Trainee teachers' experience of primary science teaching, and the perceived impact on their developing professional identity.

Abstract

This study took place within an environment of educational change in teaching and assessment in the UK, where the National Curriculum (N.C.) and National External Examination syllabi undertook significant revision. Science education specifically, has seen aspiration raised to allow pupils to achieve a greater depth of understanding at Key Stage 4 and hence facilitate advanced study. Central to the development of effective scientific understanding is teacher preparation. This study examined the factors that impacted on the experiences of primary teachers during their training. Questionnaires completed by a sample of one hundred and sixteen trainee teachers followed by semi-structured interviews of sixteen trainees were used as a means of interpreting Post-Graduate Certification in Education (PGCE) trainee teachers' experiences during taught university sessions and school based training. The findings showed that the majority of the trainees rated their training highly, and perceived themselves to be confident primary science pedagogues. They felt, however that the very limited opportunities to observe and teach science during their training negatively influenced their overall development.

Key words

Science Education, Teacher Education, Primary School Teachers and Professional Identity.

Introduction

This small-scale, exploratory study served to investigate how trainee primary teachers undertaking a one-year Post-Graduate Certificate in Education (PGCE) prepare for their role in delivering primary science, once qualified. The majority of PGCE programmes follow a similar model which is heavily influenced by the regulatory frameworks (DfE, 2011) surrounding the initial preparation of teachers. In brief, the course involves taught lectures as part of a modular certification, which focus on subject specific pedagogy, and improvements in subject knowledge alongside practical activities to model their taught practice when teaching primary pupils. In addition to this university-based element, trainees are required to complete 120 days of teaching practice across the three school terms in an academic year. In order for students to be compliant, consecutive age phase-specific experiences are provided through University-School partnerships which are, for the most part, regionally based. The combined placement and taught components of the course followed by these participants' mirrors, to a large extent, the practice undertaken by other universities across the United Kingdom (UK).

Given the diminished profile and status of primary science in the curriculum (Ofsted, 2013, Serret et al. 2016) this paper argues for the need for trainees on these PGCE training programmes to have high quality university experiences to support trainees' knowledge, confidence and pedagogical practice in science education. Given that often students enter teaching courses with a varying level of science qualification and given that one factor that has been reported to influence a teacher's sense of diminished confidence in the teaching of science is that of not holding an A level in a science subject (Wellcome Trust CFE Research, 2017) it is imperative that taught science programmes do all they can to support students' confidence by developing the level of their pedagogical and subject knowledge. Therefore, it

is argued that it is vital that access is provided to meaningful and outstanding school based science practices whilst training in order to secure confident, high quality primary science teaching from these trainees in the future. This will serve to support their positive sense of developing professionalism alongside their emerging professional identity.

Backdrop to the Study

It has been widely reported that there is a significant deficit in numbers of young people graduating with degree level science knowledge, as required by the workforce (CBI, 2014), with thirty nine percent of employers reporting to be 'struggling' to recruit workers with advanced technical skills in science, technology, engineering and mathematics (STEM). Such concerns more recently have extended to the huge reduction of girls now studying STEM subjects and the implication this has for the take up of degree and level 4 science qualifications (WISE, 2017). Given this lack of science based expertise, combined with the need to produce high quality science teachers, it seems vital that quality training of science trainees is developed in order to help ameliorate this issue. By promoting teachers who are confident and competent in the delivery of science we may hope not only to inspire children with regard to science but also change their perceptions about this subject (Wellcome Trust, 2014).

