  
59  
60

## A conflict in your head: SMK and trainee science teacher confidence

J: Yes definitely... I took the [school] textbook ... home and look[ed] at that, but I tried to go above that, because children have questions, they want extra bits of information, or, sometimes it might help you. If you only understand [a topic] to the level they need to learn it, you're never going to be able to teach it, so you need to learn it a couple of steps ahead so you can deal with those unexpected questions and understand it further than is expected for them"

In contrast, Simon, who reported no differences in lesson success, consciously used the same strategies to prepare lessons in both domains, explaining that achieving outcomes depended on finding good activities:-

"...In terms of the learning objectives they were all roughly similar... in terms of activities I would go out of my way to look in biology to find something a little bit better [than the school's Scheme of Work] so I'd go on the internet and find interactive games. In classification, and I did find a few, so some of my lessons were better than in chemistry. Sometimes depending on the topic my lessons weren't as good – they were just, depending on the topic, not as interactive or interesting, but then again, other days the chemistry was better, it just came down to the activities." (Simon, chemist)

Simon makes explicit that selection of appropriate instructional strategies is one factor that aids successful lessons. Trainees who relied on prior knowledge alone experienced more difficulty in achieving successful lessons within specialism in the early stages of their teaching.

The need to select appropriate instructional strategies and over-reliance on inappropriate ones is illustrated by Jane, a chemist, who copied the style of chemistry teaching she experienced at school:-

"A lot of the chemistry I learned at school was just copying off the board... you try hard to avoid this, but there's parts where it comes back that that's what you do.." (Jane, chemist)

Jane's school experiences exerted a powerful influence on her intuitive approach to teaching chemistry; as she had found the subject relatively straight-forward, her instincts led her to want to teach as she herself was taught, on the assumption that the learning outcomes would be the same:-

"...you've had all that background knowledge and spent all that time learning it ... you can't then understand why other people don't get it..." (Jane, chemist)

Jane realized she could not make these assumptions, and subsequently changed her practice.

Finally, Val, a biologist, illustrates that some trainees are closed to the impact of their teaching on children, until faced with difficult information:-

1  
2  
3           ".with respiration I thought I had gone through the topic really thoroughly... a lot of  
4 them didn't do well in the end of topic test.. Being a biologist didn't seem to work.."  
5 (Val, biologist)  
6  
7

8 Val is expressing her realization that possession of good SMK on her part is not the only factor  
9 determining learning outcomes.  
10

11 A "continuum" of experience from Simon, through John and Jane to Val can be seen here.  
12 Simon grasped early on the need to transform his SMK into activities, using the same strategies  
13 for preparation both within and outside specialism. John and Jane relied on prior experiences  
14 rather than transforming SMK as independent teachers. Both realized the flaws with this  
15 approach. Finally, Val taught first, then reflected from the students' test results on her  
16 performance. Interestingly, Simon and Val both fell into the "super-confident" category (see p 11)  
17 – in Val's case this proved to be over-confidence. These data suggest the importance of aiding  
18 trainees to develop reflective practices early on.  
19  
20

### 21 ***Handling subject knowledge-related questions***

22  
23  
24 Trainees' initial apprehension at being asked questions they could not answer was apparent. For  
25 example, Jane, a highly qualified academic, was one of the fifteen most anxious, according to  
26 her questionnaire responses (see p 12):-  
27  
28

29           "At the beginning one of your biggest fears is that they are going to ask you things  
30 that you don't know and you are thinking, 'What am I going to say?' So you feel like  
31 you need to know the answers to absolutely everything but as you get into the job  
32 you realize ...you don't have to know everything and they won't really ask you the  
33 questions you're thinking because [the students are] not that advanced .... that's  
34 how you're thinking at your stage, but that's not what they're asking – its like a fear  
35 of the unknown. They don't ask you things that you think they're going to." (Jane,  
36 chemist)  
37  
38

39  
40 Other trainees noted their strategies for handling questions were better in their specialist  
41 subjects. Mark and Harriet, who both expressed confidence in their ability to handle questions,  
42 said:-  
43  
44

45           "...the only thing with physics was that I needed to know what they needed to  
46 know, but if there was something outside that, then bringing it into the lesson  
47 wasn't a problem, and if there was something where I was asked a question and I  
48 wasn't sure about it I made a point of telling them I would find it out." (Mark,  
49 physicist)  
50  
51

52           "[In chemistry] I couldn't take the conversation any further, I could answer the question  
53 but that was it, and that won't last, because if I teach chemistry my knowledge will  
54 develop more and more, as I build on that knowledge, but you're limited in time, there  
55 is so much prep you need to do. I never liked it, I felt, 'I'm letting you down here'  
56 (Harriet, biologist)  
57  
58  
59  
60

## A conflict in your head: SMK and trainee science teacher confidence

John, another who expressed confidence, learned his material “a couple of steps ahead” of the children so that he could handle questions. He was asked if he was conscious of being able to handle questions better in biology than physics and chemistry:-

“In a way, but I was never scared of children asking questions, if I didn’t know the answer I would say so, at first, I thought it would be the end of the world, how stupid would I look, but if you turn around and say, ‘I don’t know’, they say ‘Oh well’, they don’t think, ‘How stupid are you?’, being embarrassed is a very adult concept.... I’ve never been concerned about being asked a question, but yes, if a child asked me a biology question I would be much more confident answering it than in physics or chemistry, but if someone asked me a question in physics and I didn’t know I would find out and answer it the next lesson.

Thus, the ability to handle questions seems to rely mainly on trainees’ self-confidence. Trainees take a pragmatic approach, finding effective strategies for handling questions to which they don’t know the answer and that children are less demanding than they expected.

### ***Changes in SMK sources and preparation during the PGCE course***

Most interviewed trainees stated that their preparation time had reduced significantly during the PGCE year. Carol and Andrew in particular felt that their science knowledge became easier to recall as the training progressed:-

“My subject knowledge in science has been sleeping. And its all come out again, in this year...[now] subject knowledge takes a back seat to creativity” (Andrew, biologist)

“I’m surprised how much I remember from my GCSEs and my A levels, its not taking me as long to refresh my memory as it was” (Carol, biologist)

Daniel commented that he felt more successful at implementing differentiated activities:-

“I’ve learned a lot more about differentiating correctly, or at least, attempting to, across a broad ability range class” (Daniel, chemist)

The notion of “speeding up” may perhaps reflect trainees’ increasing confidence in their ability to handle classroom situations, hence reducing the amount of “panic time” expended in getting SMK to a level they felt brought confidence.

Harriet and Matthew noted that they used the same approach throughout the course:-

“In the diagnostic [first, short teaching placement], I taught only KS3, and again I read the textbook, the knowledge required was so much simpler [than I expected] and I talked to the teacher.... I don’t think my strategies did change, I was reading and talking to teachers, sometimes I used the internet, but I’m

1  
2  
3 wary of the reliability of the sources you get. So I don't think they did change."  
4 (Harriet, biologist)  
5  
6

7 "I did the same things all the way through. I thought about how I was going to  
8 do it before I started the course. The only thing that did progress was  
9 confidence in what I was doing, so I realised after time that what I was doing  
10 was sufficient to acquire the knowledge to teach the lessons, I don't mean that I  
11 was just doing what I needed to and that was all, but why fix something that  
12 wasn't broken, so I kept on with it." (Matthew, physicist)  
13  
14

15 Again, pragmatism plays a role – doing what seemed to be the “right thing” and repeating this as  
16 it “seemed to work” was common. Trainees know what is expected of them and devise coping  
17 strategies. They become more skilled at applying these as the course continues.  
18  
19

## 20 Discussion

### 21 *Trainee science teachers' SMK sources for within and outside specialism teaching*

22 Evidence (Table 5) indicates that these science trainees use a much richer range of SMK  
23 sources for preparing lessons outside than within specialism. Large differences are found in  
24 reliance on experienced colleagues and school materials when preparing outside specialism  
25 lessons. Trainees also reported practicing unfamiliar experiments beforehand and consulting  
26 technicians. The questionnaire and interview data together suggest that intense SMK  
27 preparation helps transformation to PCK, as trainees found their efforts enhanced their ability to  
28 deliver outside specialism lessons with appropriate activities that met learning objectives for their  
29 students, as well as giving them confidence in their teaching skills.  
30  
31  
32  
33  
34

35 SMK preparation for within specialism teaching was more casual. Many trainees relied on quick  
36 “refreshment” aimed at finding out students' knowledge level. A few trainees confessed to using  
37 no SMK preparation strategies at all, relying only on prior knowledge. Fewer experiments were  
38 tested in advance of within specialism lessons. Perhaps most significant that few trainees  
39 consulted experienced teaching colleagues about how or what to teach within specialism. In  
40 terms of achieving learning objectives, about two-thirds of interviewees indicated their within  
41 specialism lessons were in some respects poorer than outside specialism lessons. Although  
42 none explicitly connected this to lack of preparation, a link between the paucity of SMK sources  
43 used and achievement of learning outcomes seems distinctly possible.  
44  
45  
46

47 Several interviewees hinted at possible reasons for their difficulties with early within specialism  
48 teaching – an inability to select appropriate information from their strong “pool” of knowledge,  
49 allied to a lack of experience at teaching “low level” material. The description as a “conflict” is  
50 powerful – awareness of a wide range of interlinking concepts and partial truths may hinder  
51 selection of the best approach to take or strategy to use. This hints at trainees' inability to  
52 transform within specialism SMK to PCK. A lack of SMK for outside specialism teaching drives a  
53 process that seems to lead automatically to more successful transformation to PCK, most likely  
54 because experienced colleagues are involved and trainees are academically able enough to  
55 take in new (or revise old) information rapidly. Perhaps because in trainees' minds this  
56  
57  
58  
59  
60

## A conflict in your head: SMK and trainee science teacher confidence

1  
2  
3 knowledge is uncluttered by interlinking ideas, clear explanations and transformation into  
4 activities occurs more readily. Interestingly, trainees did not perceive that consultation with  
5 experienced colleagues would aid preparation of successful within specialism lessons. The  
6 interviews revealed that trainees work out what to do for themselves “the hard way” over  
7 different time periods. Evidence collected elsewhere suggests that trainees may feel a sense of  
8 shame in asking for help in preparing lessons in their subject specialist area, and hence regard  
9 the struggle as private and personal (Youens, B., Personal communication, 6<sup>th</sup> September  
10 2007).  
11  
12

13  
14 Of course, these comments do not apply to all trainees: there is evidence that probably about  
15 one-third of the cohort were equally successful at teaching in both domains. Interview data  
16 suggest these trainees are those who perceived at the earliest possible stage that successful  
17 teaching depends (at least to some extent) on good, appropriate activities – that is, somehow,  
18 they hit on the importance of transforming SMK to PCK very early in their development. The  
19 issue of their own personal SMK appeared secondary to ensuring that appropriate activities  
20 were found and prepared in a suitable format for their students.  
21  
22

23  
24 A second finding is the contrast in relevance to trainees of school- and HEI-based SMK sources  
25 (Table 3). Despite attending sessions that, at the time, were rated (verbally and anecdotally)  
26 very positively, few trainees used any HEI-based materials regularly, preferring almost entirely  
27 school-based resources. We can speculate as to possible reasons for this: for example,  
28 sessions may be too generic to be useful to specific school situations, despite efforts to make  
29 them relevant; trainees may feel forced to abide by schools’ strict Schemes of Work; the time lag  
30 between an HEI session and teaching a topic may mean trainees forget about it; or sessions  
31 were simply too radical and contrasting to what really goes on in school. Science education  
32 research is probably perceived as too esoteric and difficult to access, as well as being difficult to  
33 use directly (one trainee commented to this effect in her questionnaire). Misconceptions may be  
34 already embedded in schools’ Schemes of Work, or have simply fallen out of fashion in the  
35 movement in England and Wales towards science courses that are more applied in nature.  
36  
37

### ***Trainee science teachers’ confidence for within and outside specialism teaching***

38  
39  
40  
41 A mixed picture is observed in data relating to trainee science teachers’ confidence (Table 5).  
42 Some trainees showed no difference in their confidence levels for teaching in either domain.  
43 This sub-group seemed to have thought through the consequences of having to teach all  
44 aspects of science in advance, preparing themselves mentally for the task. It is probably fair to  
45 say that most trainees inevitably showed some anxiety for outside specialism teaching, at least  
46 in the early stages of their teaching practice experiences. A particularly anxious sub-group rely  
47 heavily on schools’ internal documentation to support their teaching, feel nervous about  
48 deviating from prescribed Schemes of Work and nervous about answering subject-related  
49 questions outside specialism. However, a majority of these trainees developed good coping  
50 strategies and worked hard to overcome both their nerves and any initial apprehension.  
51  
52

53  
54 The trainees in this study are well-qualified academically, a fact about which they are well aware.  
55 Perhaps, then, over-confidence for within specialism teaching is to be expected, at least in the  
56 early stages. Trainees vary in their ability to recognise this - interview data point to a possible  
57  
58  
59  
60

1  
2  
3 continuum in the extent to which they can reflect meaningfully on practice, realise their mistakes  
4 and act to correct these.  
5

6  
7 Trainees' strong academic backgrounds probably also contributed to the skill set that enabled  
8 their SMK development for outside specialism teaching. Almost half express preference for  
9 teaching their specialism, but also imply they are content to learn new material. The confidence  
10 statement responses show that about one-third admit to feeling less confident teaching outside  
11 specialism, but also don't mind doing this. Evidence indicates that trainees know what to do to  
12 develop their SMK, are resourceful and resilient in using a range of sources. The average age of  
13 27 suggests that a good proportion of trainees come into teaching with skills gained in the  
14 workplace, so are flexible, persistent, diligent and industrious.  
15  
16

17  
18 A small sub-group of "super-confident" trainees seems apparent. These are older than average  
19 and particularly well-qualified. Age and work experience may contribute additional maturity at  
20 handling unfamiliar situations, greater flexibility in thinking and the ability to take in and act on  
21 new knowledge under pressure. Parents of school-aged children familiar with school  
22 environments and used to juggling a variety of situations simultaneously tend to fall into this  
23 category. This sub-group seems to include some over-confident trainees who do not reflect on  
24 their practice. Trainees combining maturity, reflective practice and insight into transformation of  
25 SMK to PCK seem particularly successful in achieving learning objectives in both domains.  
26  
27

## 28 **Conclusions, limitations and future work**

29

30  
31 This study supports earlier work of Davis (2003) indicating that good SMK helps trainee teachers  
32 select appropriate instructional strategies. However, defining "good" is required, as these  
33 trainees, possessing "good" SMK by their degree background did not automatically teach  
34 successful within specialism lessons. Counter-intuitively, greater success in terms of SMK,  
35 transforming SMK and, hence, selection of appropriate instructional strategies, seemed to occur  
36 more consistently when trainees taught outside specialism topics with limited SMK. Sources of  
37 SMK cited by trainees back up Luft et al's (2003) and Hoy and Spero's (2005) finding that  
38 specialised support helps trainee science teachers develop positively: half of respondents  
39 consulted experienced teacher colleagues when teaching outside specialism, but very few did so  
40 for within specialism teaching. One outcome of this paper is that teacher educators and school  
41 mentors should strongly encourage trainees to seek (or insist that they take) advice from  
42 experienced colleagues for teaching in both domains. There is a need to overcome any  
43 reservations trainees may have about appearing to "fail" if they request help for within specialism  
44 teaching.  
45  
46  
47

48  
49 For similar reasons, these data do not support de Jong (2000) and van Driel et al (2002) in  
50 asserting that good SMK helps trainees be more aware of students' difficulties. Trainees became  
51 aware of students' difficulties when learning SMK themselves for outside specialism lessons. No  
52 awareness of difficulties was encountered for within specialism lessons – rather, trainees tended  
53 to over-estimate students' abilities, at least initially. The lack of explicit attention paid to  
54 misconceptions is also an indicator that students' difficulties seem mainly ignored.  
55  
56  
57  
58  
59  
60

## A conflict in your head: SMK and trainee science teacher confidence

The value of HEI-based SMK sessions in aiding preparation for teaching is questioned. Much time is invested at this university in making these as potentially valuable as possible by including the latest research findings, information about up-to-date issues in science education and practical experiments that can be done in school, as well as using experienced teacher colleagues and the latest published school materials to help make sessions relevant to practice. Nevertheless, trainees make little use of these sessions as an SMK source, focusing instead on materials available in school. A second outcome is the need to ensure mentors are aware of the content and potential value of HEI-based sessions, and for teacher educators to be yet more explicit as to how to utilise HEI materials, misconceptions and research in lesson preparation.

Naturally, the study is limited – firstly by the fact that data are collected from one institution and at present constitute a relatively small set. Timing of data collection may mean that trainees' views have changed - data were collected late in the PGCE year. Different views may have been expressed earlier, although interview and questionnaire data together suggest that responses are reliable. The categorisation of trainees as “super-confident”, “working confident” and “anxious” is necessarily tentative, together with the extent to which these represent the whole group. Further evidence may help justify or alter these.

The information gathered illuminates the issue of SMK for science teacher development in a novel way: trainees' efforts to remediate weak SMK, including consulting experienced colleagues for advice, often leads to outside specialism lessons being more successful than within specialism lessons in the early stages of teacher development. Possession of “good” SMK as prior knowledge determined by possession of a science degree is insufficient to enable all trainees to prepare and deliver successful lessons within specialism: trainees lack experience to transform SMK to PCK effectively. Further, the role of good support in aiding teacher development is confirmed.

Future work will include collection of further data with the 2007 – 2008 cohort. This may yield evidence enabling sub-groups within a PGCE cohort to be identified more strongly. Knowledge of sub-groups could lead to development of personalised learning schedules that may aid trainees to acquire the skills of transforming SMK to PCK more systematically than at present. The possibility exists that further research in this area may clarify the role of SMK in science teacher preparation, together with the nature of generic skills that seem to be connected to high levels of success.

### Acknowledgements

This paper is based on an earlier version presented at the British Educational Research Association (BERA) annual conference held at the Institute of Education, London, September 2007.

## References

- Carlsen, W.S. (1999) Domains of teacher knowledge In: Examining Pedagogical Content Knowledge Eds: J. Gess-Newsome and N. Lederman, Dordrecht: Kluwer Academic Publishers
- Davis, E.A. (2003) Knowledge integration in science teaching: Analysing Teachers' Knowledge Development *Research in Science Education* 34: 21 -53
- De Jong, O. (2000) The Teacher Trainer as Researcher: exploring the initial pedagogical content concerns of prospective science teachers *European Journal of Teacher Education* 23 (2): 127 – 137
- DfES (2004) Science: The National Curriculum London: The Stationery Office
- Geddis, A.N., Onslow, B., Beynon, C. and Oesch, J. (1993) Transforming content knowledge: Learning to Teach about isotopes *Science Education* 77 (6): 575 – 591
- Hoy, A.W. and Spero, R.B. (2005) Changes in teacher efficacy during the early years of teaching: A comparison of four measures *Teaching and Teacher Education: An International Journal of Research and Studies* 21(4): 343-356
- Lederman, N.G., Gess-Newsome, J. and Latz, M.S. (1994) The nature and development of preservice science teachers' conceptions of subject matter and pedagogy *Journal of Research in Science Teaching* 31 (2): 129 – 146
- Luft, J., Roehrig, G. and Patterson, N.C. (2003) Contrasting landscapes: A comparison of the impact of different induction programmes in beginning secondary science teachers' practices beliefs and experiences *Journal of Research in Science Teaching* 40 (1): 77-97
- Magnusson, S., Krajcik, J. and Borko, H. (1999) Secondary teachers' knowledge and beliefs about subject matter and their impact on instruction In: Gess-Newsome, J. and Lederman, N.G. Eds (1999) Examining Pedagogical Content Knowledge Dordrecht: Kluwer Academic Publishers p 95 – 132
- Markic, S., Valanides, N. and Eilks, I. (2006) Freshman science student teachers' beliefs on science teaching and learning – a mixed methods study In: Towards research-based science teacher education p 29 – 40, edited by I. Eilks and B. Ralle, Shaker, Aachen Germany
- Marks, R. (1990) Pedagogical content knowledge: From a mathematical case to a modified conception *Journal of Teacher Education* 41 (3): 3-11
- Shulman, L. (1986a) Those who understand: A Conception of Teacher Knowledge *American Educator* 10(1): 9-15, 43-44

1 A conflict in your head: SMK and trainee science teacher confidence  
2

3 Shulman, L. (1986b) Those who understand: Knowledge growth in teaching *Educational*  
4 *Researcher* 15(2): 4-14  
5

6  
7 van Driel, J., De Jong, O. and Verloop, N. (2002) The development of pre-service chemistry  
8 teachers' pedagogical content knowledge *Science Education* 86: 572 – 590  
9

10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For Peer Review Only

Subject specialism	Biology		Chemistry		Physics		Totals	
No. of trainees	39 (55)		24 (34)		8 (11)		71 (100%)	
Gender	Male	Female	Male	Female	Male	Female	Male	Female
	12	27	10	14	6	2	28 (39)	43 (61)
<b>Age</b>								
21-25	8	21	3	4	4	1	41 (58)	
26-30	2	2	4	5	1	0	14 (20)	
31-35	1	2	2	3	0	0	8 (11)	
36+	1	2	1	2	1	1	8 (11)	
<b>Degree class</b>								
1st	3	2	1	4	2	0	12 (17)	
2:1	5	14	1	4	2	0	26 (37)	
2:2	3	8	4	4	1	1	21 (29)	
3rd	0	0	2	0	0	0	2 (3)	
Not stated /other	1	3	2	2	1	1	10 (14)	
Higher degrees	5	4	4	6	0	1	20 (28)	

(Figures in parentheses are percentages throughout)