One of the issues that confronts teachers in the United Kingdom (UK) regarding the teaching and learning of this subject is its reduced profile (Ofsted 2013, Serret et al. 2016). Since the abolition of Key Stage Two (KS 2) science Statutory Attainment Tests (SATs) in 2009, primary science has seemingly experienced a diminished status in the primary curriculum. Evidence cited by the Wellcome Trust (2011, 2014) clearly indicates that there is currently a reduced level of profile, coverage and time now devoted to science by primary teachers, resulting in decreased status in the primary curriculum. Such research may also find support in more historic concerns raised by Boyle and Bragg (2006) who highlight the reduced teaching time devoted to science as a result of various initiatives which focused on raising standards in literacy and numeracy. Though current research (Wellcome Trust CFE Research, 2017) would seem to indicate a somewhat more positive outlook for primary science, the importance of science to school leadership is still limited compared to that of the core subjects of English and Mathematics. With its importance to the senior leadership team being ranked by 57% of Headteachers/Acting Headteachers or Deputy Headteachers as 'very important' compared to that of English 83% and Mathematics 84% (Wellcome Trust CFE Research, 2017). Therefore, it is not unreasonable to postulate that the change to time allocation within the curriculum for science not only has a direct influence on the teaching and learning of science in primary schools, but also impacts on the emotional investment of trainee teachers in this particular curriculum area. Therefore the research questions at the centre of this study were:

(i) What opportunities, if any, do trainee primary teachers have to observe science teaching on placement in school?

(ii) How do training opportunities affect trainees' confidence in teaching primary science?

(iii) How, could the science experienced by trainees on school placement impact upon their developing sense of professional identity?

The importance of experience

Training within primary science education and science specific pedagogy are inextricably linked in a complex multi-layered manner (Cochran, 1997). Trainee teachers need to acquire relevant subject and general pedagogic knowledge (Van Driel, Verloop and DeVos 1998; Sjoer and Meirink 2015), knowledge of their pupils and their abilities and an appreciation of the learning environment (Cochran, 1997; Danielsson and Warwick, 2014). In addition to this, their practice is impacted upon by multiple external factors, for example the implementation of policy and legislation changes as suggested by Galton (1995) which can potentially lead to confusion within schools. Clearly this is a complex multi-factorial situation which must be negotiated by trainees. These internal and external influences upon trainees may resonate with the concept of bio-ecological models as advocated by Bronfenbrenner (1979) which endeavours to promote an understanding between processes and constructs relating to personal development, through a series of nested systems. Bronfenbrenner (1979) considers the development of individuals to be a direct result of the relationship between the individual and their immediate environment (in this case the trainee's placement setting. This type of interaction would be seen to take place at the 'microsystem' level (Bronfenbrenner, 1979: 22) with the 'macrosystem' reflecting the 'possible blueprints for the future as reflected in the vision of a society's political leaders' (ibid: 26). This perspective could be said to impact further on the visibility of science within the primary curriculum and leadership and management (Wellcome, 2011, Wellcome CFE Research, 2017). Similarly the trainee's position within the school social learning environment has links to the work of Wenger (2000) who described the role of individuals in social learning situations. For Wenger, being new to a community involves experiencing their world: becoming one of them. Whilst also involving modes of belonging; engagement (co-construction of meaning), imagination (constructing an image of ourselves) and alignment (interpreting actions to achieve a goal) which allows an individual to align themselves within a community of practice. Without this experience the development of identity and professional practice is compromised. (2000:241).

The impact of school-based experience on developing identity

Set amidst this backdrop of primary science teaching are post graduate trainee teachers who, through their school based practice, need to develop their skills and knowledge in order to become outstanding primary practitioners. As Pellett, Strayve and Pellett (1999) suggest such teaching experiences provide a valuable link between the theory learned during Initial Teacher Education (ITE) and the real world of teaching. Teaching practice allows opportunities for trainees to practise and refine what they have observed and learned and, through the process of constructive feedback, build up their own levels of skill and

competence in their own practice (Pellett et al. 1999; Sydnor 2016; McCullagh and Doherty, 2016).

Research such as Smith (2007) clearly identifies the differing types of knowledge teachers should acquire for successful teaching, including general pedagogical knowledge, subject matter knowledge and subject specific pedagogic knowledge (which focuses on common misconceptions and remediation strategies). This acquisition of subject based knowledge and pedagogy for trainee teachers needs to be embedded within training opportunities, not only for trainees to develop professionally in the field of science teaching, but also to shape their own beliefs, self-image and developing sense of professional identity (Bryan, 2003; Mulholland and Wallace, 2003). Such a sense of developing professionalism can also be directly linked to individual life histories and training (Hargreaves and Goodson 2006; Lee, Longhurst and Campbell 2017).

Some researchers (for example, Evans, 1998; Day and Kington, 2008) define the construction of professional identity as rooted in the specific situations in which teachers find themselves working. It is by the process of teachers allowing trainees access to teaching experiences and activities that trainees may gain in confidence (Pellett et al. 1999; Wilson, Bradbury and McGlasson, 2015). Beyond the very situations in which trainees find themselves placed, it is the act of teaching that shapes individuals (Nias, 1989). In addition to this, Evans (1998) suggests that both 'ideal' and 'real' selves are open to fluctuation and change as a direct result of situational impact. This has clear resonances with the research of Sammons et al. (2007) and Day and Kington, (2008) which discuss how teachers' professional identity may be affected by a variety of professional, situated and/or personal scenarios.

Trainee teacher emerging professional identity.

It has been suggested that student teachers are able to articulate their own understandings of professional identity tentatively during their training (Beauchamp and Thomas, 2009), although this is not always found to be explicit. These researchers in agreement with others (Beijaard, Meijer and Verloop 2004, Volkmann and Anderson, 1998; Lasky, 2005) highlight the dynamic nature of identity which is influenced by a multitude of factors, resulting in an ongoing "shift in identity" as student teachers move into their first year of practice. In the case of trainee teachers and beginning teachers, professional identity has been argued to be shaped by sharing experiences and exposure to teaching practices during the early formative stages of training (Pillen, Beijaard and den Brok 2013; Hong, 2010). Flores and Day (2006) explicitly identify key factors such as past learning experiences as pupils, school culture and leadership experienced on teaching practice as significant stimuli in the evolving professional identity of student teachers. It has been suggested that responses to shifting identity may be due to unique responses by individual student teachers to notions of their own agency and the active pursuit of professional development (Beijaard et al. 2004). Hong (2010) suggests that key factors such as value, commitment and micro politics within training settings may also contribute to specific aspects of the emergence of trainee teachers' identities. This research adds to that of Freese (2006) who highlights the importance of allowing student teachers to

discover their "teacher selves" (Freese, 2006: 100) through reflection on their own practice within the learning contexts they find themselves. Beauchamp and Thomas (2009) highlight whilst the consensus within the literature is that student teachers evolve their own professional identity this is an under researched area.

The science specific components of student teacher's identities

In view of the arguments above, it would seem fundamental that student teachers (also known as pre-service teachers, but termed in this paper as trainees) are provided with high quality experiences linked to the teaching of science during their training. Research such as McCullagh and Doherty (2016) clearly indicates the mutual benefits and synergy of student teachers and current practitioners working in collaboration when teaching science. Beyer and Davis (2011, 132) highlight how teachers "draw upon their experiences, beliefs, and knowledge" of science pedagogy to shape their future practice. Given that teachers evolve their own developing science pedagogic content knowledge (PCK) (Magnusson, Krajcik and Borko 1999), in part by considering their orientation towards science teaching it is not unreasonable to suggest that their interactions and experiences with colleagues and peers impacts upon this process. Additionally in a review by Davis and Smithey (2009) it is postulated that personal characteristic such as identity and personal history can influence beginning science teachers' development.

Bringing all these aspect together it suggests that science specific aspects of trainee teachers' pedagogic development may be influenced by their perceptions of their surfacing professional identity (Avraamidou 2014). The study reported in this paper specifically seeks to explore links between the science teaching opportunities afforded trainees during their PGCE course and their perceptions of their developing professional identity. The research aspires to identify key factors that directly influence individuals who are training in primary schools as they develop their science pedagogy.