**Table 1: Science trainees' backgrounds: gender, age and degree classification against subject specialism**

## A conflict in your head: SMK and trainee science teacher confidence

Science area	Topic	No. KS3	No. KS4
Biology	Fitness and health	20	5
	Cells	18	1
	Microbes and disease	16	2
	Classification, variation	16	2
	Feeding relationships	14	3
	Respiration	13	2
	Plants, photosynthesis	13	3
	Reproduction	12	-
	Food and digestion	11	7
	Environment, ecology, competition	4	6
	Genetics and inheritance	5	11
	Humans as organisms, circulation, eye, joints, etc	4	6
	Evolution	-	5
	Homeostasis	-	3
	Farming /agriculture, sustainable development	2	2
Radiation and life	-	3	
Chemistry	Chemical reactions, elements, compounds, mixtures	35	-
	Reactions of acids, alkalis, metals	28	-
	Solids, liquids, gases, particles, changes of state	24	-
	Rocks, weathering, rock cycle	13	7
	Solutions, solvents, solutes	4	1
	Conservation of mass	2	-
	Separation techniques	3	-
	Material choices, paints and pigments, polymers	-	9
	Organic chemistry	-	7
	Aspects of chemical reactions – halogens, noble gases, rates	-	6
	Metals and alloys, blast furnace, reactivity series	-	7
	Atomic /ionic structure	-	3
	Chemical bonding	-	2
	Air quality	-	2
	Mole calculations	-	2
Periodic table	-	2	
Physics	Electricity	24	3
	Forces	23	3
	Solar system, space, gravity	23	6
	Energy	22	-
	Light	16	2
	Heating and cooling	14	-
	Sound	13	1
	Magnetism	11	1
	Pressure and moments	6	-
	Waves and radiation	2	3
	Speeding up	4	-
	Metals	1	-
	Radioactive materials, Nuclear energy	-	3
	Construction materials, machines	-	3

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

**Table 2: Topics taught by trainees at KS3 and KS4 in biology, chemistry and physics**

For Peer Review Only

## A conflict in your head: SMK and trainee science teacher confidence

SMK source	Within specialism teaching	Outside specialism teaching
School colleague or other trainee teacher	7	33
Textbooks, school resource packs, teacher materials	19	38
Internet	19	18
Exam papers, National Curriculum document, School Schemes of Work	10	12
Knowledge from University degree or job	14	0
Information from an HEI-based session	2	2
Other source, e.g. revision guide, safety guide, practising experiments, prior knowledge check, note-making	8	15
Misconceptions information	4	5
Trainees stating "no sources used"	3	0

**Table 3: Summary of trainee science teachers' subject matter knowledge sources for within and outside specialism teaching**

	Ranked 1 or 2	3 or 4	5 or 6	7 or 8	9 or 10
Making notes	29 (41%)	13 (18)	7	6	6
School colleagues	24 (34)	19 (27)	13 (18)	3	2
Other trainees	9 (14)	20 (27)	14 (20)	9	9
Internet	16 (23)	23 (32)	10 (14)	9	3
Science Education Research	1	1	5	15 (21)	39 (55)
Misconceptions Materials	1	6	14 (20)	18 (25)	22 (31)
Textbooks	30 (42)	16 (23)	9	5	1
Exam papers, etc	4	12 (17)	18 (25)	16 (23)	11
HEI sessions	5	7	20 (17)	23 (32)	6
University notes	3	5	13 (18)	17	23 (32)

**Table 4: Science trainees' ranking of ten subject matter knowledge sources in a pre-prepared list**

## A conflict in your head: SMK and trainee science teacher confidence

Statement Group	Likert scale response Statement	Strongly agree	Slightly agree	Neutral	Slightly disagree	Disagree /strongly disagree	NR	Total
Preference	I prefer to teach topics in my specialism	22 (31%)	18 (25)	15 (21)	5	11	0	71
	I am pleased to teach topics in all areas of science	41 (58)	18 (25)	9	3	0	0	71
Confidence	I don't need to teach my specialism to feel confident	34 (48)	13 (18)	15 (21)	1	7	1	71
	I am less confident teaching outside my specialism	15 (21)	23 (32)	16 (23)	12 (17)	5	0	71
Questions	I am nervous of being asked a question I can't answer	17 (24)	15 (21)	9	14 (20)	16 (23)	0	71
	I can handle difficult questions in non-specialist areas	25 (35)	25 (35)	13 (18)	14 (20)	4	0	71
SMK attitudes	I find it difficult to develop my subject knowledge outside my specialist area	2	3	10	15 (21)	41 (58)	0	71
	I enjoy learning new subject knowledge outside my specialist area	46 (65)	13 (18)	11	1	0	0	71

NR = No response

**Table 5: Trainees' responses to Likert scale statements about preferences, confidence, handling questions and attitudes towards learning new SMK**

**Appendix 1: Interview questions**

Please confirm the topics you taught at KS3 and KS4 on both your teaching practices.

How did you prepare the subject knowledge you needed for teaching?

Did you do the same things for topics within and outside specialism?

Were you aware of differences in learning outcomes for the children?

If you had prepared really thoroughly did you feel the lessons go more smoothly?

Have your strategies for preparation changed as you went through the PGCE?

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

**“A conflict in your head”: An exploration of trainee science teachers’ subject matter knowledge development and its impact on teacher self-confidence**

Prepared for the International Journal of Science Education

Vanessa Kind

Durham University  
School of Education

Contact details:

[Vanessa.kind@durham.ac.uk](mailto:Vanessa.kind@durham.ac.uk)

+44 191 334 8369

+44 191 334 8311 (fax)

Dr. Vanessa Kind  
Durham University  
School of Education  
Leazes Road  
Durham DH1 1TA  
UK

## Introduction

### Background and context

The means by which teacher education systems ensure that secondary science teachers are well-prepared and appropriately trained for their work in science classrooms is a significant topic of international debate (Abell, 2000). One issue is how best to equip trainee science teachers with the scientific SMK required for teaching, given research evidence indicating that possession of “good” SMK is a key factor influencing teacher effectiveness (Geddis, et al, 1993; Lederman et al, 1994). This paper contributes to the discussion by offering perspectives from pre-service science teachers’ (“trainees”) experiences of training on an intensive, full-time course taking place over an extended academic year. Specifically, this paper explores the extent to which trainees’ subject matter knowledge (SMK) in science influences their self-confidence for teaching: trainees are graduates in specific science disciplines, such as biology, chemistry, physics, astronomy, geology and others, but are required to teach all sciences to 11-14s while training and, often, while working in UK state-funded secondary schools. An investigation of sources employed by trainee science teachers to develop their SMK for teaching is reported, together with the potential impact SMK may have on confidence in relation to their classroom practice. The study thus contributes to discussion of the role SMK plays in teacher development.

The study is situated in the Shulman paradigm in which subject matter knowledge (SMK) is perceived as separate from but essential to teachers’ pedagogical content knowledge (PCK). Shulman (1986a, b) proposed that teachers “transform” SMK for their students using PCK, a powerful model that has been re-interpreted widely (for example, Marks, 1990; Magnusson et al, 1999; Carlsen, 1999).

This paper takes the view that in describing a lesson as “successful”, the teacher’s ability to transform SMK is significant. Evidence presented below shows that trainee science teachers’ perceptions of their teaching as “successful” varies: some appear to consider a lesson as a “success” when they transmit knowledge, expressing confidence in the sense of personal survival when they understand the SMK for a specific lesson and can answer subject-related questions. Others take a “transforming” approach, perceiving “success” as finding good activities that help children learn, placing personal mastery of SMK as a secondary concern. Trainees’ development of SMK for personal “survival” or “transformation” may vary according to whether teaching takes place within and outside subject specialism. Given the accepted wisdom that science teachers teach their specialisms most successfully, a reasonable hypothesis is that within specialism lessons would generate fewer trainees relying on “survival” and more “transformation”. Data are presented that contradict this, suggesting that in the initial stages at least, some trainees were more confident and taught more successful lessons when teaching outside their specialist subjects.

### *The English and Welsh initial teacher education context*

The study took place in a University in northern England, using trainees attending an initial teacher education (ITE) course, the “Postgraduate Certificate in Education” (PGCE). Obtaining a

1  
2  
3 PGCE constitutes the major route into secondary school teaching. The PGCE is an intensive  
4 programme requiring nine months of full-time study from September – June. The course  
5 combines school-based practice (24 weeks) and Higher Education Institution (HEI)-based work  
6 (12 weeks). All participants are graduates with a Bachelor's degree in a subject linked closely to  
7 a National Curriculum (DfES, 2004) subject. In science, trainees' degree subjects dictate their  
8 teaching subject specialisms of chemistry, physics, or biology. A majority of trainees have  
9 backgrounds in biology or biology-related subjects, and little or no post-16 education in either  
10 physics and/or chemistry. Trainees' minimum age is 21, so at least five years and for many, ten  
11 years have passed since these sciences were studied.  
12  
13

14  
15 The National Curriculum for science stipulates the content of 11-16 science courses taught in  
16 state-funded secondary schools. Pupils' learning is measured by tests taken at age 14 and 16.  
17 Hence, teaching divides into topics for 11-14s (Key Stage 3) and 14-16s (Key Stage 4). To  
18 deliver the curriculum, school science teachers write "Schemes of Work" (SoWs), giving precise  
19 details of lessons, often based on published materials and textbooks. Teachers are expected to  
20 teach all aspects of science to 11-14s and, frequently, 14-16s regardless of their subject  
21 "specialism"; hence, this is also expected of trainees. During the school-based practice, trainees  
22 teach 11-16s and, exceptionally, 16-18s in two different schools located within 50 miles (80 km)  
23 of the university. Trainees are often expected to follow schools' defined schemes of work, but  
24 may have freedom to develop their own lessons or parts of lessons.  
25  
26

27  
28 Trainees participated in forty-five hours of HEI-based sessions to develop their SMK for teaching  
29 specific science topics at Key Stage 3 and Key Stage 4. Topics included electricity, forces,  
30 chemical reactions, energy, waves, ecosystems, the genome, Earth and space, substances and  
31 investigations. Materials for use when teaching were provided with details of experiments and  
32 potential misconceptions. Trainees were introduced to science education research through these  
33 sessions and also by preparing a written assignment.  
34  
35

## 36 **Literature review**

### 37 ***The role of SMK***

38  
39 The notion that possession of good SMK is an essential component of effective teaching has  
40 been demonstrated in a number of research studies, including those by Shulman (1986b, 1987).  
41 A useful summary of the position and value ascribed to SMK in teaching is provided by Carré  
42 (1998):-  
43  
44

45  
46 "The more you know about science, the more you will be able to provide a framework to help  
47 children think in scientific ways; in so doing you will also represent the subject with integrity" (p  
48 103)  
49  
50

51  
52 Hashweh's (1987) work with six experienced science teachers offers evidence for this. He found  
53 that "knowledgeable" teachers had more detailed knowledge of the topic being taught,  
54 demonstrated wider knowledge of the same subject, and were more readily able to relate a topic  
55 to other aspects of the subject. More specifically, Hashweh reported that possessing good SMK  
56 positively affected a range of aspects considered essential to good science teaching. These  
57  
58  
59  
60

1  
2  
3 included teachers' abilities to transform material for delivery in lessons by planning novel  
4 activities and their responses to critical incidents in the classroom. Knowledgeable teachers  
5 posed higher cognitive level questions while "unknowledgeable" teachers asked for recall and  
6 relied heavily on textbook information.  
7

8  
9 An exploration of research relating to the precise role played by SMK in teacher development  
10 yields a varied picture. De Jong (2000) and van Driel et al (2002) provide evidence that good  
11 SMK helps trainees be more readily aware of students' difficulties, a key aspect of Shulman's  
12 model for PCK. In a highly specialised but extremely thorough study, Davis (2003) indicates that  
13 good SMK helps trainees select appropriate instructional strategies, also a feature of Shulman's  
14 PCK model. Thirdly, Markic et al (2006) indicate that SMK contributes to teachers' orientations  
15 towards teaching and beliefs about science. All these factors are likely to vary according to  
16 whether trainees are working within and outside their subject specialisms – for example, a  
17 physics specialist teaching biology topics may find it more difficult to select appropriate  
18 instructional strategies and be less aware of students' difficulties than a biologist teaching the  
19 same topic. As an indication of the possible effects of outside specialism teaching, Carlsen's  
20 (1993) study of four trainee biology teachers found that when teaching an unfamiliar topic,  
21 participants tended to talk more often, for longer periods of time, asked questions frequently and  
22 relied heavily on low cognitive level questions.  
23  
24  
25  
26

27 Misconceptions about science concepts are a significant concern for science education  
28 researchers. In terms of educating science teachers, learning outcomes related to  
29 misconceptions achieved by trainees may differ, depending on whether a lesson is being taught  
30 within or outside specialism. A biology lesson taught by a physicist may be less satisfactory than  
31 the same lesson taught by a biology specialist, as the physics trainee may have similar  
32 misconceptions to the children being taught. Sanders (1993) explored the views of South African  
33 biology teachers about respiration, finding that many seemed to hold misconceptions about  
34 basic principles within this topic. However, the study did not distinguish between specialist and  
35 non-specialist biology teachers.  
36  
37

38  
39 Besides these specifically SMK related issues, other research evidence indicates that  
40 specialised support helps trainee science teachers develop positively (Luft et al, 2003). In the  
41 present system, each trainee teacher is provided with an experienced science teacher as a  
42 "mentor" to assist them on teaching practice, as well as a university tutor. Mentors help trainees  
43 gain access to additional support within school science departments and hold regular (usually  
44 weekly) one-to-one meetings with trainees. Despite mentors' and tutors' good intentions, Youens  
45 and McCarthy (2007) found that trainees tend not to use mentors and university tutors as  
46 sources for SMK development, due to awareness of their roles in assessing progress. Trainees  
47 think that asking for help may imply they are failing. This perception may impact on trainees'  
48 preparation for and subsequent success in within and outside specialism teaching.  
49  
50

### 51 ***Science teachers' perceptions of success, self-confidence and self-efficacy***

52  
53  
54 The influence of specialized support on teachers' confidence or "efficacy" has been investigated  
55 by Hoy and Spero (2005), who showed that positive effects are seen where this is effective.  
56 However, Youens and McCarthy's (2007) work shows that these may be negated in situations  
57  
58  
59  
60

1  
2  
3 where a dual role is perceived –mentors and university tutors are involved in reporting on  
4 trainees' progress, controlling whether they “pass” or “fail”, as well as providing support. As  
5 mentioned above, the assessment role appears to dominate, as trainees forgo asking for  
6 support, in case this indicates weakness on their part. In which case, it would be valuable to  
7 know what sources of SMK are used by trainee teachers and why these are selected, given that  
8 obvious collegial support is, at least by some, cast aside. Further, any differences between SMK  
9 sources for within and outside specialism teaching may exist and these may impinge on  
10 trainees' success in teaching and perceptions of success.  
11  
12

13  
14 The role of support and teacher self-confidence emerged as factors influencing success in  
15 teaching science among nine novice primary school teachers studied by Appleton and Kindt  
16 (1999). This study makes an interesting and significant connection between weak subject matter  
17 knowledge and self-confidence, reporting that teachers lacked confidence to teach science and  
18 that this seemed to be associated with limited background knowledge (p 160). Teachers' self-  
19 confidence was negatively affected by believing that they had to be competent to answer  
20 children's subject-related questions. In contrast to Youens and McCarthy's (2007) findings, once  
21 beyond the bounds of a training experience, the teachers in this study found collegial support  
22 valuable, providing, for example, the confidence to try new activities and teaching strategies and  
23 support for planning science teaching.  
24  
25

26  
27 Borko, Lalik and Tomchin (1987) examined trainees' conceptions of “successful” teaching,  
28 comparing journal writings of “stronger” and “weaker” novice teachers. They found that although  
29 trainees generally agreed about what constitutes “successful” teaching, differences were  
30 observed regarding “unsuccessful” teaching. By “successful”, trainees indicated they meant  
31 using creative and novel activities, generating a variety of experiences for their students.  
32 Preparation of lessons with these characteristics involved going beyond the prescribed  
33 curriculum and associated tasks. Trainees emphasized trying out new ideas, maintaining pace  
34 and handling behaviour issues effectively. When describing “unsuccessful” lessons, weaker  
35 trainees focused more on behaviour issues and planning, while stronger trainees focused on a  
36 lack of creativity on their part.  
37  
38

39  
40 Teachers' beliefs about the potential influence of specific environmental factors on their science  
41 teaching were investigated by Lumpe, Haney and Czerniak (2000). These authors developed a  
42 “Context Beliefs About Teaching Science” (CBATS) instrument designed to assess the extent to  
43 which teachers beliefs about aspects of their work were positive or negative. They report that  
44 more positive beliefs emerge among more experienced teachers, describing a majority as  
45 holding “robust, modest and tenacious” belief patterns (p 285). These sustain teachers when  
46 working in frustrating circumstances, providing a structure that helps them function effectively in  
47 the classroom. A minority were found to be “vulnerable, fragile and self-doubting”. The authors  
48 comment that teaching may select against such weak profiles, and teachers possessing these  
49 belief systems may leave the profession at an early stage.  
50  
51

52  
53 Given these previous studies, the possibility exists that trainees experience different levels of  
54 confidence for teaching within and outside specialism, as well as using different sources to  
55 develop their SMK.  
56  
57  
58  
59  
60

## Hypothesis and research questions

Hence, this study investigates:

- What sources do trainee science teachers use for developing their subject matter knowledge for within and outside specialism teaching while on a ten month postgraduate teacher education course?
- To what extent is the confidence of trainee science teachers influenced by teaching within and outside their specialist subjects?

## Methodology

The design of the study follows the tradition of interpretative and descriptive qualitative work (Merriam, 2002), although data were collected using both interviews and questionnaires. These methods gave the best overview of trainees' experiences, providing an insight into the widest possible range of opinions and views within this context. The interviews were designed to validate questionnaire responses.

Data were analysed to characterise trainees' attitudes and confidence relating to SMK for within and outside specialism teaching. Categories emerged from the data – a combination of responses to open questions and Likert scale statements together with interview responses revealed specific characteristics. These are discussed in detail below.

### *The questionnaire*

The questionnaire, devised for this study, comprised three probe types:-

- Open questions probed trainees' sources of SMK for preparing science topics for teaching within and outside their specialist subjects
- A closed question invited trainees to rank preferred sources of subject knowledge from a pre-prepared list
- Eight paired statements explored trainees' thinking about SMK and teacher confidence using a five-point Likert scale.

The components of the questionnaire were validated by discussion with colleagues.

In addition, background information such as trainees' education, age and gender were collected. The questionnaire is provided in Appendix 1.

### *The interviews*

Individual interviews of approximately 30 minutes each were conducted using a semi-structured protocol. The interviews collected data relating to the topics trainees had taught; sources used to develop SMK needed for teaching within and outside specialism; trainees' awareness of the

1  
2  
3 impact of their preparation on achievement of intended learning outcomes; and the extent to  
4 which their modes of subject matter knowledge acquisition and lesson preparation changed  
5 during the PGCE course.  
6

7  
8 Questionnaires were administered in April 2006 and April 2007 after completion of all HEI-based  
9 sessions and towards the end of the main teaching placement. Interviews were conducted in  
10 June 2006 and June 2007 when all parts of the course had been completed.  
11

### 12 **The sample**

13  
14 A total of 71 trainees completed the questionnaire. These comprised twenty-eight respondents  
15 from the 2005 – 2006 cohort and forty-three from 2006 – 2007. Maxima of forty (2005- 2006)  
16 and fifty-two (2006-2007) were possible – absences and fall-out from the course on the day of  
17 data collection account for discrepancies. For reporting purposes, all respondents are treated as  
18 one group – this is reasonable given that both cohorts had as identical experiences as possible.  
19

20  
21 Twelve trainees were interviewed, divided 5:7 between the 2005- 2006 and 2006 – 2007  
22 cohorts. The trainees were volunteers, but care was taken to ensure participants were as far as  
23 possible representative of all respondents in terms of subject specialism, age and gender.  
24  
25

## 26 **Results**

### 27 **Trainees' backgrounds**

28  
29 [Insert Table 1 about here]  
30  
31

32  
33 Table 1 provides information about the gender distribution, degree class<sup>1</sup>, age and science  
34 subject specialism of the respondents.  
35  
36

37  
38 The samples were representative of the full cohorts, being skewed approximately 60:40 towards  
39 females. Most trainees were born in North East England and Scotland. Four trainees born  
40 outside the UK were classified formally as “ethnic minority” trainees. Eight participants who  
41 completed the questionnaire did not complete the successfully for different reasons.  
42

43  
44 Degree subject is the key indicator used to decide trainees' science specialism as physics,  
45 chemistry or biology. Trainees' degree subjects are broad-ranging: data indicate that about 65%  
46 of respondents were “biology specialists”, holding degrees in biology (16%) or “biology-related”  
47 subjects (49%). The latter included graduates in genetics, ecology, biomedical sciences, aquatic  
48 / marine bioscience and physiology. Nine (12%) trainees held degrees in chemistry, while a  
49 further eight (11%) were classified as “chemistry-related”; this group included biochemists,  
50  
51

52  
53  
54 <sup>1</sup> Degree class is divided into four categories of “Honours”: the highest achieving students, usually around 10% of a  
55 cohort, are awarded “First” (1<sup>st</sup>) class degrees. These students normally score around 70 – 75% in their final  
56 examinations. About 40% are placed in the next category, “Upper Second” (2:1) class. About 30% gain “Lower  
57 Second” (2:2) class degrees. About 20% are awarded “Third” class honours. Those whose work is deemed not of  
58 Honours standard may be awarded “Ordinary” or “Pass” degrees.  
59  
60

geologists, environmental chemists and pharmacologists. Eight trainees held degrees physics or physics-related subjects, such as astronomy, mechanical engineering and optometry.

Degree class is widely respected as an indicator of the quality of trainees' science specialist knowledge. These trainees are regarded as "academically well-qualified": Table 1 shows that about 54% held Upper Second (2:1) or First Class (1<sup>st</sup>) honours degrees, these being the two highest degree classifications possible, while a further twenty-one held Lower Second (2:2) class degrees. Thus, overall around 83% of respondents held "good" degrees. Nineteen also held Masters or Doctorate qualifications in science. One held a Masters degree in Law. Possession of a "good" degree means that a trainee would respond correctly to GCSE (General Certificate of Secondary Education: the Key Stage 4 examination taken at age 16) questions in their specialism.

Trainees' average age was 27. Around 58% were aged 21 – 25. For this sub-group, teaching is their first career choice. The remainder comprise those changing career, such as post-doctoral scientists, science graduates who have worked in non-science fields and parents returning to work.

### **Preferred sources of SMK for teaching**

[Insert Table 2 about here]

In responding to the questionnaire, trainees ranked a pre-prepared list of possible SMK sources from 1 (most preferred) to 10 (least preferred). These data indicate strong preference for school-based or school-oriented material, reliance on note-taking and reading. HEI-based teaching sessions, misconceptions and science education research literature received low rankings. Ten trainees did not provide sufficient information to be included.

### **SMK sources for teaching within and outside specialism**

Open questions prompted trainees to choose one topic each from within and outside their specialisms that they had taught and describe sources used to prepare the SMK required. Table 3 summarises the SMK sources trainees cited in their responses. The figures represent the numbers of trainees citing each source. Most trainees cited more than one.

[INSERT TABLE 3 ABOUT HERE]

#### ***Within specialism teaching SMK preparation***

Table 3 indicates four main sources of SMK - the internet, textbooks, prior knowledge and formal documentation – were used for within specialism teaching preparation. Comments emphasised trainees' sense of "already knowing" the topic, implying little work was needed, for example:-

"I knew it and only had to skip through the Key Stage 3 revision book, ie. 5 mins"  
(Chemist)

1  
2  
3 “Forces – looked at QCA<sup>2</sup>, school and exploring science SoWs and tests to come up  
4 with learning objectives and teaching scheme... otherwise did not need to think about  
5 own subject knowledge” (Physicist)  
6  
7

8 Three trainees explicitly stated they consulted no additional SMK sources, relying entirely on  
9 prior knowledge.  
10

11 The 19 trainees citing “textbooks” regarded these as low level material, of whom six described  
12 this choice as “background reading”, or “refreshing knowledge”, for example:-  
13  
14

15 “Cells. Background reading which brought back what I already knew ... I already felt  
16 quite confident with the topic” (Biologist)  
17  
18

19 Five used revision guides (classified as “other) to check the level of knowledge required by their  
20 students, for example:-  
21

22 “Light – I used subject revision guides to establish what the content should be. My  
23 subject knowledge was already adequate” (Physicist)  
24  
25

26 Five trainees believed they had the necessary subject knowledge, but wanted to find good  
27 resources or explanations to use in teaching, for example:-  
28

29 “Acids and alkalis – [I] looked at how to describe ideas using simple vocabulary”  
30 (Chemist)  
31  
32

33 “Variation – I.. researched for novel activities....” (Biologist)  
34

35 These trainees seem aware of transforming SMK to pedagogical content knowledge (PCK).  
36  
37

38 Table 3 indicates that few trainees prepared for within specialism teaching by seeking  
39 colleagues’ advice, consulting misconceptions or science education research literature or testing  
40 out practical experiments prior to lessons.  
41

### 42 ***Outside specialism SMK preparation***

43 Table 3 shows that a more intense pattern of SMK sources emerges for outside specialism  
44 preparation. School colleagues and textbooks were consulted by about half of respondents. The  
45 internet and formal documentation were also popular. The range of sources reflects trainees’  
46 awareness of SMK weaknesses and perceived need for more detailed preparation, for example:-  
47  
48

49 “Electromagnetic spectrum – [I] read around the subject and to a higher level than I  
50 was required to teach. [I] prepared an extensive lesson plan with difficult concepts  
51 fully written out” (Biologist)  
52  
53  
54  
55

56  
57 <sup>2</sup> The QCA is the Qualifications and Curriculum Authority, the organisation responsible for setting examination  
58 standards. The QCA has produced a scheme of work for teaching KS3 used by some schools. [www.qca.org.uk](http://www.qca.org.uk)  
59  
60

1  
2  
3 The role of school colleagues in helping trainees prepare for outside specialism teaching is  
4 apparent, for example:-  
5

6  
7 “Environments – had long conversations with other teachers...” (Physicist)  
8

9 “Radiation – [I] spoke to the physics teacher (he knows everything)” (Biologist)  
10

11 “Gravity and Space - ....Teachers at school and technicians were very helpful” (Chemist)  
12

13  
14 Trainees using textbooks did so to learn the information necessary, rather than to check the  
15 level of understanding required, for example:-  
16

17 “Paints and pigments – [I] read over student textbook then looked in A level book to  
18 improve higher knowledge then researched on internet” (Biologist)  
19

20  
21 The increase in “Other” sources for outside specialism SMK arises from trainees stating that  
22 they practiced experiments before lessons, or asked for help in setting up equipment.  
23

### 24 ***Comparing SMK sources for within and outside specialism teaching***

25 Table 3 shows that about 50% of trainees actively seek colleagues’ advice in preparing outside  
26 specialism lessons. SMK preparation for within specialism teaching is characterised by trainees  
27 relying heavily on prior knowledge and not seeking advice or testing experiments prior to  
28 teaching.  
29

30  
31 About two-thirds of trainees expressed clear differences in their approaches to within and  
32 outside lesson preparation, for example:-  
33

34  
35 “My biology topics are fairly clear in my mind and so I do not need to look at basic  
36 knowledge ... with Chemistry I am not sure of my basic knowledge and must look  
37 at the topic as though I am teaching myself.” (Biologist)  
38

39  
40 “I needed to make sure I was prepared for any additional questions students may  
41 ask” (Biologist)  
42

43  
44 About ten trainees indicated that outside specialist subject lessons were sometimes “easier”, for  
45 example:-  
46

47 “Non-specialism takes longer [to prepare] but is sometimes easier to teach as  
48 you don’t have the same extent of knowledge” (Biologist)  
49

50  
51 This response, found also at interview (see below, p 16) suggests that possession of too  
52 much subject matter knowledge could be problematic. Outside specialism teaching meant  
53 that trainees taught what they learned, resulting in more clearly focused lessons than those  
54 taught within specialism.  
55

Other emerging issues relating to outside specialism teaching included one trainee who sought to avoid misconceptions:-

[Outside specialism] – emphasis on accuracy and avoidance of misconception perpetration” (Biologist)

and this trainee who explicitly stated she prepared to enhance her confidence:-

“[I did] far more preparation for the physics topic to feel more secure and confident” (Biologist)

Two trainees stated specifically they used the same preparation method throughout, for example:-

“I used similar strategies as I find them most effective to refresh my knowledge and ensure my understanding” (Biologist).

### The extent to which trainees’ confidence for teaching relies on subject matter knowledge

[Insert Table 4 about here]

Trainees’ responses to eight statements scored using a five-point Likert scale are summarised in table 4. The statements were paired to permit exploration for consistencies in response patterns: one pair each investigates trainees’ **preference** for teaching within and outside specialism; their **confidence** for teaching; the extent to which trainees believe they can handle students’ **questions**; and trainees’ **attitudes** towards SMK.

Detailed data relating to combinations of responses are presented below. For this purpose, the scale has been summarised to three points by adding “strongly agree” to “agree” and “strongly disagree” to “disagree”, with neutral in the centre. The words “agree” and “disagree” are used to express extremes. All 71 trainees responded to all statements.

#### ***Preferences for within and outside specialism teaching***

Two statements, “I prefer to teach topics in my specialism” (abbreviated to “prefer specialism”) and “I am pleased to teach topics in all areas of science” (abbreviated to “all science”) assessed trainees’ preferences. A trainee preferring in-specialism teaching may respond positively (strongly agree/ agree) to the first statement and negatively (disagree/ strongly disagree) to the second; vice versa for a trainee preferring to teach all sciences.

Table 4 shows that around 56% (total of “strongly agree” and “agree”) of respondents prefer to teach their specialism, while over 80% (total of “strongly agree” and “agree”) say they do not mind teaching all aspects of science. However, these data mask underlying response patterns. These are analysed next. Four clear patterns emerge:-

32 (45%) Trainees agreed with both statements  
15 (21%) Trainees disagreed with “prefer specialism” and agreed with “all science”

- 1  
2  
3 12 (17%) Trainees were neutral to “prefer specialism” and agreed with “all science”  
4 8 (11%) Trainees agreed with “prefer specialism” and disagreed or were neutral to “all  
5 science”  
6  
7

8 Four trainees’ responses did not fit these categories.  
9

10 Trainees agreeing with both statements are not necessarily inconsistent – they may be saying  
11 that although they prefer to teach within specialism, they are also pleased to teach all topics.  
12 They can work on SMK and may enjoy this. Around 21% claim preference for teaching all  
13 science topics. This group could be described as “generalist” in outlook. The twelve trainees  
14 neutral to the “I prefer to teach...” statement could also be “generalist”, although they express  
15 their preference less strongly. Finally, a small sub-group of “specialists” exists; these trainees  
16 express strong preference for within specialism teaching.  
17  
18

### 19 **Confidence for teaching**

20 The statement pair exploring trainees’ confidence for teaching was “I am less confident teaching  
21 outside my specialism” (“less confident outside”) and “I do not need to teach my specialism to  
22 feel confident as a teacher” (“don’t need specialism”). A trainee with good self-confidence may  
23 respond negatively to the first statement (strongly disagree or disagree) and positively to the  
24 second. A more anxious trainee may state the reverse.  
25  
26

27  
28 Table 4 shows that 53% respond “strongly agree/ agree” to “less confident outside”, while twelve  
29 disagree. This significant minority express confidence in their ability to teach outside specialism.  
30 However, in a seemingly contradictory fashion, about two-thirds agree or strongly agree with  
31 “Don’t need specialism”, implying that they can teach anything. Closer inspection of underlying  
32 response combinations reveals these pairings:-  
33  
34

35 14 (21%) Trainees disagreed with “less confident outside” and agreed with or were neutral  
36 to “don’t need specialism”  
37

38 9 (12%) Trainees were neutral to “less confident outside” and agreed with “don’t need  
39 specialism”  
40

41 25 (35%) Trainees agreed with both statements  
42

43 5 (7%) Trainees agreed with “less confident outside” and disagreed with “don’t need  
44 specialism”  
45  
46

47 7 (10%) Trainees agreed with “less confident outside” and were neutral to “don’t need  
48 specialism”  
49  
50

51 Eleven trainees’ responses did not fit into these categories.  
52

53 The disagree / agree sub-group (14, 21%) could be labelled “super-confident”, as they state that  
54 outside specialism teaching does not affect their confidence. Examining these trainees’  
55 backgrounds shows that seven have degrees in the highest two classes (1<sup>st</sup> or 2:1) or hold a  
56  
57  
58  
59  
60

1  
2  
3 higher degree, while ten are female. The average age is 31: six are aged 30 or over. Tentatively,  
4 “super-confident” trainees could be academically well-qualified females older than the average  
5 age of the cohort.  
6

7  
8 Those agreeing with both statements (25, 35%) may indicate that despite feeling less confident  
9 teaching outside their specialism, this can be handled by putting in the necessary work on SMK,  
10 hence, they can respond positively to “I do not need to teach my specialism...”. This sub-group  
11 could be labelled “working-confident”.  
12

13  
14 Twelve trainees agreeing with “less confident outside” could be described as “anxious”. These  
15 split 50:50 by gender and degree class, with six possessing 1<sup>st</sup> or 2:1 degrees. The average age  
16 is 25, below that of the whole group, although four trainees were aged 30 or over. Reasons for  
17 trainees’ lack of confidence are unclear, but collectively their backgrounds differ from “super-  
18 confident” and “working-confident” trainees.  
19

### 20 21 **Handling SMK-related questions**

22 Statements investigating trainees’ attitudes towards handling SMK-related questions were: “I can  
23 handle the situation if I am asked difficult questions outside my specialist area” (“I can handle”)  
24 and “I am nervous that I will be asked a question I cannot answer” (“I am nervous”). Anecdotally,  
25 handling subject-related questions causes anxiety among many science trainees, particularly in  
26 the early stages. A trainee able to cope with these may respond positively (strongly agree /  
27 agree) to the first statement and negatively (strongly disagree/ disagree) to the second. A more  
28 nervous trainee may respond oppositely.  
29  
30

31  
32 Table 4 shows thirty-two trainees felt nervous about being asked a question they could not  
33 answer (strongly agree /agree), while fifty agreed or strongly agreed with “I can handle”. Overall,  
34 a majority of respondents appear confident about difficult questions, perhaps accepting that  
35 nerves are to be expected. These underlying response combinations were found:-  
36

- 37  
38 34 (48%) Trainees agreed with “I can handle” and disagreed or were neutral to “I am  
39 nervous”  
40 17 (24%) Trainees agreed with both statements  
41 15 (22%) Trainees agreed with “I am nervous” and disagreed or were neutral to “I can  
42 handle”  
43

44  
45 Five trainees disagreed with “I am nervous”.  
46

47 These figures suggest that about 48% express confidence in their ability to handle questions  
48 outside their specialist area and feel little or no nerves about being asked questions they cannot  
49 answer. About one-quarter (24%) seem to regard nerves as “part of the game”, responding  
50 positively to both statements. About 22% seem to have a more “anxious” disposition, admitting  
51 to feeling nervous and not being able to handle difficult questions. Background information  
52 shows sixteen of the thirty-four trainees (47%) feeling most confident at handling questions are  
53 male, skewing this sub-group away from the cohort’s 60:40 split. Twelve of the fifteen trainees  
54 (75%) feeling least confident were female, a skew in the opposite direction.  
55  
56  
57  
58  
59  
60

### **Attitudes to SMK**

The statements exploring trainees' attitudes to SMK were "I find it difficult to develop my subject knowledge outside my specialist area" ("I find it difficult") and "I enjoy learning new subject knowledge outside my specialist area" ("I enjoy learning"). A trainee with a positive attitude towards outside specialism teaching may respond negatively (strongly disagree / disagree) to the first statement and positively (strongly agree / agree) to the second. A trainee feeling uncomfortable learning new SMK may respond oppositely.

Table 4 shows highly polarised responses to these statements. About 79% strongly disagree / disagree with the first and 83% strongly agree / agree with the second. Although this is a strong indication that the majority of respondents have positive attitudes towards acquiring new SMK, examination of underlying response patterns shows that small sub-groups showing slight variations exist:-

50 (70%) Trainees agreed with "I enjoy learning" and disagreed with "I find it difficult"

10 (14%) Trainees were neutral to "I enjoy learning" and were neutral to or disagreed with "I find it difficult"

3 Trainees agreed with both statements

2 Trainees were neutral to "I enjoy learning" and agreed with "I find it difficult"

Six trainees' responses did not fit into these categories.

Perhaps most interesting to note is the small number of trainees (3 + 2, last two categories) whose responses suggest they find learning new SMK is difficult: three were females aged over 30 and three held 2:2 degrees, while the remaining two held 2:1s. This sub-group are noticeable amongst the overwhelmingly positive responses.

### **Semi-structured interview data**

The twelve interviews indicated the impact perceived by trainees of SMK on their teaching, as well as validating responses found in the questionnaires. The interviewees were slightly more skewed towards males (6/12, 50%) and chemists / physicists (5/12, 42%) than the whole cohort. Interviews explored how trainees perceived their SMK and confidence as a teacher impacted on students' learning. Verification of questionnaire responses emerged naturally during discussion. Trainees' voices are reported verbatim, although colloquial and dialectical expressions have been modified to ease comprehension. Names used are pseudonyms. All interviewees completed the PGCE course successfully but with differing teaching abilities. In reporting their viewpoints, reference is made to interviewees' Likert scale responses, hence references to "super-confident", "working-confident" and "anxious". The interviews supported the responses given on the questionnaire. Interviews were transcribed verbatim. Transcripts were then compared with individual interviewees' questionnaires for commonality of views.

### **Views about teaching outside specialism**

1  
2  
3 Three main viewpoints corresponding to questionnaire categories (p 12) were apparent.  
4 Matthew, an “anxious” trainee according to his confidence responses, said this about teaching  
5 outside specialism :-  
6

7  
8 “In physics when I felt the [children] weren’t grasping it [the topic] I could tackle it  
9 from a different angle by thinking myself, ‘How’s the best way to put this across?’  
10 and going down a different route. That was very limited for me with biology ....I  
11 wouldn’t have had the knowledge to do that. If it had happened, I would have had  
12 to extend into a different lesson, and gone away, thought about it and brought it  
13 back in another lesson.” (Matthew, physicist)  
14  
15

16 Daniel and Mary reported differences in the ease with which they prepared for teaching in the  
17 two domains. Their confidence responses corresponded to the “working confident” category:-  
18

19  
20 “I felt I could prepare resources for my specialism much easier, and I was a lot less  
21 confident at trying new things, so for chemistry I stuck exactly to what the Scheme of  
22 Work gave me ... with biology [when I thought] ” I don’t agree with that”, it was much  
23 easier to change things.” (Mary, biologist)  
24

25  
26 “I was a lot less creative with biology and physics – that went down to confidence in  
27 the material... I went down traditional lines... I didn’t tend to [experiment] unlike my  
28 chemistry where I liked to [be] more creative.”  
29 (“Daniel”, chemist)  
30

31  
32 These trainees connect their lack of confidence in their subject matter knowledge for an outside  
33 specialism topic to their ability to develop their own ideas for lessons. “Sticking to the scheme”  
34 enabled them to feel safe and secure.  
35

36 Another approach to teaching outside specialism was expressed by George, a “working-  
37 confident” physicist:-  
38

39  
40 “I think I just don’t do enough for biology...you’re always looking at your notes  
41 checking you’ve spelt [words] right, whereas in physics you can go off at a tangent  
42 because you know you haven’t got a problem explaining something...” (George,  
43 physicist)  
44

45  
46 In contrast, Simon, a “super-confident”, expressed confidence in his ability to teach outside  
47 specialism:-  
48

49  
50 “...as long as I’d prepared I felt confident teaching the subject, I was quite  
51 comfortable, if you said I was teaching physics top set [most able children], I would  
52 go away... do my research and then I’d be pretty comfortable, you might always get  
53 a question where someone might pull you up, but then you just say to them I’ll have  
54 to go and look at that.” (Simon, chemist)  
55  
56  
57  
58  
59  
60

Thus, trainees perceived differences in confidence for within and outside specialism teaching, and articulated reasons for these that corresponded with their questionnaire responses.

### ***Views about teaching within specialism***

Eight interviewees thought that learning objectives were achieved more easily when teaching outside specialism. This is counter-intuitive to expectations, supporting questionnaire data reported above (p 10). Three trainees said that initially they knew “too much” and failed to select information effectively. Mary, for example, found a much lower knowledge level than expected was required:-

”...at the start, [with my KS4 biology class] I didn’t think [the learning objectives] were all met. They were a “Gifted and Talented” [high ability] class....I was going quite quickly ... and I really enjoyed it. I don’t think they were keeping up with me as well as I thought they would do....Towards the end things were better and I would say yes, the learning objectives were being met. In chemistry I would say yes, they were met, because I was sticking so closely to the Scheme [of Work]” (Mary, biologist)

Matthew commented:-

”I feel that teaching outside specialism is better because to a certain extent I ‘m learning as the children are, so I can see [the topic] from their angle, and there is no confusion about what they need to know... With physics it's different ... there were times that I knew I was thinking [about] quite high level stuff and then dumbing it down to something they would understand, and that sometimes made my job a bit harder ...[I didn’t have] enough experience teaching low level things” (Matthew, physicist)

The feeling of having to condense specialist subject matter knowledge was expressed by John, whose comment contributes to this paper’s title:-

“[In chemistry and physics lessons] I could explain things at the level [they] should be explained at. For a biology concept you’ve got all this [knowledge] in your mind overriding what you’re telling them. [You know what you say is] almost a white lie, it should be in much more depth, or there are things that you know need to be accompanied with it [that are] not part of the curriculum, its not part of what they need to know. There is a conflict in your head” (John, biologist)

None of the interviewees whose early teaching was more successful outside specialism connected variation in success explicitly to strategies for preparation, although three noted differences in their strategies. John, for example, relied on his prior learning in school as preparation for within specialism teaching, whereas he more actively prepared for physics and chemistry lessons:-

I: How did you prepare the subject knowledge you needed?

1  
2  
3  
4 J: For biology I already had an idea of what I'd already done in school myself...  
5 I did think about what I'd learned and I did find it easier to remember the biology  
6 related lessons ... so planning biology lessons, I think I'd already thought about  
7 it before coming on the course...  
8  
9

10 With regard to chemistry and physics ...there was a lot more preparation,  
11 relearning things ...[for example] I haven't touched on any physics ... since  
12 GCSE. ...[so] there was a lot more preparation, I used colleagues in school,  
13 speaking to other physics teachers, and other people on the course, getting  
14 their advice...  
15  
16

17 I: So when you were preparing you were more aware of spending time on  
18 outside specialism?  
19

20  
21 J: Yes definitely... I took the [school] textbook ... home and look[ed] at that, but  
22 I tried to go above that, because children have questions, they want extra bits  
23 of information... If you only understand [a topic] to the level they need to learn  
24 it, you're never going to be able to teach it, so you need to learn it a couple of  
25 steps ahead so you can deal with those unexpected questions and understand  
26 it further than is expected for them"  
27  
28

29 In contrast, Simon, who reported no differences in lesson success, consciously used the same  
30 strategies to prepare lessons in both domains, explaining that achieving outcomes depended on  
31 finding good activities:-  
32  
33

34 "...In terms of the learning objectives they were all roughly similar... in terms of  
35 activities I would go out of my way to look in biology to find something a little bit  
36 better [than the school's Scheme of Work] so I'd go on the internet and find  
37 interactive games. In classification, I did find a few, so some of my lessons  
38 were better than in chemistry.... it just came down to the activities." (Simon,  
39 chemist)  
40  
41

42 Simon makes explicit that selection of appropriate instructional strategies is one factor that aids  
43 successful lessons. Trainees relying on prior knowledge alone experienced more difficulty in  
44 achieving successful lessons within specialism in the early stages of their teaching.  
45  
46

47 The need to select appropriate instructional strategies and over-reliance on inappropriate ones is  
48 illustrated by Jane, a chemist, who copied the style of chemistry teaching she experienced at  
49 school:-  
50  
51

52 "A lot of the chemistry I learned at school was just copying off the board... you try  
53 hard to avoid this, but there's parts where it comes back that that's what you do.."  
54 (Jane, chemist)  
55  
56  
57  
58  
59  
60

Jane's school experiences exerted a powerful influence on her intuitive approach to teaching chemistry; as she had found the subject relatively straight-forward, her instincts led her to want to teach as she herself was taught, on the assumption that the learning outcomes would be the same:-

"...you've had all that background knowledge and spent all that time learning it ... you can't then understand why other people don't get it..." (Jane, chemist)

Jane realized she could not make these assumptions, and subsequently changed her practice.

Finally, Val, a biologist, illustrates that some trainees are closed to the impact of their teaching on children, until faced with difficult information:-

"...with respiration I thought I had gone through the topic really thoroughly... a lot of them didn't do well in the end of topic test.. Being a biologist didn't seem to work.."  
(Val, biologist)

Val is expressing her realization that possession of good SMK on her part is not the only factor determining learning outcomes.

A "continuum" of experience from Simon, through John and Jane to Val can be seen here. Simon grasped early on the need to transform his SMK into activities, using the same strategies for preparation both within and outside specialism. John and Jane relied on prior experiences to help them survive, rather than transforming SMK. Both realized the flaws with this approach. Finally, Val taught first, then reflected from the students' test results on her performance. Interestingly, Simon and Val both fell into the "super-confident" category (see p 11) – in Val's case this proved to be over-confidence. These data suggest the importance of aiding trainees to develop reflective practices early on.

### ***Handling subject knowledge-related questions***

Trainees' initial apprehension at being asked questions they could not answer was apparent. For example, Jane, a highly qualified trainee with a doctorate degree, was one of the fifteen most anxious, according to her questionnaire responses (see p 12):-

"At the beginning one of your biggest fears is that they are going to ask you things that you don't know and you are thinking, 'What am I going to say?' ... but as you get into the job you realize ...you don't have to know everything and they won't really ask you the questions you're thinking because [the students are] not that advanced ...– its like a fear of the unknown. They don't ask you things that you think they're going to." (Jane, chemist)

Other trainees noted their strategies for handling questions were better in their specialist subjects. Mark who expressed confidence in his ability to handle questions, said:-

"...the only thing with physics was that I needed to know what they needed to know, but if there was something outside that, then bringing it into the lesson

1  
2  
3 wasn't a problem, and if there was something where I was asked a question and I  
4 wasn't sure about it I made a point of telling them I would find it out." (Mark,  
5 physicist)  
6  
7

8 John, a "working confident", learned his material "a couple of steps ahead" of the children so that  
9 he could handle questions. He was asked if he was conscious of being able to handle questions  
10 better in biology than physics and chemistry:-  
11

12 "In a way, but I was never scared of children asking questions, if I didn't know the answer  
13 I would say so, at first, I thought it would be the end of the world, how stupid would I look  
14 ... but yes, if a child asked me a biology question I would be much more confident  
15 answering it than in physics or chemistry, but if someone asked me a question in physics  
16 and I didn't know I would find out and answer it the next lesson."  
17  
18

19  
20 Thus, the ability to handle questions seems to rely mainly on trainees' self-confidence. Trainees  
21 take a pragmatic approach, finding effective strategies for handling questions to which they don't  
22 know the answer and that children are less demanding than they expected.  
23

### 24 ***Changes in SMK sources and preparation during the PGCE course***

25 Ten interviewees stated their preparation time had reduced significantly during the PGCE year.  
26 Andrew, for example, said that recalling SMK became easier as training progressed:-  
27

28 "My subject knowledge in science has been sleeping. And its all come out again, in  
29 this year...[now] subject knowledge takes a back seat to creativity" (Andrew,  
30 biologist)  
31  
32

33  
34 His use of the word "creativity" suggests he has moved from "survival" and transmission of  
35 knowledge to "transformation" of SMK.  
36

37 The notion of "speeding up" may reflect trainees' increasing confidence in handling classroom  
38 situations, reducing the time needed to get their SMK to a level they felt brought confidence.  
39

40  
41 Harriet was one trainee who used unchanged approaches throughout the course:-  
42

43 "In the diagnostic [first, short teaching placement], I taught only KS3, and again  
44 I read the textbook, the knowledge required was so much simpler.... I don't  
45 think my strategies did change, I was reading and talking to teachers,  
46 sometimes I used the internet.... So I don't think they did change." (Harriet,  
47 biologist)  
48  
49

50  
51 Again, pragmatism plays a role -trainees know what is expected of them and devise coping  
52 strategies. They become more skilled at applying these as the course continues.  
53  
54  
55  
56  
57  
58  
59  
60

## Discussion

### ***Trainee science teachers' SMK sources for within and outside specialism teaching***

Evidence (Tables 2 and 3) indicates that these science trainees use more SMK sources for preparing lessons outside specialism than within specialism. Trainees rely on experienced colleagues and school materials more frequently when preparing outside specialism lessons. Trainees also practice unfamiliar experiments before lessons and consult technicians more often for lessons in this domain. The questionnaire and interview data together suggest that intense SMK preparation helps transformation to PCK, as trainees believed their efforts enhanced their ability to deliver outside specialism lessons with appropriate activities that met learning objectives for their students, as well as giving confidence in their teaching skills.

SMK preparation for within specialism teaching was more casual. Trainees relied on finding out students' knowledge levels. Three trainees used no SMK preparation strategies at all, relying only on prior knowledge. Fewer experiments were tested in advance of within specialism lessons. Perhaps most significant is that trainees consulted experienced teaching colleagues for within specialism preparation much less frequently. In terms of achieving learning objectives, eight interviewees indicated their within specialism lessons were in some respects poorer than outside specialism lessons. Although none explicitly connected this to poor preparation, a link between the paucity of SMK sources used and achievement of learning outcomes seems distinctly possible.

Three interviewees indicated that their difficulties teaching within specialism arose from an inability to select appropriate information from their knowledge base, allied to a lack of experience at teaching "low level" material. The description as a "conflict" is powerful – awareness of a wide range of interlinking concepts and partial truths may hinder selection of the best approach to take or strategy to use. This may be a contributing factor to trainees' inability to transform within specialism SMK to PCK. A lack of SMK for outside specialism teaching seems to lead automatically to more successful transformation to PCK, most likely because trainees involve experienced colleagues and are academically able enough to take in new (or revise old) information rapidly. For teaching within specialism, interviews revealed that trainees work out what to do for themselves over different time periods.

Of course, these comments do not apply to all trainees: there is evidence that 20 – 30% of the cohort were equally successful at teaching in both domains. Interview data suggest these trainees are those who perceived at the earliest possible stage that successful teaching depends (at least to some extent) on good, appropriate activities – that is, somehow, they hit on the importance of transforming SMK to PCK very early in their practice. Their own personal SMK appeared secondary to ensuring that appropriate activities were found and prepared in a suitable format for teaching.

A second finding is the contrast in importance that trainees place on SMK sources from teaching practice schools and HEI-based sessions. Despite attending sessions that, at the time, were rated (verbally and anecdotally) positively, few trainees used any HEI-based materials or ideas regularly, using almost entirely SMK sources from their teaching practice schools. We can only speculate as to possible reasons: for example, HEI sessions may be too generic to be useful to

1  
2  
3 specific school situations, despite efforts to make them relevant; trainees may feel forced to  
4 abide by schools' strict Schemes of Work; the time lag between an HEI session and teaching a  
5 topic may be too long, so the session is forgotten; or sessions were simply too radical and  
6 contrasting to what really goes on in school. Science education research is probably perceived  
7 as too esoteric and difficult to access, as well as being difficult to use directly (one trainee  
8 commented to this effect in her questionnaire). Misconceptions may be already embedded in  
9 schools' Schemes of Work, or are no longer fashionable in the movement in England and Wales  
10 towards general scientific literacy.  
11  
12

### 13 ***Trainee science teachers' confidence for within and outside specialism teaching***

14 A mixed picture is observed in data relating to trainee science teachers' confidence. About 20%  
15 of trainees showed no difference in confidence levels for teaching in either domain. This "super-  
16 confident" sub-group seemed to have prepared themselves mentally for the task of teaching all  
17 aspects of science. This group aside, it is probably fair to say that most trainees inevitably  
18 showed some anxiety for outside specialism teaching, at least in the early stages of their  
19 teaching practice experiences. A sub-group of about twelve demonstrate particularly "anxious"  
20 qualities. They feel nervous about deviating from prescribed Schemes of Work and express  
21 concern about answering subject-related questions. However, observations made outside the  
22 confines of this study indicated that a majority of these trainees developed good coping  
23 strategies and worked hard to overcome both their nerves and any initial apprehension.  
24  
25  
26  
27

28 The trainees in this study are aware that they are well-qualified academically. Over-confidence  
29 for within specialism teaching among some is therefore to be expected, at least in the early  
30 stages. Trainees vary in their ability to recognise this - interview data point to a possible  
31 continuum in the extent to which trainees can reflect meaningfully on their practice.  
32  
33

34 Trainees' strong academic backgrounds probably also contributed to their SMK development for  
35 outside specialism teaching. Around half express preference for teaching their specialism, but  
36 also imply they are content to learn new material. The confidence statement responses show  
37 that about one-third feel less confident teaching outside specialism, but also don't mind doing  
38 this. Evidence indicates that trainees know how to develop their SMK, and are resourceful and  
39 resilient in using a range of sources. The average age of 27 suggests that a good proportion of  
40 trainees come into teaching from previous jobs, bringing skills that confer maturity in handling  
41 novel situations.  
42  
43

44 The "super-confident" trainees are older than average and particularly well-qualified. Age and  
45 work experience may contribute additional maturity at handling unfamiliar situations, greater  
46 flexibility in thinking and the ability to take in and act on new knowledge under pressure. Parents  
47 of school-aged children familiar with school environments and used to juggling a variety of  
48 situations simultaneously tend to fall into this category.  
49  
50  
51

## 52 **Conclusions, limitations and practical relevance**

### 53 ***Conclusions***

54 These data, albeit of a preliminary nature, add to evidence that SMK clearly exerts an influence  
55 on teachers' practices. This study, set in a training environment, supports Davis's (2003)  
56  
57  
58  
59  
60

1  
2  
3 findings, indicating that good SMK helps trainee teachers select appropriate instructional  
4 strategies. However, we may need to adjust our definition of “good”, as these data suggest that  
5 75% of interviewed trainees, who possessed “good” SMK from their degree backgrounds, did  
6 not teach successful within specialism lessons, at least in the early stages of their teaching  
7 practices. Counter-intuitively, transforming SMK and, hence, selection of appropriate  
8 instructional strategies, seemed to occur more consistently when teaching outside specialism  
9 topics. This position may change as trainees become more experienced. Hashweh’s (1987)  
10 findings, for example, contradict these data. Appleton and Kindt’s (1999) work, also with  
11 experienced teachers, supports the connection made here: when teaching outside specialism  
12 trainees express a lack of confidence in their SMK and work hard to remedy this. However, the  
13 role of colleagues is clearly different – Appleton and Kindt show collegial support is valued  
14 among teachers post-training, whereas this study shows trainees only ask for this when  
15 preparing for outside specialism teaching. Youens and McCarthy’s (2007) work suggests that  
16 trainees may think seeking colleagues help for outside specialism teaching is regarded as “safe”,  
17 while asking for help for within specialism teaching, that is, for a topic they are supposed to  
18 “know”, may signal weakness.  
19  
20  
21  
22

23 The effectiveness of specialised, collegial support on outside specialism teaching supports the  
24 findings of Luft et al (2003) and Hoy and Spero (2005). These data also confirm the work of  
25 Youens and McCarthy (2007) in showing that school-based materials are used much more  
26 frequently than HEI-based sources for developing SMK (discussed below). Teacher educators  
27 and school mentors should strongly encourage trainees to seek (or insist that they take) advice  
28 from experienced colleagues for teaching in both domains, as well as consider the role that HEI-  
29 based sessions could play.  
30  
31  
32

33 These data do not provide clear support for de Jong (2000) and van Driel et al (2002) in  
34 asserting that good SMK helps trainees be more aware of students’ difficulties, although, of  
35 course, these studies presented other factors as also being involved. In this case, trainees  
36 became aware of students’ difficulties when learning SMK themselves for outside specialism  
37 lessons. No awareness of difficulties was encountered for within specialism lessons – rather,  
38 trainees tended to over-estimate students’ abilities, at least initially.  
39  
40

41 The value placed on HEI-based SMK sessions is questioned. Much time is invested in making  
42 these as valuable as possible by including latest research findings, information about up-to-date  
43 issues in science education and practical experiments, as well as using experienced teacher  
44 colleagues and up-to-date published school materials to help make sessions relevant to  
45 practice. Nevertheless, trainees make little use of these sessions as an SMK source, focusing  
46 instead on materials available in school. A second outcome is the need to ensure mentors are  
47 aware of the content and potential value of HEI-based sessions, and for teacher educators to be  
48 yet more explicit as to how to utilise HEI materials, misconceptions and research in lesson  
49 preparation.  
50  
51  
52

### 53 **Limitations**

54 Naturally, the study is limited – firstly by the fact that data are collected from one institution and  
55 at present constitute a relatively small set. Timing of data collection may mean that trainees’  
56 views have changed during the year - data were collected late in the PGCE course. Different  
57  
58  
59  
60

1  
2  
3 views may have been expressed earlier, although interview and questionnaire data together  
4 collected over a three month period, suggest that responses are reliable. The questionnaire was  
5 designed for this study and has not been validated through use elsewhere, other than by  
6 discussion. However, responses from the two cohorts showed no significant differences, and  
7 interviewees responded in very similar ways over the two years of the study to date. Further, the  
8 interviews did support the questionnaire data – trainees were invited to talk openly about their  
9 experiences, without direct reference to the questionnaire, and did so in ways that supported the  
10 viewpoints they expressed in their questionnaire responses. This suggests that questionnaire  
11 responses were internally reliable.  
12  
13

14  
15 An additional limitation is that what we read is trainees' viewpoints – they were self-reflecting. No  
16 information was gained from other sources, such as mentors or tutors to support these  
17 observations, so the statements about "success" or "failure" of specific lessons are entirely  
18 based on the trainees' perceptions. Hence, of course, findings must be regarded as tentative.  
19

### 20 21 **Practical relevance**

22 Despite the limitations, the information gathered illuminates the issue of SMK for science teacher  
23 development in a training setting in a novel way. Trainees' efforts to remediate weak SMK,  
24 including consulting experienced colleagues for advice, leads to outside specialism lessons  
25 being successful in the early stages of teacher development. Possession of "good" SMK as prior  
26 knowledge is insufficient to enable all trainees to prepare and deliver successful lessons within  
27 specialism, as they lack experience to transform SMK to PCK effectively. Further, the role of  
28 good support in aiding teacher development is confirmed.  
29  
30

31  
32 The issue of how best to prepare trainees for teaching remains open. This study draws attention  
33 to the possibility of identifying sub-groups of trainees with different characteristics. Further work  
34 may help identify "super-confident", "working confident" and "anxious" groups more rigorously,  
35 with a view to offering different specialised support. Differentiation of support may help enhance  
36 the skills of the "super-confident", and encourage more trainees to develop these characteristics.  
37

38  
39 The connection between "super-confident" and the ability to transform SMK to PCK was  
40 apparent. Trainees with these characteristics challenge the assumption that science specialist  
41 subjects are best taught by those possessing specialist degrees. High academic performance in  
42 a specialist subject is not an automatic precursor to good teaching. Trainees with good  
43 academic backgrounds tend more often to work from the "survival" perspective and regard  
44 teaching as knowledge "transmission". Interviews in this study show the limitations of this  
45 approach. We anticipate that most trainees make the transition from "survival" and simple  
46 transmission of knowledge to transformation of SMK at some stage during the training  
47 programme. The role of colleagues in providing support is identified as a factor aiding success:  
48 where help is asked for, evidence presented here shows this was always regarded positively.  
49  
50

51  
52 This study points towards the unique, raw nature of teachers' starting positions. In the early  
53 stages, heavy reliance on teaching practice schools is perhaps not unexpected, given the wide  
54 range of intense experiences that these naive beginners face. Research with experienced  
55 teachers post-training shows that skill development continues. A greater reliance on HEI-based  
56 sources may occur when the basic range of teaching abilities are in place. Accordingly, we may  
57  
58  
59  
60

1  
2  
3 need to review the nature and content of HEI-sessions on teacher education courses to ensure  
4 maximum impact during training. However, over the early years of a teacher's career, full  
5 support from HEI- and school-based colleagues is effective in aiding their development. Overall,  
6 then, the practical relevance of this study lies in the notion that assessing trainees' personal  
7 characteristics and offering appropriate, realistic, professional support from both HEIs and  
8 schools in accordance with these may help science teachers develop in the best possible ways.  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For Peer Review Only

## References

- Abell, S.K. (2000) *Science Teacher Education* Dodrecht: Kluwer Academic Publishers
- Appleton, K. and Kindt, I. (1999) Why teach primary science? Influences on beginning teachers' practices *International Journal of Science Education* 21 (2) 155 - 168
- Borko, H., Lalik, R. and Tomchin, E. (1987) Student teachers' understandings of successful and unsuccessful teaching *Teaching and Teacher Education* 3(2): 77 – 90
- Carlsen, W. S. (1993) Teacher knowledge and discourse control: Quantitative evidence from novice biology teachers' classrooms *Journal of Research in Science Teaching* 30 (5): 471 - 481
- Carlsen, W.S. (1999) Domains of teacher knowledge In: *Examining Pedagogical Content Knowledge* Eds: J. Gess-Newsome and N. Lederman, Dordrecht: Kluwer Academic Publishers
- Carré, C. (1998) Invitations to think in primary science lessons, in Birden, R. and Williams, M. (Eds) *Thinking through the curriculum* (London: Routledge)
- Davis, E.A. (2003) Knowledge integration in science teaching: Analysing Teachers' Knowledge Development *Research in Science Education* 34: 21 -53
- De Jong, O. (2000) The Teacher Trainer as Researcher: exploring the initial pedagogical content concerns of prospective science teachers *European Journal of Teacher Education* 23 (2): 127 – 137
- DfES (2004) *Science: The National Curriculum* London: The Stationery Office
- Geddis, A.N., Onslow, B., Beynon, C. and Oesch, J. (1993) Transforming content knowledge: Learning to Teach about isotopes *Science Education* 77 (6): 575 – 591
- Hashweh, M. Z. (1987) Effects of subject-matter knowledge in the teaching of biology and physics *Teaching and Teacher Education* 3 (2): 109 – 120
- Hoy, A.W. and Spero, R.B. (2005) Changes in teacher efficacy during the early years of teaching: A comparison of four measures *Teaching and Teacher Education: An International Journal of Research and Studies* 21(4): 343-356
- Lederman, N.G., Gess-Newsom, J. and Latz, M.S. (1994) The nature and development of preservice science teachers' conceptions of subject matter and pedagogy *Journal of Research in Science Teaching* 31 (2): 129 – 146
- Luft, J., Roehrig, G. and Patterson, N.C. (2003) Contrasting landscapes: A comparison of the impact of different induction programmes in beginning secondary science teachers' practices beliefs and experiences *Journal of Research in Science Teaching* 40 (1): 77-97

- 1  
2  
3  
4 Lumpe, A.T., Haney, J.J. and Czerniak, C.M. (2000) Assessing teachers' beliefs about their  
5 science teaching context *Journal of Research in Science Teaching* 37 (3) :275 – 292  
6  
7  
8 Magnusson, S., Krajcik, J. and Borko, H. (1999) Secondary teachers' knowledge and beliefs  
9 about subject matter and their impact on instruction In: Gess-Newsome, J. and Lederman, N.G.  
10 Eds (1999) *Examining Pedagogical Content Knowledge* Dordrecht: Kluwer Academic Publishers  
11 p 95 – 132  
12  
13  
14 Markic, S., Valanides, N. and Eilks, I. (2006) Freshman science student teachers' beliefs on  
15 science teaching and learning – a mixed methods study In: *Towards research-based science*  
16 *teacher education* p 29 – 40, edited by I. Eilks and B. Ralle, Shaker, Aachen Germany  
17  
18  
19 Marks, R. (1990) Pedagogical content knowledge: From a mathematical case to a modified  
20 conception *Journal of Teacher Education* 41 (3): 3-11  
21  
22  
23 Sanders, M. (1993) Erroneous ideas about respiration: The Teacher Factor *Journal of Research*  
24 *in Science Teaching* 30 (8): 919 – 934  
25  
26 Shulman, L. (1986a) Those who understand: A Conception of Teacher Knowledge *American*  
27 *Educator* 10(1): 9-15, 43-44  
28  
29 Shulman, L. (1986b) Those who understand: Knowledge growth in teaching *Educational*  
30 *Researcher* 15(2): 4-14  
31  
32  
33 Shulman, L. (1987) Knowledge and teaching: foundations of the new reform Harvard  
34 *Educational Review* 57 (1): 1 – 22  
35  
36 Van Driel, J., De Jong, O. and Verloop, N. (2002) The development of pre-service chemistry  
37 teachers' pedagogical content knowledge *Science Education* 86: 572 – 590  
38  
39  
40 Youens, B. and McCarthy, S. (2007) Subject knowledge development by science student  
41 teachers: the role of university tutors and school-based subject mentors *Research in Science*  
42 *and Technological Education* 25 (3): 293 – 306  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Subject specialism	Biology		Chemistry		Physics		Totals	
No. of trainees	39 (55)		24 (34)		8 (11)		71 (100%)	
Gender	Male	Female	Male	Female	Male	Female	Male	Female
	12	27	10	14	6	2	28 (39)	43 (61)
<b>Age</b>								
21-25	8	21	3	4	4	1	41 (58)	
26-30	2	2	4	5	1	0	14 (20)	
31-35	1	2	2	3	0	0	8 (11)	
36+	1	2	1	2	1	1	8 (11)	
<b>Degree class</b>								
1st	3	2	1	4	2	0	12 (17)	
2:1	5	14	1	4	2	0	26 (37)	
2:2	3	8	4	4	1	1	21 (29)	
3rd	0	0	2	0	0	0	2 (3)	
Not stated /other	1	3	2	2	1	1	10 (14)	
Higher degrees	5	4	4	6	0	1	20 (28)	

(Figures in parentheses are percentages throughout)

**Table 1: Science trainees' backgrounds: gender, age and degree classification against subject specialism**

	Ranked 1 or 2	3 or 4	5 or 6	7 or 8	9 or 10	Total
Making notes	29 (41%)	13 (18)	7	6	6	61
School colleagues	24 (34)	19 (27)	13 (18)	3	2	61
Other trainees	9 (14)	20 (27)	14 (20)	9	9	61
Internet	16 (23)	23 (32)	10 (14)	9	3	61
Science Education Research	1	1	5	15 (21)	39 (55)	61
Misconceptions Materials	1	6	14 (20)	18 (25)	22 (31)	61
Textbooks	30 (42)	16 (23)	9	5	1	61
Exam papers, etc	4	12 (17)	18 (25)	16 (23)	11	61
HEI sessions	5	7	20 (17)	23 (32)	6	61
University notes	3	5	13 (18)	17	23 (32)	61

Figures in parentheses are percentages

**Table 2: Science trainees' ranking of ten subject matter knowledge sources from a pre-prepared list**

SMK source	Within specialism teaching	Outside specialism teaching
School colleague or other trainee teacher	7	33
Textbooks, school resource packs, teacher materials	19	38
Internet	19	18
Formal documentation such as Exam papers, National Curriculum document, School Schemes of Work	10	12
Prior knowledge from University degree or job	14	0
Information from an HEI-based session	2	2
Other source, e.g. revision guide, safety guide, practising experiments, prior knowledge check, note-making	8	15
Misconceptions information	4	5
Trainees stating "no sources used"	3	0

**Table 3: Summary of trainee science teachers' subject matter knowledge sources for within and outside specialism teaching**

Statement Pair	Likert scale response Statement	Strongly agree	Slightly agree	Neutral	Slightly disagree	Disagree /strongly disagree	NR	Total
Preference	I prefer to teach topics in my specialism	22 (31%)	18 (25)	15 (21)	5	11	0	71
	I am pleased to teach topics in all areas of science	41 (58)	18 (25)	9	3	0	0	71
Confidence	I don't need to teach my specialism to feel confident	34 (48)	13 (18)	15 (21)	1	7	1	71
	I am less confident teaching outside my specialism	15 (21)	23 (32)	16 (23)	12 (17)	5	0	71
Questions	I am nervous of being asked a question I can't answer	17 (24)	15 (21)	9	14 (20)	16 (23)	0	71
	I can handle difficult questions in non-specialist areas	25 (35)	25 (35)	13 (18)	14 (20)	4	0	71
SMK attitudes	I find it difficult to develop my subject knowledge outside my specialist area	2	3	10	15 (21)	41 (58)	0	71
	I enjoy learning new subject knowledge outside my specialist area	46 (65)	13 (18)	11	1	0	0	71

NR = No response

**Table 4: Trainees' responses to Likert scale statements about preferences, confidence, handling questions and attitudes towards learning new SMK**

## Appendix 1: Questionnaire

### Developing trainee science teachers' subject knowledge

#### Background information

Name \_\_\_\_\_ Gender \_\_\_\_\_ Age \_\_\_\_\_

1<sup>st</sup> degree subject and class \_\_\_\_\_

Higher degrees \_\_\_\_\_ Subject specialism on PGCE \_\_\_\_\_

1. Please complete the table showing science topics you have taught so far.

In your specialist area	Key stage	In areas outside your specialism	Key stage
[Space provided for lists]			

2. From the specialist list, choose one topic you found especially “easy” to teach (i.e. you felt confident you could teach it well). Describe what you did to prepare the subject knowledge required.

3. From the non-specialist list, choose the topic you found hardest to teach (i.e. you felt the most unconfident you could teach it well). Describe what you did to prepare the subject knowledge required.

4. Compare your answers to 2 and 3. Explain the background to any differences and, if you did exactly the same, why you used the same strategies.

5. Here is a list of strategies that trainee science teachers may use for developing subject knowledge. Rank the items in order from **1(Highest)** – **10 (lowest)** according to how useful you think these are. *Please number each item separately; don't rank two with the same number.*

Strategy	Ranking from 1-10
Making notes from textbooks	
Asking colleagues at school	
Asking other trainees	
Searching the internet	
Reading science education research	
Reading misconceptions literature	
Reading textbooks	
Trying exam papers / questions	
Using information from University sessions	
Using university notes from your degree course	

6. Here are some statements about subject knowledge and teacher confidence. Select the alternative in each case that corresponds most closely to your opinion as it stands based on your teaching experience so far.

	1 - strongly agree	2	3	4	5 strongly disagree
I prefer to teach topics in my specialist area.	1	2	3	4	5
I like to feel confident in my subject knowledge when teaching.	1	2	3	4	5
I am nervous that I will be asked a question I cannot answer.	1	2	3	4	5
I am less confident when I teach outside my specialist area.	1	2	3	4	5
I can handle the situation if I am asked difficult questions outside my specialist area.	1	2	3	4	5
I am pleased to teach topics in all areas of science.	1	2	3	4	5
I find it difficult to develop my subject knowledge outside my specialist area.	1	2	3	4	5
I do not need to teach my specialism to feel confident as a teacher.	1	2	3	4	5

Please indicate here if you would be prepared to take part in a (short) recorded discussion about the issues being explored in this study.

Thank you very much indeed for your help.

## Appendix 2: Interview questions

Please confirm the topics you taught at KS3 and KS4 on both your teaching practices.

How did you prepare the subject knowledge you needed for teaching?

Did you use the same strategies for preparing subject knowledge for teaching topics within and outside specialism?

Were you aware of differences in learning outcomes for the children when you taught within and outside specialism topics?

How did the quality of your lesson preparation affect the achievement of learning objectives?

Have your strategies for preparation changed during the PGCE course?

Trainees were also asked to bring lesson plans, teaching materials and evaluations of their teaching for within and outside specialism lessons that they felt best represented their work. Discussion about these followed the interview questions.

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For Peer Review Only

## Introduction

### Background and context

The means by which teacher education systems ensure that secondary science teachers are well-prepared and appropriately trained for their work in science classrooms is a significant topic of international debate (Abell, 2000, 2007). One issue is how best to equip trainee science teachers with the scientific SMK required for teaching, given evidence that possession of “good” SMK influences teacher effectiveness positively (Abell, 2007, Geddis, et al, 1993; Lederman et al, 1994). This paper contributes to the discussion by offering perspectives from pre-service science teachers’ (“trainees”) experiences of training on an intensive, full-time course taking place over an extended academic year. Specifically, this paper explores the extent to which trainees’ subject matter knowledge (SMK) in science influences their self-confidence for teaching: trainees are graduates in specific science disciplines, such as biology, chemistry, physics, astronomy, geology and others, but are required to teach all sciences to 11-14s while training and, often, while working in UK state-funded secondary schools. An investigation of sources employed by trainee science teachers to develop their SMK for teaching is reported, together with the potential impact SMK may have on confidence in relation to their classroom practice. The study thus contributes to discussion of the role SMK plays in teacher development.

The work also contributes to the ongoing debate as to whether science should be split into its internal disciplines for teaching purposes. By way of illustration, discussion is ongoing in the UK, for example, as to whether or not physics should be taught by specialist physicists, chemistry by chemists and biology by biologists. For example, a lobbying group, the Campaign for Science and Engineering in the UK (CaSE) argues:

“Children need to be taught by specialist [science] teachers. Teachers’ qualifications predict teaching quality and are the second greatest predictor of performance in physics after pupil ability” (CaSE Opinion Forum, May 2007)

Similarly, the Royal Society of Chemistry (RSC), a professional organisation representing chemists internationally, states:

“The best teachers are those who have specialist subject knowledge and a real passion and enthusiasm for the subject they teach.... The RSC believes that young people deserve to be taught the sciences by subject specialists” (Royal Society of Chemistry, 2004)

These views are set against a factual background showing considerable imbalance in the proportions of science teachers with physics, chemistry and biology degrees. A 2006 UK Government report showed that 25% of UK science teachers (in a sample of 2756) hold degrees in biology or biology-related subjects, compared to 16% with chemistry degrees and 10% with physics degrees. Of the remainder, 47% hold degrees in other science subjects or possess teaching qualifications in general science, while 2% have no science degree (Moor, Jones, Johnson, Martin, Cowell and Bojke, 2006). Social status also plays a part: in schools with higher than average examination results and lower than average numbers of children receiving free

1  
2  
3 school meals (a standard indicator of high social need) more science teachers held specialist  
4 degrees in physics, chemistry and biology (Moor et al, 2006).  
5  
6

7 Hence, establishing factors shaping how trainee science teachers teach within and outside their  
8 specialist subjects would contribute to enhancing science teacher education.  
9

10 The study is situated in the Shulman paradigm in which subject matter knowledge (SMK) is  
11 perceived as separate from but essential to teachers' pedagogical content knowledge (PCK).  
12 Shulman (1986a, b) proposed that teachers "transform" SMK for their students using PCK, a  
13 powerful model that has been re-interpreted widely (for example, Marks, 1990; Magnusson et al,  
14 1999; Carlsen, 1999).  
15  
16

17 This paper takes the view that in describing a lesson as "successful", the teacher's ability to  
18 transform SMK is significant. Evidence presented below shows that trainee science teachers'  
19 perceptions of their teaching as "successful" varies: some appear to consider a lesson as a  
20 "success" when they transmit knowledge, expressing confidence in the sense of personal  
21 survival when they understand the SMK for a specific lesson and can answer subject-related  
22 questions. Others take a "transforming" approach, perceiving "success" as finding good activities  
23 that help children learn, placing personal mastery of SMK as a secondary concern. Trainees'  
24 development of SMK for personal "survival" or "transformation" may vary according to whether  
25 teaching takes place within and outside subject specialism. Given the accepted wisdom that  
26 science teachers teach their specialisms most successfully, a reasonable hypothesis is that  
27 within specialism lessons would generate fewer trainees relying on "survival" and more  
28 "transformation". Data are presented that contradict this, suggesting that in the initial stages at  
29 least, some trainees were more confident and taught more successful lessons when teaching  
30 outside their specialist subjects.  
31  
32  
33  
34  
35

### 36 ***The English and Welsh initial teacher education context***

37  
38 The study took place in a University in northern England, using trainees attending an initial  
39 teacher education (ITE) course, the "Postgraduate Certificate in Education" (PGCE). Obtaining a  
40 PGCE constitutes the major route into secondary school teaching. The PGCE is an intensive  
41 programme requiring nine months of full-time study from September – June. The course  
42 combines school-based practice (24 weeks) and Higher Education Institution (HEI)-based work  
43 (12 weeks). All participants are graduates with a Bachelor's degree in a subject linked closely to  
44 a National Curriculum (DfES, 2004) subject. In science, trainees' degree subjects dictate their  
45 teaching subject specialisms of chemistry, physics, or biology. A majority of trainees have  
46 backgrounds in biology or biology-related subjects, and little or no post-16 education in either  
47 physics and/or chemistry. Trainees' minimum age is 21, so at least five years and for many, ten  
48 years have passed since these sciences were studied.  
49  
50  
51  
52

53 The National Curriculum for science stipulates the content of 11-16 science courses taught in  
54 state-funded secondary schools. Pupils' learning is measured by tests taken at age 14 and 16.  
55 Hence, teaching divides into topics for 11-14s (Key Stage 3) and 14-16s (Key Stage 4). To  
56 deliver the curriculum, school science teachers write "Schemes of Work" (SoWs), giving precise  
57  
58  
59  
60

1  
2  
3 details of lessons, often based on published materials and textbooks. Teachers are expected to  
4 teach all aspects of science to 11-14s and, frequently, 14-16s regardless of their subject  
5 “specialism”; hence, this is also expected of trainees. During the school-based practice, trainees  
6 teach 11-16s and, exceptionally, 16-18s in two different schools located within 50 miles (80 km)  
7 of the university. Trainees are often expected to follow schools’ defined schemes of work, but  
8 may have freedom to develop their own lessons or parts of lessons. Trainees participated in  
9 forty-five hours of HEI-based sessions to develop their SMK for teaching specific science topics  
10 at Key Stage 3 and Key Stage 4. Topics included electricity, forces, chemical reactions, energy,  
11 waves, ecosystems, the genome, Earth and space, substances and investigations. Materials for  
12 use when teaching were provided with details of experiments and potential misconceptions.  
13 Trainees were introduced to science education research through these sessions and also by  
14 preparing a written assignment.  
15  
16  
17

## 18 **Literature review**

### 19 ***The role of SMK***

20  
21 The notion that possession of good SMK is an essential component of effective teaching has  
22 been demonstrated in a number of research studies, including those by Shulman (1986b, 1987)  
23 and those reviewed by Abell (2007) and Gess-Newsome (1999). A useful summary of the  
24 position and value ascribed to SMK in teaching is provided by Carré (1998):-  
25  
26  
27

28  
29 “The more you know about science, the more you will be able to provide a framework to help  
30 children think in scientific ways; in so doing you will also represent the subject with integrity” (p  
31 103)  
32  
33

34 Hashweh’s (1987) work with six experienced science teachers offers evidence for this. He found  
35 that “knowledgeable” teachers had more detailed knowledge of the topic being taught,  
36 demonstrated wider knowledge of the same subject, and were more readily able to relate a topic  
37 to other aspects of the subject. More specifically, Hashweh reported that possessing good SMK  
38 positively affected a range of aspects considered essential to good science teaching. These  
39 included teachers’ abilities to transform material for delivery in lessons by planning novel  
40 activities and their responses to critical incidents in the classroom. Knowledgeable teachers  
41 posed higher cognitive level questions while “unknowledgeable” teachers asked for recall and  
42 relied heavily on textbook information. Sanders, Borko and Lockard (1993) followed the teaching  
43 of three experienced secondary science teachers working within and outside specialism.  
44 Although general pedagogical practices were similar in both domains, when teaching within  
45 specialism teachers talked less, involved students more and selected “riskier” activities.  
46  
47  
48

49 An exploration of research relating to the precise role played by SMK in teacher development  
50 yields a varied picture. De Jong (2000) and van Driel et al (2002) provide evidence that good  
51 SMK helps trainees be more readily aware of students’ difficulties, a key aspect of Shulman’s  
52 model for PCK. In a highly specialised but extremely thorough study, Davis (2003) indicates that  
53 good SMK helps trainees select appropriate instructional strategies, also a feature of Shulman’s  
54 PCK model. Thirdly, Markic et al (2006) indicate that SMK contributes to teachers’ orientations  
55 towards teaching and beliefs about science. All these factors are likely to vary according to  
56  
57  
58  
59  
60

1  
2  
3 whether trainees are working within and outside their subject specialisms – for example, a  
4 physics specialist teaching biology topics may find it more difficult to select appropriate  
5 instructional strategies and be less aware of students' difficulties than a biologist teaching the  
6 same topic. As an indication of the possible effects of outside specialism teaching, Carlsen's  
7 (1993) study of four trainee biology teachers found that when teaching an unfamiliar topic,  
8 participants tended to talk more often, for longer periods of time, asked questions frequently and  
9 relied heavily on low cognitive level questions.  
10  
11

12 Misconceptions about science concepts are a significant concern for science education  
13 researchers. In terms of educating science teachers, learning outcomes related to  
14 misconceptions achieved by trainees may differ, depending on whether a lesson is being taught  
15 within or outside specialism. A biology lesson taught by a physicist may be less satisfactory than  
16 the same lesson taught by a biology specialist, as the physics trainee may have similar  
17 misconceptions to the children being taught. Sanders (1993) explored the views of South African  
18 biology teachers about respiration, finding that many seemed to hold misconceptions about  
19 basic principles within this topic. However, the study did not distinguish between specialist and  
20 non-specialist biology teachers.  
21  
22  
23

24 Besides these specifically SMK related issues, other research evidence indicates that  
25 specialised support helps trainee science teachers develop positively (Luft et al, 2003). In the  
26 present system, each trainee teacher is provided with an experienced science teacher as a  
27 "mentor" to assist them on teaching practice, as well as a university tutor. Mentors help trainees  
28 gain access to additional support within school science departments and hold regular (usually  
29 weekly) one-to-one meetings with trainees. Despite mentors' and tutors' good intentions, Youens  
30 and McCarthy (2007) found that trainees tend not to use mentors and university tutors as  
31 sources for SMK development, due to awareness of their roles in assessing progress. Trainees  
32 think that asking for help may imply they are failing. This perception may impact on trainees'  
33 preparation for and subsequent success in within and outside specialism teaching.  
34  
35  
36

### 37 ***Science teachers' perceptions of success, self- confidence and self-efficacy***

38  
39 The influence of specialized support on teachers' confidence or "efficacy" has been investigated  
40 by Hoy and Spero (2005), who showed that positive effects are seen where this is effective.  
41 However, Youens and McCarthy's (2007) work shows that these may be negated in situations  
42 where a dual role is perceived –mentors and university tutors are involved in reporting on  
43 trainees' progress, controlling whether they "pass" or "fail", as well as providing support. As  
44 mentioned above, the assessment role appears to dominate, as trainees forgo asking for  
45 support, in case this indicates weakness on their part. In which case, it would be valuable to  
46 know what sources of SMK are used by trainee teachers and why these are selected, given that  
47 obvious collegial support is, at least by some, cast aside. Further, any differences between SMK  
48 sources for within and outside specialism teaching may exist and these may impinge on  
49 trainees' success in teaching and perceptions of success.  
50  
51  
52  
53

54 The role of support and teacher self-confidence emerged as factors influencing success in  
55 teaching science among nine novice primary school teachers studied by Appleton and Kindt  
56 (1999). This study makes an interesting and significant connection between weak subject matter  
57  
58  
59  
60

1  
2  
3 knowledge and self-confidence, reporting that teachers lacked confidence to teach science and  
4 that this seemed to be associated with limited background knowledge (p 160). Teachers' self-  
5 confidence was negatively affected by believing that they had to be competent to answer  
6 children's subject-related questions. In contrast to Youens and McCarthy's (2007) findings, once  
7 beyond the bounds of a training experience, the teachers in this study found collegial support  
8 valuable, providing, for example, the confidence to try new activities and teaching strategies and  
9 support for planning science teaching.  
10  
11

12 Borko, Lalik and Tomchin (1987) examined trainees' conceptions of "successful" teaching,  
13 comparing journal writings of "stronger" and "weaker" novice teachers. They found that although  
14 trainees generally agreed about what constitutes "successful" teaching, differences were  
15 observed regarding "unsuccessful" teaching. By "successful", trainees indicated they meant  
16 using creative and novel activities, generating a variety of experiences for their students.  
17 Preparation of lessons with these characteristics involved going beyond the prescribed  
18 curriculum and associated tasks. Trainees emphasized trying out new ideas, maintaining pace  
19 and handling behaviour issues effectively. When describing "unsuccessful" lessons, weaker  
20 trainees focused more on behaviour issues and planning, while stronger trainees focused on a  
21 lack of creativity on their part.  
22  
23  
24  
25

26 Teachers' beliefs about the potential influence of specific environmental factors on their science  
27 teaching were investigated by Lumpe, Haney and Czerniak (2000). These authors developed a  
28 "Context Beliefs About Teaching Science" (CBATS) instrument designed to assess the extent to  
29 which teachers beliefs about aspects of their work were positive or negative. They report that  
30 more positive beliefs emerge among more experienced teachers, describing a majority as  
31 holding "robust, modest and tenacious" belief patterns (p 285). These sustain teachers when  
32 working in frustrating circumstances, providing a structure that helps them function effectively in  
33 the classroom. A minority were found to be "vulnerable, fragile and self-doubting". The authors  
34 comment that teaching may select against such weak profiles, and teachers possessing these  
35 belief systems may leave the profession at an early stage.  
36  
37  
38

39 Given these previous studies, the possibility exists that trainees experience different levels of  
40 confidence for teaching within and outside specialism, as well as using different sources to  
41 develop their SMK.  
42

### 43 **Hypothesis and research questions**

44 Hence, this study investigates:

- 45 • What sources do trainee science teachers use for developing their subject matter  
46 knowledge for within and outside specialism teaching while on a ten month postgraduate  
47 teacher education course?
- 48 • To what extent is the confidence of trainee science teachers influenced by teaching within  
49 and outside their specialist subjects?  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

## Methodology

The design of the study follows the tradition of interpretative and descriptive qualitative work (Merriam, 2002), although data were collected using both interviews and questionnaires. These methods gave the best overview of trainees' experiences, providing an insight into the widest possible range of opinions and views within this context. The interviews were designed to validate questionnaire responses.

Data were analysed to characterise trainees' attitudes and confidence relating to SMK for within and outside specialism teaching. Categories emerged from the data – a combination of responses to open questions and Likert scale statements together with interview responses revealed specific characteristics. These are discussed in detail below.

### *The questionnaire*

The questionnaire, devised for this study (Appendix 1) comprised three probe types:-

- Open questions (numbers 2 and 3) probed trainees' sources of SMK for preparing science topics for teaching within and outside their specialist subjects
- A closed question (number 4) invited trainees to rank preferred sources of subject knowledge from a pre-prepared list
- Four sets of paired statements explored trainees' thinking about SMK and teacher confidence using a five-point Likert scale. The pairs were named "Attitude" (A), "Preference" (P), "Confidence" (C) and "Handling questions" (H). For reference purposes, these letters are shown against the statements in the questionnaire (Appendix 1).

The components of the questionnaire were validated by discussion with colleagues.

In addition, background information such as trainees' education, age and gender were collected.

### *The interviews*

Individual interviews of approximately 30 minutes each were conducted using a semi-structured protocol. The interviews collected data relating to the topics trainees had taught; sources used to develop SMK needed for teaching within and outside specialism; trainees' awareness of the impact of their preparation on achievement of intended learning outcomes; and the extent to which their modes of subject matter knowledge acquisition and lesson preparation changed during the PGCE course.

Questionnaires were administered in April 2006 and April 2007 after completion of all HEI-based sessions and towards the end of the main teaching placement. Interviews were conducted in June 2006 and June 2007 when all parts of the course had been completed.

### *The sample*

1  
2  
3 A total of 71 trainees completed the questionnaire. These comprised twenty-eight respondents  
4 from the 2005 – 2006 cohort and forty-three from 2006 – 2007. Maxima of forty (2005- 2006)  
5 and fifty-two (2006-2007) were possible – absences and fall-out from the course on the day of  
6 data collection account for discrepancies. For reporting purposes, all respondents are treated as  
7 one group – this is reasonable given that both cohorts had as identical experiences as possible.  
8  
9

10 Twelve trainees were interviewed, divided 5:7 between the 2005- 2006 and 2006 – 2007  
11 cohorts. The trainees were volunteers, but care was taken to ensure participants were as far as  
12 possible representative of all respondents in terms of subject specialism, age and gender.  
13  
14

### 15 **Data analysis**

16  
17 Each questionnaire was given a code number. The same codes were used to identify  
18 interviewees to check for triangulation of responses between interview and questionnaire data.  
19  
20

### 21 **Background information**

22  
23 Trainees' background information was counted and used to generate the data in Table 1.  
24  
25

### 26 **Questionnaire**

27  
28 Questionnaire responses were edited to establish the extent of completion and examined for any  
29 inaccuracies. All 71 trainees responded to the open questions, the closed question and paired  
30 statements. Ten trainees mis-interpreted the ranking for the closed question (number 4 in  
31 Appendix 1) so their responses were excluded from the data (see Table 2, Total)  
32  
33

34 Open question responses (questions 2 and 3) were coded by the researcher. A coding frame  
35 was used to establish the range of responses offered. The same frame was applied to questions  
36 2 and 3 (see Appendix 1). Responses were grouped by:-  
37  
38

- 39 • Trainees' subject specialism (drawn from background information)
- 40 • Trainees' chosen topic
- 41 • Trainees' stated preparation strategy/ies
- 42 • Other information provided by the trainee
- 43
- 44

45 Responses from two trainees who gave only general comments relating to their school  
46 circumstances and no information about preparation strategies were excluded. Thus, Table 3  
47 presents data from 69 trainees.  
48  
49

50 The preparation strategies described were grouped into the categories shown in Table 3. Other  
51 information, most often about teaching, included phrases such as "tried to break down the  
52 information into key sentences".  
53  
54

55 For example, Question 2 required trainees to name topic they had taught within specialism and  
56 describe SMK preparation. Three biology specialists named "Microbes and Disease" as their  
57 topic. Two trainees cited "knowledge from degree" and one "knowledge from own University  
58  
59  
60

1  
2  
3 research". These three responses appear in Table 3 as "Prior knowledge from University  
4 degree or job".  
5

6  
7 Question 3 required trainees to name a topic they had taught outside specialism and describe  
8 SMK preparation. Two biology specialists and one physics specialist named "Chemical  
9 reactions". Their SMK strategies, with Table 3 "SMK source" in parentheses were: two cited  
10 teacher involvement (School colleague or other trainee teacher), two used the internet (Internet),  
11 two used school textbooks (Textbooks, school resource packs, teacher materials), one looked at  
12 an examination paper for the year group (Formal documentation), and two tried out experiments  
13 prior to the lessons (Other source).  
14

15  
16 Responses to the closed question, number 4 were counted and recorded against the suggested  
17 strategies. These data are presented in Table 2.  
18

19  
20 The paired statement analysis was done by counting systematically through all the responses,  
21 noting the code numbers and background information for each respondent for each pair. Scores  
22 1 and 2 were summarised as "Agree" while 4 and 5 became "Disagree". This generated a series  
23 of sub-groups for each response pair (see p 15 – 18). The background characteristics were  
24 examined and compared with the data for the whole cohort (Table 1). Where marked differences  
25 were observed, these were noted in the results.  
26

27  
28 For example, in response to the "Preferences" pair, 8 trainees responded "agree" (Likert score 2  
29 on the questionnaire) or "strongly agree" (1) to "I prefer to teach topics in my specialism" and  
30 were "neutral" (3) or disagreed (4, 5) with "I am pleased to teach topics in all areas of science".  
31 Analysis of the background information for this group showed that these respondents divided  
32 equally into male and female, had an average age of 29 and all except one held degrees at the  
33 standard of 2:2 or better. This sub-group expressed "specialist" views, but revealed no  
34 characteristics that were markedly different from the whole group. Hence, the existence of the  
35 group was noted (see p 14) but no further comments could be made.  
36  
37

38  
39 Analysis of the "Confidence" pair showed a sub-group of 14 trainees who disagreed with "I am  
40 less confident when I teach outside my specialism" (Likert score 4 or 5) and agreed with "I do not  
41 need to teach my specialism to feel confident as a teacher" (1 or 2). These trainees had two  
42 background characteristics that differed from those of the whole group. Six were aged 31 or  
43 over, comprising a significant proportion of the 16 trainees in this age group shown in Table 1.  
44 Two others were aged 28 and 29. Four trainees (28%) were aged 21 -25 compared to 58% of  
45 the whole cohort. Thus, the overall age profile of this sub-group is higher than that of the whole  
46 cohort. Ten of the fourteen, 71% were female (61% for the whole cohort). Seven held degrees in  
47 the two highest classifications "1<sup>st</sup>" and "2:1", a figure similar to that for the whole cohort.  
48 Consequently, comments to this effect are made in the results section (p 15).  
49  
50

## 51 Interviews

52  
53 Interviewees were volunteers who knew the researcher as a PGCE course tutor. To ensure  
54 comparability of responses, a standardised set of questions (LeCompte and Preissle, 1993) was  
55 prepared (Appendix 2). This was sent in advance to participants by email. No potential  
56  
57  
58  
59  
60

interviewee refused to attend having seen the questions. Interviewees were invited to bring documentation such as lesson plans and lesson evaluations for discussion. These were considered once responses to the standard questions were concluded.

Five questions triangulated responses to questionnaire questions (Q) and/or paired statements (P, followed by reference letter) as follows:-

Interview	Q1 supports questionnaire	Q1	
	Q2	Q4	
	Q3	Q2, 3	PA, PC
	Q4	Q2, 3	PP, PH
	Q5	PP, PH	

The purpose of question 6 was to illustrate the extent to which trainees' practice had altered during the PGCE course and to serve as a means of validation: two months had elapsed between collection of questionnaire and interview data. Indicative responses to this question are provided on p 23. Ten trainees referred only to their planning and preparation "speeding up" as the course proceeded, noting no other changes. Two trainees (see p 23) specifically said no changes had occurred.

Interviews lasted about 30 minutes each. Follow-up questions were posed in addition to the standard ones where necessary to illuminate or clarify answers or to draw out more information when a trainee seemed shy or reluctant. Hence the format could in practice be described as "semi-structured", as these varied according to the interviewee.

The recorded interviews were transferred to ATLAS for analysis. Pseudonyms were devised for each trainee at this stage. A transcript was prepared from each interview. After transcription trainees were matched against their questionnaires. Consistently excellent correspondence could be ascertained between interview and questionnaire responses. To illustrate this, two questionnaire response profiles are provided:-

***Matthew, aged 38, Male, Physicist, 1<sup>st</sup> class degree***

Questionnaire Q2 response:- Light – I used subject revision guides to establish what the content should be. My subject knowledge was already adequate

Questionnaire Q3 response:- Cells – I read revision guides and subject books.

Questionnaire Q4 response:- My strategies were the same apart from I researched in more depth the cells topic

Paired statement responses:-

Attitudes:	Agree with "I enjoy learning..."	Disagree with "I find it difficult..."
Preference:	Agree with "I prefer to teach..."	Disagree with "I am pleased to teach..."

Confidence: Agree with "I am less confident .." Disagree with "I do not need to teach..."  
 Handling questions: Agree with "I can handle.." Disagree with "I am nervous..."

Matthew's responses indicate he may be anxious about teaching outside specialism (see p 17).  
 His views about outside specialism teaching expressed at interview are stated on p 18.

### ***Simon, aged 28, Male, Chemistry, 2:2 degree with PhD***

Questionnaire Q2 response: Particles – Looked at textbook, school's scheme of work, resources from HEI-based session, internet

Questionnaire Q3 response: classification – Same as above (ie as Q2)

Questionnaire Q4 response: I used [the] same strategies because [I] drew on large area of resources and ideas. [I] prepared in the same way for topics I know about and topics I don't.

Paired statement responses:-

Attitudes:	Agree with "I enjoy learning..."	Disagree with "I find it difficult..."
Preference:	Disagree with "I prefer to teach..."	Agree with "I am pleased to teach..."
Confidence:	Disagree with "I am less confident .."	Agree with "I do not need to teach..."
Handling questions:	Agree with "I can handle.."	Disagree with "I am nervous..."

Simon's responses indicate he is confident teaching all aspects of science (see p 17). His views about teaching outside specialism are on p 20.

## **Results**

### **Trainees' backgrounds**

[Insert Table 1 about here]

Table 1 provides information about the gender distribution, degree class<sup>1</sup>, age and science subject specialism of the respondents.

The samples were representative of the full cohorts, being skewed approximately 60:40 towards females. Most trainees were born in North East England and Scotland. Four trainees born

---

<sup>1</sup> Degree class is divided into four categories of "Honours": the highest achieving students, usually around 10% of a cohort, are awarded "First" (1<sup>st</sup>) class degrees. These students normally score around 70 – 75% in their final examinations. About 40% are placed in the next category, "Upper Second" (2:1) class. About 30% gain "Lower Second" (2:2) class degrees. About 20% are awarded "Third" class honours. Those whose work is deemed not of Honours standard may be awarded "Ordinary" or "Pass" degrees.

1  
2  
3 outside the UK were classified formally as “ethnic minority” trainees. Eight participants who  
4 completed the questionnaire did not complete the successfully for different reasons.  
5  
6

7 Degree subject is the key indicator used to decide trainees’ science specialism as physics,  
8 chemistry or biology. Trainees’ degree subjects are broad-ranging: data indicate that about 65%  
9 of respondents were “biology specialists”, holding degrees in biology (16%) or “biology-related”  
10 subjects (49%). The latter included graduates in genetics, ecology, biomedical sciences, aquatic  
11 / marine bioscience and physiology. Nine (12%) trainees held degrees in chemistry, while a  
12 further eight (11%) were classified as “chemistry-related”; this group included biochemists,  
13 geologists, environmental chemists and pharmacologists. Eight trainees held degrees physics  
14 or physics-related subjects, such as astronomy, mechanical engineering and optometry.  
15  
16

17 Degree class is widely respected as an indicator of the quality of trainees’ science specialist  
18 knowledge. These trainees are regarded as “academically well-qualified”: Table 1 shows that  
19 about 54% held Upper Second (2:1) or First Class (1<sup>st</sup>) honours degrees, these being the two  
20 highest degree classifications possible, while a further twenty-one held Lower Second (2:2) class  
21 degrees. Thus, overall around 83% of respondents held “good” degrees. Nineteen also held  
22 Masters or Doctorate qualifications in science. One held a Masters degree in Law. Possession of  
23 a “good” degree means that a trainee would respond correctly to GCSE (General Certificate of  
24 Secondary Education: the Key Stage 4 examination taken at age 16) questions in their  
25 specialism.  
26  
27  
28

29 Trainees’ average age was 27. Around 58% were aged 21 – 25. For this sub-group, teaching is  
30 their first career choice. The remainder comprise those changing career, such as post-doctoral  
31 scientists, science graduates who have worked in non-science fields and parents returning to  
32 work.  
33  
34

### 35 **Preferred sources of SMK for teaching**

36  
37 [Insert Table 2 about here]  
38  
39

40 In responding to the questionnaire, trainees ranked a pre-prepared list of possible SMK sources  
41 from 1 (most preferred) to 10 (least preferred). These data indicate strong preference for school-  
42 based or school-oriented material, reliance on note-taking and reading. HEI-based teaching  
43 sessions, misconceptions and science education research literature received low rankings. Ten  
44 trainees did not provide sufficient information to be included.  
45  
46

### 47 **SMK sources for teaching within and outside specialism**

48  
49 Open questions prompted trainees to choose one topic each from within and outside their  
50 specialisms that they had taught and describe sources used to prepare the SMK required. Table  
51 3 summarises the SMK sources trainees cited in their responses. The figures represent the  
52 numbers of trainees citing each source. Most trainees cited more than one.  
53  
54

55 [INSERT TABLE 3 ABOUT HERE]  
56  
57  
58  
59  
60

### ***Within specialism teaching SMK preparation***

Table 3 indicates four main sources of SMK - the internet, textbooks, prior knowledge and formal documentation – were used for within specialism teaching preparation. Comments emphasised trainees' sense of "already knowing" the topic, implying little work was needed, for example:-

"I knew it and only had to skip through the Key Stage 3 revision book, ie. 5 mins"  
(Chemist)

"Forces – looked at QCA<sup>2</sup>, school and exploring science SoWs and tests to come up with learning objectives and teaching scheme... otherwise did not need to think about own subject knowledge" (Physicist)

Three trainees explicitly stated they consulted no additional SMK sources, relying entirely on prior knowledge.

The 19 trainees citing "textbooks" regarded these as low level material, of whom six described this choice as "background reading", or "refreshing knowledge", for example:-

"Cells. Background reading which brought back what I already knew ... I already felt quite confident with the topic" (Biologist)

Five used revision guides (classified as "other) to check the level of knowledge required by their students, for example:-

"Light – I used subject revision guides to establish what the content should be. My subject knowledge was already adequate" (Physicist)

Five trainees believed they had the necessary subject knowledge, but wanted to find good resources or explanations to use in teaching, for example:-

"Acids and alkalis – [I] looked at how to describe ideas using simple vocabulary"  
(Chemist)

"Variation – I.. researched for novel activities...." (Biologist)

These trainees seem aware of transforming SMK to pedagogical content knowledge (PCK).

Table 3 indicates that few trainees prepared for within specialism teaching by seeking colleagues' advice, consulting misconceptions or science education research literature or testing out practical experiments prior to lessons.

### ***Outside specialism SMK preparation***

Table 3 shows that a more intense pattern of SMK sources emerges for outside specialism preparation. School colleagues and textbooks were consulted by about half of respondents. The

<sup>2</sup> The QCA is the Qualifications and Curriculum Authority, the organisation responsible for setting examination standards. The QCA has produced a scheme of work for teaching KS3 used by some schools. [www.qca.org.uk](http://www.qca.org.uk)

internet and formal documentation were also popular. The range of sources reflects trainees' awareness of SMK weaknesses and perceived need for more detailed preparation, for example:-

“Electromagnetic spectrum – [I] read around the subject and to a higher level than I was required to teach. [I] prepared an extensive lesson plan with difficult concepts fully written out” (Biologist)

The role of school colleagues in helping trainees prepare for outside specialism teaching is apparent, for example:-

“Environments – had long conversations with other teachers...” (Physicist)

“Radiation – [I] spoke to the physics teacher (he knows everything)” (Biologist)

“Gravity and Space - ....Teachers at school and technicians were very helpful” (Chemist)

Trainees using textbooks did so to learn the information necessary, rather than to check the level of understanding required, for example:-

“Paints and pigments – [I] read over student textbook then looked in A level book to improve higher knowledge then researched on internet” (Biologist)

The increase in “Other” sources for outside specialism SMK arises from trainees stating that they practiced experiments before lessons, or asked for help in setting up equipment.

### ***Comparing SMK sources for within and outside specialism teaching***

Table 3 shows that about 50% of trainees actively seek colleagues' advice in preparing outside specialism lessons. SMK preparation for within specialism teaching is characterised by trainees relying heavily on prior knowledge and not seeking advice or testing experiments prior to teaching.

About two-thirds of trainees expressed clear differences in their approaches to within and outside lesson preparation, for example:-

“My biology topics are fairly clear in my mind and so I do not need to look at basic knowledge ... with Chemistry I am not sure of my basic knowledge and must look at the topic as though I am teaching myself.” (Biologist)

“I needed to make sure I was prepared for any additional questions students may ask” (Biologist)

About ten trainees indicated that outside specialist subject lessons were sometimes “easier”, for example:-

“Non-specialism takes longer [to prepare] but is sometimes easier to teach as you don't have the same extent of knowledge” (Biologist)

1  
2  
3  
4 This response, found also at interview (see below, p 16) suggests that possession of too  
5 much subject matter knowledge could be problematic. Outside specialism teaching meant  
6 that trainees taught what they learned, resulting in more clearly focused lessons than those  
7 taught within specialism.  
8

9  
10 Other emerging issues relating to outside specialism teaching included one trainee who  
11 sought to avoid misconceptions:-  
12

13  
14 [Outside specialism] – emphasis on accuracy and avoidance of misconception  
15 perpetration” (Biologist)  
16

17 and this trainee who explicitly stated she prepared to enhance her confidence:-  
18

19  
20 “[I did] far more preparation for the physics topic to feel more secure and confident”  
21 (Biologist)  
22

23 Two trainees stated specifically they used the same preparation method throughout, for  
24 example:-  
25

26  
27 “I used similar strategies as I find them most effective to refresh my knowledge and  
28 ensure my understanding” (Biologist).  
29

### 30 **The extent to which trainees’ confidence for teaching relies on subject matter knowledge**

31  
32 [Insert Table 4 about here]  
33  
34

35 Trainees’ responses to eight statements scored using a five-point Likert scale are summarised in  
36 table 4. The statements were paired to permit exploration for consistencies in response patterns:  
37 one pair each investigates trainees’ **preference** for teaching within and outside specialism; their  
38 **confidence** for teaching; the extent to which trainees believe they can handle students’  
39 **questions**; and trainees’ **attitudes** towards SMK.  
40  
41

42 Detailed data relating to combinations of responses are presented below. For this purpose, the  
43 scale has been summarised to three points by adding “strongly agree” to “agree” and “strongly  
44 disagree” to “disagree”, with neutral in the centre. The words “agree” and “disagree” are used  
45 to express extremes. All 71 trainees responded to all statements.  
46  
47

#### 48 ***Preferences for within and outside specialism teaching***

49 Two statements, “I prefer to teach topics in my specialism” (abbreviated to “prefer specialism”)  
50 and “I am pleased to teach topics in all areas of science” (abbreviated to “all science”) assessed  
51 trainees’ preferences. A trainee preferring in-specialism teaching may respond positively  
52 (strongly agree/ agree) to the first statement and negatively (disagree/ strongly disagree) to the  
53 second; vice versa for a trainee preferring to teach all sciences.  
54  
55  
56  
57  
58  
59  
60

Table 4 shows that around 56% (total of “strongly agree” and “agree”) of respondents prefer to teach their specialism, while over 80% (total of “strongly agree” and “agree”) say they do not mind teaching all aspects of science. However, these data mask underlying response patterns. These are analysed next. Four clear patterns emerge:-

- 32 (45%) Trainees agreed with both statements
- 15 (21%) Trainees disagreed with “prefer specialism” and agreed with “all science”
- 12 (17%) Trainees were neutral to “prefer specialism” and agreed with “all science”
- 8 (11%) Trainees agreed with “prefer specialism” and disagreed or were neutral to “all science”

Four trainees’ responses did not fit these categories.

Trainees agreeing with both statements are not necessarily inconsistent – they may be saying that although they prefer to teach within specialism, they are also pleased to teach all topics. They can work on SMK and may enjoy this. Around 21% claim preference for teaching all science topics. This group could be described as “generalist” in outlook. The twelve trainees neutral to the “I prefer to teach...” statement could also be “generalist”, although they express their preference less strongly. Finally, a small sub-group of “specialists” exists; these trainees express strong preference for within specialism teaching.

### ***Confidence for teaching***

The statement pair exploring trainees’ confidence for teaching was “I am less confident teaching outside my specialism” (“less confident outside”) and “I do not need to teach my specialism to feel confident as a teacher” (“don’t need specialism”). A trainee with good self-confidence may respond negatively to the first statement (strongly disagree or disagree) and positively to the second. A more anxious trainee may state the reverse.

Table 4 shows that 53% respond “strongly agree/ agree” to “less confident outside”, while twelve disagree. This significant minority express confidence in their ability to teach outside specialism. However, in a seemingly contradictory fashion, about two-thirds agree or strongly agree with “Don’t need specialism”, implying that they can teach anything. Closer inspection of underlying response combinations reveals these pairings:-

- 14 (21%) Trainees disagreed with “less confident outside” and agreed with or were neutral to “don’t need specialism”
- 9 (12%) Trainees were neutral to “less confident outside” and agreed with “don’t need specialism”
- 25 (35%) Trainees agreed with both statements
- 5 (7%) Trainees agreed with “less confident outside” and disagreed with “don’t need specialism”

1  
2  
3  
4 7 (10%) Trainees agreed with “less confident outside” and were neutral to “don’t need  
5 specialism”  
6

7  
8 Eleven trainees’ responses did not fit into these categories.  
9

10 The disagree / agree sub-group (14, 21%) could be labelled “super-confident”, as they state that  
11 outside specialism teaching does not affect their confidence. Examining these trainees’  
12 backgrounds shows that seven have degrees in the highest two classes (1<sup>st</sup> or 2:1) or hold a  
13 higher degree, while ten are female. The average age is 31: six are aged 31 or over. Tentatively,  
14 “super-confident” trainees could be academically well-qualified females older than the average  
15 age of the cohort.  
16  
17

18 Those agreeing with both statements (25, 35%) seem to offer contradictory statements. Without  
19 going back to every trainee, it is difficult to comment as to why this is the case. However,  
20 interview data suggests that despite feeling less confident or apprehensive about teaching  
21 outside their specialism, this can be handled by working on their SMK (see p 16, Views about  
22 teaching within specialism). Hence, trainees could respond positively to “I do not need to teach  
23 my specialism...”, while at the same time feeling less confident. This sub-group are tentatively  
24 labelled “working-confident”.  
25  
26  
27

28 Twelve trainees agreeing with “less confident outside” could be described as “anxious”. These  
29 split 50:50 by gender and degree class, with six possessing 1<sup>st</sup> or 2:1 degrees. The average age  
30 is 25, below that of the whole group, although four trainees were aged 30 or over. Reasons for  
31 trainees’ lack of confidence are unclear, but collectively their backgrounds differ from “super-  
32 confident” and “working-confident” trainees.  
33  
34

### 35 **Handling SMK-related questions**

36 Statements investigating trainees’ attitudes towards handling SMK-related questions were: “I can  
37 handle the situation if I am asked difficult questions outside my specialist area” (“I can handle”)  
38 and “I am nervous that I will be asked a question I cannot answer” (“I am nervous”). Anecdotally,  
39 handling subject-related questions causes anxiety among many science trainees, particularly in  
40 the early stages. A trainee able to cope with these may respond positively (strongly agree /  
41 agree) to the first statement and negatively (strongly disagree/ disagree) to the second. A more  
42 nervous trainee may respond oppositely.  
43  
44  
45

46 Table 4 shows thirty-two trainees felt nervous about being asked a question they could not  
47 answer (strongly agree /agree), while fifty agreed or strongly agreed with “I can handle”. Overall,  
48 a majority of respondents appear confident about difficult questions, perhaps accepting that  
49 nerves are to be expected. These underlying response combinations were found:-  
50  
51

52 34 (48%) Trainees agreed with “I can handle” and disagreed or were neutral to “I am  
53 nervous”

54 17 (24%) Trainees agreed with both statements

55 15 (22%) Trainees agreed with “I am nervous” and disagreed or were neutral to “I can  
56 handle”  
57  
58  
59  
60

Five trainees disagreed with “I am nervous”.

These figures suggest that about 48% express confidence in their ability to handle questions outside their specialist area and feel little or no nerves about being asked questions they cannot answer. About one-quarter (24%) seem to regard nerves as “part of the game”, responding positively to both statements. About 22% seem to have a more “anxious” disposition, admitting to feeling nervous and not being able to handle difficult questions. Background information shows sixteen of the thirty-four trainees (47%) feeling most confident at handling questions are male, skewing this sub-group away from the cohort’s 60:40 split. Twelve of the fifteen trainees (75%) feeling least confident were female, a skew in the opposite direction.

### **Attitudes to SMK**

The statements exploring trainees’ attitudes to SMK were “I find it difficult to develop my subject knowledge outside my specialist area” (“I find it difficult”) and “I enjoy learning new subject knowledge outside my specialist area” (“I enjoy learning”). A trainee with a positive attitude towards outside specialism teaching may respond negatively (strongly disagree / disagree) to the first statement and positively (strongly agree / agree) to the second. A trainee feeling uncomfortable learning new SMK may respond oppositely.

Table 4 shows highly polarised responses to these statements. About 79% strongly disagree / disagree with the first and 83% strongly agree / agree with the second. Although this is a strong indication that the majority of respondents have positive attitudes towards acquiring new SMK, examination of underlying response patterns shows that small sub-groups showing slight variations exist:-

50 (70%) Trainees agreed with “I enjoy learning” and disagreed with “I find it difficult”

10 (14%) Trainees were neutral to “I enjoy learning” and were neutral to or disagreed with “I find it difficult”

3 Trainees agreed with both statements

2 Trainees were neutral to “I enjoy learning” and agreed with “I find it difficult”

Six trainees’ responses did not fit into these categories.

Perhaps most interesting to note is the small number of trainees (3 + 2, last two categories) whose responses suggest they find learning new SMK is difficult: three were females aged over 30 and three held 2:2 degrees, while the remaining two held 2:1s. This sub-group are noticeable amongst the overwhelmingly positive responses.

### **Semi-structured interview data**

The twelve interviews indicated the impact perceived by trainees of SMK on their teaching, as well as validating responses found in the questionnaires. The interviewees were slightly more skewed towards males (6/12, 50%) and chemists / physicists (5/12, 42%) than the whole cohort. Interviews explored how trainees perceived their SMK and confidence as a teacher impacted on

1  
2  
3 students' learning. Trainees' voices are reported verbatim, although colloquial and dialectical  
4 expressions have been modified to ease comprehension. Names used are pseudonyms. All  
5 interviewees completed the PGCE course successfully but with differing teaching abilities. In  
6 reporting their viewpoints, reference is made to interviewees' Likert scale responses, hence  
7 references to "super-confident", "working-confident" and "anxious".  
8  
9

### 10 **Views about teaching outside specialism**

11 Three main viewpoints corresponding to questionnaire categories (p 12) were apparent.  
12 Matthew, an "anxious" trainee according to his confidence responses, said this about teaching  
13 outside specialism :-  
14  
15

16 "In physics when I felt the [children] weren't grasping it [the topic] I could tackle it  
17 from a different angle by thinking myself, 'How's the best way to put this across?'  
18 and going down a different route. That was very limited for me with biology ....I  
19 wouldn't have had the knowledge to do that. If it had happened, I would have had  
20 to extend into a different lesson, and gone away, thought about it and brought it  
21 back in another lesson." (Matthew, physicist)  
22  
23

24 Daniel and Mary reported differences in the ease with which they prepared for teaching in the  
25 two domains. Their confidence responses corresponded to the "working confident" category:-  
26  
27

28 "I felt I could prepare resources for my specialism much easier, and I was a lot less  
29 confident at trying new things, so for chemistry I stuck exactly to what the Scheme of  
30 Work gave me ... with biology [when I thought] "I don't agree with that", it was much  
31 easier to change things." (Mary, biologist)  
32  
33

34 "I was a lot less creative with biology and physics – that went down to confidence in  
35 the material... I went down traditional lines... I didn't tend to [experiment] unlike my  
36 chemistry where I liked to [be] more creative."  
37 ("Daniel", chemist)  
38  
39

40 These trainees connect their lack of confidence in their subject matter knowledge for an outside  
41 specialism topic to their ability to develop their own ideas for lessons. "Sticking to the scheme"  
42 enabled them to feel safe and secure.  
43  
44

45 Another approach to teaching outside specialism was expressed by George, a "working-  
46 confident" physicist:-  
47  
48

49 "I think I just don't do enough for biology...you're always looking at your notes  
50 checking you've spelt [words] right, whereas in physics you can go off at a tangent  
51 because you know you haven't got a problem explaining something..." (George,  
52 physicist)  
53

54 In contrast, Simon, a "super-confident", expressed confidence in his ability to teach outside  
55 specialism:-  
56  
57  
58  
59  
60

1  
2  
3 “...as long as I’d prepared I felt confident teaching the subject, I was quite  
4 comfortable, if you said I was teaching physics top set [most able children], I would  
5 go away... do my research and then I’d be pretty comfortable, you might always get  
6 a question where someone might pull you up, but then you just say to them I’ll have  
7 to go and look at that.” (Simon, chemist)  
8  
9

10 Thus, trainees perceived differences in confidence for within and outside specialism teaching,  
11 and articulated reasons for these that corresponded with their questionnaire responses.  
12

### 13 ***Views about teaching within specialism***

14 Eight interviewees thought that learning objectives were achieved more easily when teaching  
15 outside specialism. This is counter-intuitive to expectations, supporting questionnaire data  
16 reported above (p 10). Three trainees said that initially they knew “too much” and failed to select  
17 information effectively. Mary, for example, found a much lower knowledge level than expected  
18 was required:-  
19  
20

21  
22 “...at the start, [with my KS4 biology class] I didn’t think [the learning objectives]  
23 were all met. They were a “Gifted and Talented” [high ability] class....I was going  
24 quite quickly ... and I really enjoyed it. I don’t think they were keeping up with me  
25 as well as I thought they would do....Towards the end things were better and I  
26 would say yes, the learning objectives were being met. In chemistry I would say  
27 yes, they were met, because I was sticking so closely to the Scheme [of Work]”  
28 (Mary, biologist)  
29  
30

31 Matthew commented:-  
32  
33

34 “I feel that teaching outside specialism is better because to a certain extent I ‘m  
35 learning as the children are, so I can see [the topic] from their angle, and there is no  
36 confusion about what they need to know... With physics it's different ... there were  
37 times that I knew I was thinking [about] quite high level stuff and then dumbing it  
38 down to something they would understand, and that sometimes made my job a bit  
39 harder ...[I didn’t have] enough experience teaching low level things” (Matthew,  
40 physicist)  
41  
42

43 The feeling of having to condense specialist subject matter knowledge was expressed by John,  
44 whose comment contributes to this paper’s title:-  
45  
46

47 “[In chemistry and physics lessons] I could explain things at the level [they]  
48 should be explained at. For a biology concept you’ve got all this [knowledge] in  
49 your mind overriding what you’re telling them. [You know what you say is]  
50 almost a white lie, it should be in much more depth, or there are things that you  
51 know need to be accompanied with it [that are] not part of the curriculum, its not  
52 part of what they need to know. There is a conflict in your head” (John,  
53 biologist)  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 None of the interviewees whose early teaching was more successful outside specialism  
4 connected variation in success explicitly to strategies for preparation, although three noted  
5 differences in their strategies. John, for example, relied on his prior learning in school as  
6 preparation for within specialism teaching, whereas he more actively prepared for physics and  
7 chemistry lessons:-  
8  
9

10 I: How did you prepare the subject knowledge you needed?  
11

12 J: For biology I already had an idea of what I'd already done in school myself...  
13 I did think about what I'd learned and I did find it easier to remember the biology  
14 related lessons ... so planning biology lessons, I think I'd already thought about  
15 it before coming on the course...  
16  
17

18 With regard to chemistry and physics ...there was a lot more preparation,  
19 relearning things ...[for example] I haven't touched on any physics ... since  
20 GCSE. ...[so] there was a lot more preparation, I used colleagues in school,  
21 speaking to other physics teachers, and other people on the course, getting  
22 their advice...  
23  
24

25 I: So when you were preparing you were more aware of spending time on  
26 outside specialism?  
27  
28

29 J: Yes definitely... I took the [school] textbook ... home and look[ed] at that, but  
30 I tried to go above that, because children have questions, they want extra bits  
31 of information... If you only understand [a topic] to the level they need to learn  
32 it, you're never going to be able to teach it, so you need to learn it a couple of  
33 steps ahead so you can deal with those unexpected questions and understand  
34 it further than is expected for them"  
35  
36

37 In contrast, Simon, who reported no differences in lesson success, consciously used the same  
38 strategies to prepare lessons in both domains, explaining that achieving outcomes depended on  
39 finding good activities:-  
40  
41

42 "...In terms of the learning objectives they were all roughly similar... in terms of  
43 activities I would go out of my way to look in biology to find something a little bit  
44 better [than the school's Scheme of Work] so I'd go on the internet and find  
45 interactive games. In classification, I did find a few, so some of my lessons  
46 were better than in chemistry.... it just came down to the activities." (Simon,  
47 chemist)  
48  
49

50 Simon makes explicit that selection of appropriate instructional strategies is one factor that aids  
51 successful lessons. Trainees relying on prior knowledge alone experienced more difficulty in  
52 achieving successful lessons within specialism in the early stages of their teaching.  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 The need to select appropriate instructional strategies and over-reliance on inappropriate ones is  
4 illustrated by Jane, a chemist, who copied the style of chemistry teaching she experienced at  
5 school:-  
6

7  
8 "A lot of the chemistry I learned at school was just copying off the board... you try  
9 hard to avoid this, but there's parts where it comes back that that's what you do.."  
10 (Jane, chemist)  
11

12 Jane's school experiences exerted a powerful influence on her intuitive approach to teaching  
13 chemistry; as she had found the subject relatively straight-forward, her instincts led her to want  
14 to teach as she herself was taught, on the assumption that the learning outcomes would be the  
15 same:-  
16

17  
18 "...you've had all that background knowledge and spent all that time learning it ...  
19 you can't then understand why other people don't get it..." (Jane, chemist)  
20  
21

22 Jane realized she could not make these assumptions, and subsequently changed her practice.  
23

24 Finally, Val, a biologist, illustrates that some trainees are closed to the impact of their teaching  
25 on children, until faced with difficult information:-  
26

27  
28 "...with respiration I thought I had gone through the topic really thoroughly... a lot of  
29 them didn't do well in the end of topic test.. Being a biologist didn't seem to work.."  
30 (Val, biologist)  
31

32 Val is expressing her realization that possession of good SMK on her part is not the only factor  
33 determining learning outcomes.  
34

35  
36 A "continuum" of experience from Simon, through John and Jane to Val can be seen here.  
37 Simon grasped early on the need to transform his SMK into activities, using the same strategies  
38 for preparation both within and outside specialism. John and Jane relied on prior experiences to  
39 help them survive, rather than transforming SMK. Both realized the flaws with this approach.  
40 Finally, Val taught first, then reflected from the students' test results on her performance.  
41 Interestingly, Simon and Val both fell into the "super-confident" category (see p 11) – in Val's  
42 case this proved to be over-confidence. These data suggest the importance of aiding trainees to  
43 develop reflective practices early on.  
44  
45

### 46 ***Handling subject knowledge-related questions***

47 Trainees' initial apprehension at being asked questions they could not answer was apparent. For  
48 example, Jane, a highly qualified trainee with a doctorate degree, was one of the fifteen most  
49 anxious, according to her questionnaire responses (see p 12):-  
50

51  
52  
53 "At the beginning one of your biggest fears is that they are going to ask you things  
54 that you don't know and you are thinking, 'What am I going to say?' ... but as you  
55 get into the job you realize ...you don't have to know everything and they won't  
56 really ask you the questions you're thinking because [the students are] not that  
57  
58  
59  
60

1  
2  
3 advanced ...– its like a fear of the unknown. They don't ask you things that you  
4 think they're going to." (Jane, chemist)  
5  
6

7 Other trainees noted their strategies for handling questions were better in their specialist  
8 subjects. Mark who expressed confidence in his ability to handle questions, said:-  
9

10 "...the only thing with physics was that I needed to know what they needed to  
11 know, but if there was something outside that, then bringing it into the lesson  
12 wasn't a problem, and if there was something where I was asked a question and I  
13 wasn't sure about it I made a point of telling them I would find it out." (Mark,  
14 physicist)  
15  
16

17 John, a "working confident", learned his material "a couple of steps ahead" of the children so that  
18 he could handle questions. He was asked if he was conscious of being able to handle questions  
19 better in biology than physics and chemistry:-  
20  
21

22 "In a way, but I was never scared of children asking questions, if I didn't know the answer  
23 I would say so, at first, I thought it would be the end of the world, how stupid would I look  
24 ... but yes, if a child asked me a biology question I would be much more confident  
25 answering it than in physics or chemistry, but if someone asked me a question in physics  
26 and I didn't know I would find out and answer it the next lesson."  
27  
28

29 Thus, the ability to handle questions seems to rely mainly on trainees' self-confidence. Trainees  
30 take a pragmatic approach, finding effective strategies for handling questions to which they don't  
31 know the answer and that children are less demanding than they expected.  
32  
33

### 34 ***Changes in SMK sources and preparation during the PGCE course***

35 Ten interviewees stated their preparation time had reduced significantly during the PGCE year.  
36 Andrew, for example, said that recalling SMK became easier as training progressed:-  
37  
38

39 "My subject knowledge in science has been sleeping. And its all come out again, in  
40 this year...[now] subject knowledge takes a back seat to creativity" (Andrew,  
41 biologist)  
42  
43

44 His use of the word "creativity" suggests he has moved from "survival" and transmission of  
45 knowledge to "transformation" of SMK.  
46

47 The notion of "speeding up" may reflect trainees' increasing confidence in handling classroom  
48 situations, reducing the time needed to get their SMK to a level they felt brought confidence.  
49  
50

51 Harriet was one trainee who used unchanged approaches throughout the course:-  
52

53 "In the diagnostic [first, short teaching placement], I taught only KS3, and again  
54 I read the textbook, the knowledge required was so much simpler.... I don't  
55 think my strategies did change, I was reading and talking to teachers,  
56  
57  
58  
59  
60

1  
2  
3 sometimes I used the internet.... So I don't think they did change." (Harriet,  
4 biologist)  
5  
6

7 Again, pragmatism plays a role -trainees know what is expected of them and devise coping  
8 strategies. They become more skilled at applying these as the course continues.  
9

## 11 Discussion

### 14 *Trainee science teachers' SMK sources for within and outside specialism teaching*

15 Evidence (Tables 2 and 3) indicates that these science trainees use more SMK sources for  
16 preparing lessons outside specialism than within specialism. Trainees rely on experienced  
17 colleagues and school materials more frequently when preparing outside specialism lessons.  
18 Trainees also practice unfamiliar experiments before lessons and consult technicians more often  
19 for lessons in this domain. The questionnaire and interview data together suggest that intense  
20 SMK preparation helps transformation to PCK, as trainees believed their efforts enhanced their  
21 ability to deliver outside specialism lessons with appropriate activities that met learning  
22 objectives for their students, as well as giving confidence in their teaching skills.  
23  
24

25  
26 SMK preparation for within specialism teaching was more casual. Trainees relied on finding out  
27 students' knowledge levels. Three trainees used no SMK preparation strategies at all, relying  
28 only on prior knowledge. Fewer experiments were tested in advance of within specialism  
29 lessons. Perhaps most significant is that trainees consulted experienced teaching colleagues for  
30 within specialism preparation much less frequently. In terms of achieving learning objectives,  
31 eight interviewees indicated their within specialism lessons were in some respects poorer than  
32 outside specialism lessons. Although none explicitly connected this to poor preparation, a link  
33 between the paucity of SMK sources used and achievement of learning outcomes seems  
34 distinctly possible.  
35  
36

37  
38 Three interviewees indicated that their difficulties teaching within specialism arose from an  
39 inability to select appropriate information from their knowledge base, allied to a lack of  
40 experience at teaching "low level" material. The description as a "conflict" is powerful –  
41 awareness of a wide range of interlinking concepts and partial truths may hinder selection of the  
42 best approach to take or strategy to use. This may be a contributing factor to trainees' inability to  
43 transform within specialism SMK to PCK. A lack of SMK for outside specialism teaching seems  
44 to lead automatically to more successful transformation to PCK, most likely because trainees  
45 involve experienced colleagues and are academically able enough to take in new (or revise old)  
46 information rapidly. For teaching within specialism, interviews revealed that trainees work out  
47 what to do for themselves over different time periods.  
48  
49

50  
51 Of course, these comments do not apply to all trainees: there is evidence that 20 – 30% of the  
52 cohort were equally successful at teaching in both domains. Interview data suggest these  
53 trainees are those who perceived at the earliest possible stage that successful teaching depends  
54 (at least to some extent) on good, appropriate activities – that is, somehow, they hit on the  
55 importance of transforming SMK to PCK very early in their practice. Their own personal SMK  
56  
57  
58  
59  
60

1  
2  
3 appeared secondary to ensuring that appropriate activities were found and prepared in a  
4 suitable format for teaching.  
5  
6

7 A second finding is the contrast in importance that trainees place on SMK sources from teaching  
8 practice schools and HEI-based sessions. Despite attending sessions that, at the time, were  
9 rated (verbally and anecdotally) positively, few trainees used any HEI-based materials or ideas  
10 regularly, using almost entirely SMK sources from their teaching practice schools. We can only  
11 speculate as to possible reasons: for example, HEI sessions may be too generic to be useful to  
12 specific school situations, despite efforts to make them relevant; trainees may feel forced to  
13 abide by schools' strict Schemes of Work; the time lag between an HEI session and teaching a  
14 topic may be too long, so the session is forgotten; or sessions were simply too radical and  
15 contrasting to what really goes on in school. Science education research is probably perceived  
16 as too esoteric and difficult to access, as well as being difficult to use directly (one trainee  
17 commented to this effect in her questionnaire). Misconceptions may be already embedded in  
18 schools' Schemes of Work, or are no longer fashionable in the movement in England and Wales  
19 towards general scientific literacy.  
20  
21  
22

### 23 ***Trainee science teachers' confidence for within and outside specialism teaching***

24 A mixed picture is observed in data relating to trainee science teachers' confidence. About 20%  
25 of trainees showed no difference in confidence levels for teaching in either domain. This "super-  
26 confident" sub-group seemed to have prepared themselves mentally for the task of teaching all  
27 aspects of science. This group aside, it is probably fair to say that most trainees inevitably  
28 showed some anxiety for outside specialism teaching, at least in the early stages of their  
29 teaching practice experiences. A sub-group of about twelve demonstrate particularly "anxious"  
30 qualities. They feel nervous about deviating from prescribed Schemes of Work and express  
31 concern about answering subject-related questions. However, observations made outside the  
32 confines of this study indicated that a majority of these trainees developed good coping  
33 strategies and worked hard to overcome both their nerves and any initial apprehension.  
34  
35  
36

37 The trainees in this study are aware that they are well-qualified academically. Over-confidence  
38 for within specialism teaching among some is therefore to be expected, at least in the early  
39 stages. Trainees vary in their ability to recognise this - interview data point to a possible  
40 continuum in the extent to which trainees can reflect meaningfully on their practice.  
41  
42

43 Trainees' strong academic backgrounds probably also contributed to their SMK development for  
44 outside specialism teaching. Around half express preference for teaching their specialism, but  
45 also imply they are content to learn new material. The confidence statement responses show  
46 that about one-third feel less confident teaching outside specialism, but also don't mind doing  
47 this. Evidence indicates that trainees know how to develop their SMK, and are resourceful and  
48 resilient in using a range of sources. The average age of 27 suggests that a good proportion of  
49 trainees come into teaching from previous jobs, bringing skills that confer maturity in handling  
50 novel situations.  
51  
52

53  
54 The "super-confident" trainees are older than average and particularly well-qualified. Age and  
55 work experience may contribute additional maturity at handling unfamiliar situations, greater  
56 flexibility in thinking and the ability to take in and act on new knowledge under pressure. Parents  
57  
58  
59  
60

1  
2  
3 of school-aged children familiar with school environments and used to juggling a variety of  
4 situations simultaneously tend to fall into this category.  
5  
6

## 7 **Conclusions, limitations and practical relevance**

### 9 **Conclusions**

10 These data, albeit of a preliminary nature, add to evidence that SMK clearly exerts an influence  
11 on teachers' practices. This study, set in a training environment, supports Davis's (2003)  
12 findings, indicating that good SMK helps trainee teachers select appropriate instructional  
13 strategies. However, we may need to adjust our definition of "good", as these data suggest that  
14 75% of interviewed trainees, who possessed "good" SMK from their degree backgrounds, did  
15 not teach successful within specialism lessons, at least in the early stages of their teaching  
16 practices. Counter-intuitively, transforming SMK and, hence, selection of appropriate  
17 instructional strategies, seemed to occur more consistently when teaching outside specialism  
18 topics. This position may change as trainees become more experienced. Hashweh's (1987)  
19 findings, for example, contradict these data. Appleton and Kindt's (1999) work, also with  
20 experienced teachers, supports the connection made here: when teaching outside specialism  
21 trainees express a lack of confidence in their SMK and work hard to remedy this. However, the  
22 role of colleagues is clearly different – Appleton and Kindt show collegial support is valued  
23 among teachers post-training, whereas this study shows trainees only ask for this when  
24 preparing for outside specialism teaching. Youens and McCarthy's (2007) work suggests that  
25 trainees may think seeking colleagues help for outside specialism teaching is regarded as "safe",  
26 while asking for help for within specialism teaching, that is, for a topic they are supposed to  
27 "know", may signal weakness.  
28  
29  
30  
31  
32

33 The effectiveness of specialised, collegial support on outside specialism teaching supports the  
34 findings of Luft et al (2003) and Hoy and Spero (2005). These data also confirm the work of  
35 Youens and McCarthy (2007) in showing that school-based materials are used much more  
36 frequently than HEI-based sources for developing SMK (discussed below). Teacher educators  
37 and school mentors should strongly encourage trainees to seek (or insist that they take) advice  
38 from experienced colleagues for teaching in both domains, as well as consider the role that HEI-  
39 based sessions could play.  
40  
41

42 These data do not provide clear support for de Jong (2000) and van Driel et al (2002) in  
43 asserting that good SMK helps trainees be more aware of students' difficulties, although, of  
44 course, these studies presented other factors as also being involved. In this case, trainees  
45 became aware of students' difficulties when learning SMK themselves for outside specialism  
46 lessons. No awareness of difficulties was encountered for within specialism lessons – rather,  
47 trainees tended to over-estimate students' abilities, at least initially.  
48  
49

50 The value placed on HEI-based SMK sessions is questioned. Much time is invested in making  
51 these as valuable as possible by including latest research findings, information about up-to-date  
52 issues in science education and practical experiments, as well as using experienced teacher  
53 colleagues and up-to-date published school materials to help make sessions relevant to  
54 practice. Nevertheless, trainees make little use of these sessions as an SMK source, focusing  
55 instead on materials available in school. A second outcome is the need to ensure mentors are  
56  
57  
58  
59  
60

1  
2  
3 aware of the content and potential value of HEI-based sessions, and for teacher educators to be  
4 yet more explicit as to how to utilise HEI materials, misconceptions and research in lesson  
5 preparation.  
6  
7

### 8 **Limitations**

9 Naturally, the study is limited – firstly by the fact that data are collected from one institution and  
10 at present constitute a relatively small set. Timing of data collection may mean that trainees’  
11 views have changed during the year - data were collected late in the PGCE course. Different  
12 views may have been expressed earlier, although interview and questionnaire data together  
13 collected over a three month period, suggest that responses are reliable. The questionnaire was  
14 designed for this study and has not been validated through use elsewhere, other than by  
15 discussion. However, responses from the two cohorts showed no significant differences, and  
16 interviewees responded in very similar ways over the two years of the study to date. Further, the  
17 interviews did support the questionnaire data – trainees were invited to talk openly about their  
18 experiences, without direct reference to the questionnaire, and did so in ways that supported the  
19 viewpoints they expressed in their questionnaire responses. This suggests that questionnaire  
20 responses were internally reliable.  
21  
22  
23

24 An additional limitation is that what we read is trainees’ viewpoints – they were self-reflecting. No  
25 information was gained from other sources, such as mentors or tutors to support these  
26 observations, so the statements about “success” or “failure” of specific lessons are entirely  
27 based on the trainees’ perceptions. Hence, of course, findings must be regarded as tentative.  
28  
29

### 30 **Practical relevance**

31 Despite the limitations, the information gathered illuminates the issue of SMK for science teacher  
32 development in a training setting in a novel way. Trainees’ efforts to remediate weak SMK,  
33 including consulting experienced colleagues for advice, leads to outside specialism lessons  
34 being successful in the early stages of teacher development. Possession of “good” SMK as prior  
35 knowledge is insufficient to enable all trainees to prepare and deliver successful lessons within  
36 specialism, as they lack experience to transform SMK to PCK effectively. Further, the role of  
37 good support in aiding teacher development is confirmed.  
38  
39  
40

41 The issue of how best to prepare trainees for teaching remains open. This study draws attention  
42 to the possibility of identifying sub-groups of trainees with different characteristics. Further work  
43 may help identify “super-confident”, “working confident” and “anxious” groups more rigorously,  
44 with a view to offering different specialised support. Differentiation of support may help enhance  
45 the skills of the “super-confident”, and encourage more trainees to develop these characteristics.  
46  
47

48 The connection between “super-confident” and the ability to transform SMK to PCK was  
49 apparent. Trainees with these characteristics challenge the assumption that science specialist  
50 subjects are best taught by those possessing specialist degrees. High academic performance in  
51 a specialist subject is not an automatic precursor to good teaching. Trainees with good  
52 academic backgrounds tend more often to work from the “survival” perspective and regard  
53 teaching as knowledge “transmission”. Interviews in this study show the limitations of this  
54 approach. We anticipate that most trainees make the transition from “survival” and simple  
55 transmission of knowledge to transformation of SMK at some stage during the training  
56  
57  
58  
59  
60

1  
2  
3 programme. The role of colleagues in providing support is identified as a factor aiding success:  
4 where help is asked for, evidence presented here shows this was always regarded positively.  
5  
6

7 In terms of the specialist – generalist debate, this paper indicates that the “subject specialists are  
8 best” assumption (Introduction) is not proven. Evidence here is more supportive of the notion  
9 that possession of genuine “teacher skills”, that is, the ability to transform SMK to PCK, is a  
10 more significant factor influencing success as a trainee science teacher than simply possession  
11 of a good degree in a specific subject. The trainee whose comment inspires this paper’s title is  
12 an academic biologist talking about teaching biology. His conflict was not about how he should  
13 teach physics. Of course, following trainees’ development long term may yield changes – over  
14 time, perceptions of confidence and abilities may change with experience, suggesting that a  
15 longitudinal study is worthwhile.  
16  
17

18 This study points towards the unique, raw nature of teachers’ starting positions. In the early  
19 stages, heavy reliance on teaching practice schools is perhaps not unexpected, given the wide  
20 range of intense experiences that these naive beginners face. Research with experienced  
21 teachers post-training shows that skill development continues. A greater reliance on HEI-based  
22 sources may occur when the basic range of teaching abilities are in place. Accordingly, we may  
23 need to review the nature and content of HEI-sessions on teacher education courses to ensure  
24 maximum impact during training. However, over the early years of a teacher’s career, full  
25 support from HEI- and school-based colleagues is effective in aiding their development. Overall,  
26 then, the practical relevance of this study lies in the notion that assessing trainees’ personal  
27 characteristics and offering appropriate, realistic, professional support from both HEIs and  
28 schools in accordance with these may help science teachers develop in the best possible ways.  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

## References

- Abell, S.K. (2000) *Science Teacher Education* Dordrecht: Kluwer Academic Publishers
- Abell, S.K. (2007) Research on Science Teacher Knowledge In: Handbook of Research on Science Education, Eds Abell, S.K. and Lederman, N.G New Jersey, USA: Lawrence Erlbaum Associates
- Appleton, K. and Kindt, I. (1999) Why teach primary science? Influences on beginning teachers' practices *International Journal of Science Education* 21 (2) 155 - 168
- Borko, H., Lalik, R. and Tomchin, E. (1987) Student teachers' understandings of successful and unsuccessful teaching *Teaching and Teacher Education* 3(2): 77 – 90
- Carlsen, W. S. (1993) Teacher knowledge and discourse control: Quantitative evidence from novice biology teachers' classrooms *Journal of Research in Science Teaching* 30 (5): 471 - 481
- Carlsen, W.S. (1999) Domains of teacher knowledge In: *Examining Pedagogical Content Knowledge* Eds: J. Gess-Newsome and N. Lederman, Dordrecht: Kluwer Academic Publishers
- Carré, C. (1998) Invitations to think in primary science lessons, in Birden, R. and Williams, M. (Eds) *Thinking through the curriculum* (London: Routledge)
- Davis, E.A. (2003) Knowledge integration in science teaching: Analysing Teachers' Knowledge Development *Research in Science Education* 34: 21 -53
- De Jong, O. (2000) The Teacher Trainer as Researcher: exploring the initial pedagogical content concerns of prospective science teachers *European Journal of Teacher Education* 23 (2): 127 – 137
- DfES (2004) *Science: The National Curriculum* London: The Stationery Office
- Geddis, A.N., Onslow, B., Beynon, C. and Oesch, J. (1993) Transforming content knowledge: Learning to Teach about isotopes *Science Education* 77 (6): 575 – 591
- Gess-Newsome, J. (1999) Secondary teachers' knowledge and beliefs about subject matter and their impact on instruction In: *Pedagogical Content Knowledge: The Construct and Its Implications for Science Education*, Gess-Newsome, J. and Lederman, N. G. (Eds) Dordrecht: Kluwer
- Hashweh, M. Z. (1987) Effects of subject-matter knowledge in the teaching of biology and physics *Teaching and Teacher Education* 3 (2): 109 – 120

- 1  
2  
3 Hoy, A.W. and Spero, R.B. (2005) Changes in teacher efficacy during the early years of  
4 teaching: A comparison of four measures *Teaching and Teacher Education: An International*  
5 *Journal of Research and Studies* 21(4): 343-356  
6  
7  
8 LeCompte, M. and Preissle, J. *Ethnography and Qualitative Design in Educational Research* (2<sup>nd</sup>  
9 Edition London: Academic Press  
10  
11 Lederman, N.G., Gess-Newsom, J. and Latz, M.S. (1994) The nature and development of  
12 preservice science teachers' conceptions of subject matter and pedagogy *Journal of Research*  
13 *in Science Teaching* 31 (2): 129 – 146  
14  
15  
16 Luft, J., Roehrig, G. and Patterson, N.C. (2003) Contrasting landscapes: A comparison of the  
17 impact of different induction programmes in beginning secondary science teachers' practices  
18 beliefs and experiences *Journal of Research in Science Teaching* 40 (1): 77-97  
19  
20  
21 Lumpe, A.T., Haney, J.J. and Czerniak, C.M. (2000) Assessing teachers' beliefs about their  
22 science teaching context *Journal of Research in Science Teaching* 37 (3) :275 – 292  
23  
24  
25 Magnusson, S., Krajcik, J. and Borko, H. (1999) Secondary teachers' knowledge and beliefs  
26 about subject matter and their impact on instruction In: Gess-Newsome, J. and Lederman, N.G.  
27 Eds (1999) *Examining Pedagogical Content Knowledge* Dordrecht: Kluwer Academic Publishers  
28 p 95 – 132  
29  
30  
31 Markic, S., Valanides, N. and Eilks, I. (2006) Freshman science student teachers' beliefs on  
32 science teaching and learning – a mixed methods study In: *Towards research-based science*  
33 *teacher education* p 29 – 40, edited by I. Eilks and B. Ralle, Shaker, Aachen Germany  
34  
35  
36 Marks, R. (1990) Pedagogical content knowledge: From a mathematical case to a modified  
37 conception *Journal of Teacher Education* 41 (3): 3-11  
38  
39 Meriam, S.B. and Associates (2002) *Qualitative Research in Practice* San Francisco: Wiley  
40  
41 Moor, H, Jones, M., Johnson, F., Martin, K., Cowell, E. and Bojke, C. (2006) *Mathematics and*  
42 *Science in Secondary Schools The Deployment of Teachers and Support Staff to Deliver the*  
43 *Curriculum* Department for Education and Skills Research Report No 708 Slough: National  
44 Foundation for Education Research and  
45 <http://www.dfes.gov.uk/research/data/uploadfiles/RR708.pdf> (Accessed April 2008)  
46  
47  
48 Royal Society of Chemistry (2004) *Who teaches our children chemistry?* Policy Bulletin Issue 3  
49 London: Royal Society of Chemistry available at  
50 <http://www.rsc.org/ScienceAndTechnology/Policy/Bulletins/Issue3/TeachingChildren.asp>  
51 (accessed April 2008)  
52  
53  
54 Sanders, L.R., Borko, H. and Lockard, J.D. (1993) Secondary science teachers' knowledge base  
55 when teaching science courses in and out of their area of certification *Journal of Research in*  
56 *Science Teaching*, 30: 723 – 736  
57  
58  
59  
60

1  
2  
3  
4 Sanders, M. (1993) Erroneous ideas about respiration: The Teacher Factor *Journal of Research*  
5 in Science Teaching 30 (8): 919 – 934  
6  
7

8  
9 Shulman, L. (1986a) Those who understand: A Conception of Teacher Knowledge *American*  
10 *Educator* 10(1): 9-15, 43-44  
11

12 Shulman, L. (1986b) Those who understand: Knowledge growth in teaching *Educational*  
13 *Researcher* 15(2): 4-14  
14  
15

16 Shulman, L. (1987) Knowledge and teaching: foundations of the new reform Harvard  
17 *Educational Review* 57 (1): 1 – 22  
18  
19

20 Van Driel, J., De Jong, O. and Verloop, N. (2002) The development of pre-service chemistry  
21 teachers' pedagogical content knowledge *Science Education* 86: 572 – 590  
22

23 Youens, B. and McCarthy, S. (2007) Subject knowledge development by science student  
24 teachers: the role of university tutors and school-based subject mentors *Research in Science*  
25 *and Technological Education* 25 (3): 293 – 306  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Subject specialism	Biology		Chemistry		Physics		Totals	
No. of trainees	39 (55)		24 (34)		8 (11)		71 (100%)	
Gender	Male 12	Female 27	Male 10	Female 14	Male 6	Female 2	Male 28 (39)	Female 43 (61)
<b>Age</b>								
21-25	8	21	3	4	4	1	41 (58)	
26-30	2	2	4	5	1	0	14 (20)	
31-35	1	2	2	3	0	0	8 (11)	
36+	1	2	1	2	1	1	8 (11)	
<b>Degree class</b>								
1st	3	2	1	4	2	0	12 (17)	
2:1	5	14	1	4	2	0	26 (37)	
2:2	3	8	4	4	1	1	21 (29)	
3rd	0	0	2	0	0	0	2 (3)	
Not stated /other	1	3	2	2	1	1	10 (14)	
Higher degrees	5	4	4	6	0	1	20 (28)	

(Figures in parentheses are percentages throughout)

**Table 1: Science trainees' backgrounds: gender, age and degree classification against subject specialism**

	Ranked 1 or 2	3 or 4	5 or 6	7 or 8	9 or 10	Total
Making notes	29 (41%)	13 (18)	7	6	6	61
School colleagues	24 (34)	19 (27)	13 (18)	3	2	61
Other trainees	9 (14)	20 (27)	14 (20)	9	9	61
Internet	16 (23)	23 (32)	10 (14)	9	3	61
Science Education Research	1	1	5	15 (21)	39 (55)	61
Misconceptions Materials	1	6	14 (20)	18 (25)	22 (31)	61
Textbooks	30 (42)	16 (23)	9	5	1	61
Exam papers, etc	4	12 (17)	18 (25)	16 (23)	11	61
HEI sessions	5	7	20 (17)	23 (32)	6	61
University notes	3	5	13 (18)	17	23 (32)	61

Figures in parentheses are percentages

**Table 2: Science trainees' ranking of ten subject matter knowledge sources from a pre-prepared list**

SMK source	Within specialism teaching	Outside specialism teaching
School colleague or other trainee teacher	7	33
Textbooks, school resource packs, teacher materials	19	38
Internet	19	18
Formal documentation such as Exam papers, National Curriculum document, School Schemes of Work	10	12
Prior knowledge from University degree or job	14	0
Information from an HEI-based session	2	2
Other source, e.g. revision guide, safety guide, practising experiments, prior knowledge check, note-making	8	15
Misconceptions information	4	5
Trainees stating "no sources used"	3	0

**Table 3: Summary of trainee science teachers' subject matter knowledge sources for within and outside specialism teaching**

Statement Pair	Likert scale response Statement	Strongly agree	Slightly agree	Neutral	Slightly disagree	Disagree /strongly disagree	NR	Total
Preference	I prefer to teach topics in my specialism	22 (31%)	18 (25)	15 (21)	5	11	0	71
	I am pleased to teach topics in all areas of science	41 (58)	18 (25)	9	3	0	0	71
Confidence	I don't need to teach my specialism to feel confident	34 (48)	13 (18)	15 (21)	1	7	1	71
	I am less confident teaching outside my specialism	15 (21)	23 (32)	16 (23)	12 (17)	5	0	71
Questions	I am nervous of being asked a question I can't answer	17 (24)	15 (21)	9	14 (20)	16 (23)	0	71
	I can handle difficult questions in non-specialist areas	25 (35)	25 (35)	13 (18)	14 (20)	4	0	71
SMK attitudes	I find it difficult to develop my subject knowledge outside my specialist area	2	3	10	15 (21)	41 (58)	0	71
	I enjoy learning new subject knowledge outside my specialist area	46 (65)	13 (18)	11	1	0	0	71

NR = No response

**Table 4: Trainees' responses to Likert scale statements about preferences, confidence, handling questions and attitudes towards learning new SMK**

## Appendix 1: Questionnaire

### Developing trainee science teachers' subject knowledge

#### Background information

Name \_\_\_\_\_ Gender \_\_\_\_\_ Age \_\_\_\_\_

1<sup>st</sup> degree subject and class \_\_\_\_\_

Higher degrees \_\_\_\_\_ Subject specialism on PGCE \_\_\_\_\_

1. Please complete the table showing science topics you have taught so far.

In your specialist area	Key stage	In areas outside your specialism	Key stage
[Space provided for lists]			

2. From the specialist list, choose one topic you found especially “easy” to teach (i.e. you felt confident you could teach it well). Describe what you did to prepare the subject knowledge required.

3. From the non-specialist list, choose the topic you found hardest to teach (i.e. you felt the most unconfident you could teach it well). Describe what you did to prepare the subject knowledge required.

4. Here is a list of strategies that trainee science teachers may use for developing subject knowledge. Rank the items in order from **1(Highest)** – **10 (lowest)** according to how useful you think these are. *Please number each item separately; don't rank two with the same number.*

Strategy	Ranking from 1-10
Making notes from textbooks	
Asking colleagues at school	
Asking other trainees	
Searching the internet	
Reading science education research	
Reading misconceptions literature	
Reading textbooks	
Trying exam papers / questions	
Using information from University sessions	
Using university notes from your degree course	

5. Here are some statements about subject knowledge and teacher confidence. Select the alternative in each case that corresponds most closely to your opinion as it stands based on your teaching experience so far.

	1 - strongly agree	2	3	4	5 strongly disagree
I prefer to teach topics in my specialist area. P	1	2	3	4	5
I enjoy learning new subject knowledge outside my specialist area. A	1	2	3	4	5
I am nervous that I will be asked a question I cannot answer. H	1	2	3	4	5
I am less confident when I teach outside my specialist area. C	1	2	3	4	5
I can handle the situation if I am asked difficult questions outside my specialist area. H	1	2	3	4	5
I am pleased to teach topics in all areas of science. P	1	2	3	4	5
I find it difficult to develop my subject knowledge outside my specialist area. A	1	2	3	4	5
I do not need to teach my specialism to feel confident as a teacher. C	1	2	3	4	5

Please indicate here if you would be prepared to take part in a (short) recorded discussion about the issues being explored in this study. o

Thank you very much indeed for your help.

## Appendix 2: Interview questions

1. Please confirm the topics you taught at KS3 and KS4 on both your teaching practices.
2. How did you prepare the subject knowledge you needed for teaching?
3. Did you use the same strategies for preparing subject knowledge for teaching topics within and outside specialism? Please explain.
4. Were you aware of differences in learning outcomes for the children when you taught within and outside specialism topics? Please explain
5. How did the quality of your lesson preparation affect the achievement of learning objectives?
6. Have your strategies for preparation changed during the PGCE course? Please explain.

Trainees were also asked to bring lesson plans, teaching materials and evaluations of their teaching for within and outside specialism lessons that they felt best represented their work. Discussion about these followed the interview questions.