Research design

The position adopted for this research is grounded in a reality of social constructivism where knowledge is fluid and truth is negotiated. We aim to make interpretations of empirical data to develop a persuasive argument surrounding the factors that impact on trainees' professional development. We will endeavour to ensure adequate dialogue between researchers and participants in order to collaboratively construct a meaningful reality of their experiences.

The study was undertaken using a mixed methods approach as advocated by Tashakkori and Teddlie (2010), as it was considered desirable to collect, analyse and integrate both quantitative data and qualitative data in a single study. In this way the quantitative data from the questionnaires was used to determine the time afforded trainees to observe or teach science and collect information concerning the training settings, whilst the qualitative data was utilised to explore trainees perspectives, feelings and attitudes towards their training and professional development. It is argued in agreement with Lieber and Weisner (2010) that this

type of research strategy, which incorporated both qualitative and quantitative components in combination, provides a better understanding of the research questions than these methods used in isolation.

Sample

The participants in this study were postgraduate trainee teachers who were enrolled with a regional ITE provider in the Midlands region of the UK. As part of their course, trainees are required to spend 120 days on school-based practice across a range of phases (e.g. nursery, first, primary and middle schools) and settings (e.g. state and independent schools). The trainees teach up to a maximum of 80 percent of a normal teaching load during their final school experience placements. Alongside this practical experience, trainees receive fifty hours of specialist science lectures which enables individual trainees to develop aspects of their primary science pedagogy and subject knowledge.

Questionnaires were administered to a convenience sample of one hundred and forty five PGCE trainees towards the end of their last school experience. The selection criteria were that the trainees had completed at least three periods of school based training and were actively studying on the course. Trainees were chosen (approximately half of the whole cohort) as a proportionate sample from university groups both specialising in the education of children in the Early Years Foundation Stage and Later Stages (Key Stage One and Key Stage Two). This strategy was adopted in order to provide data from a manageable number of trainees and also ensure an appropriate sample size for meaningful analysis. A response rate of 80% (n=116) was achieved from this initial method. A further purposive sample of sixteen trainees was chosen from amongst those who indicated on the questionnaire a willingness to be interviewed. Although not fully representative, this sub sample of participants reflected a range of school settings, course subject groups and ages across the cohort.

[Table 1 near here]

Methods

It was hoped to achieve triangulation of data by using two data collection tools; questionnaire survey, and interviews.

i) Questionnaire survey

A questionnaire was developed which could be used to as a means of obtaining both quantitative and qualitative data from a statistically significant number of trainee teachers. The questions were informed by an initial review of literature and were designed to determine the:

- opportunities that trainee teachers had been afforded to observe and deliver science teaching whilst on school experience placement;

- the levels of science resourcing they had encountered in schools.

- the opportunities trainees had been provided with to deploy teaching approaches and knowledge gained in taught university sessions.

- trainees' attitudes to science teaching as a component of their overall emerging professional identity.

The questionnaire contained eight closed ended questions under these main areas:

- Training setting details.
- Time allowed to observe science teaching.
- Time allowed to teach science.
- Level of practical science resources available.

With respect to the questions surrounding how much time trainees had observed and been allowed to teach primary science, it was stressed to the trainee teachers that the total of time recorded could be made up in any way, for example two lessons of twenty minute duration or one of forty minutes.

In addition the questionnaire included two open ended questions where trainees were asked to expand on the opportunities they had experienced to observe or discuss excellent science pedagogical practice within school and the impact this had had on their development.

ii) Interviews with trainees

Semi-structured interviews were chosen to give individuals an opportunity to clarify and expand on responses given in the questionnaire survey. The interviews were conducted within a mutually respectful but "low key" context which allowed for focused, conversational, two-way communication (Denzin, 2001). In order for the trainees to express a view of their overall training experience the interviews were undertaken at the end of the PGCE course once course results had been finalised.

The interview design followed the overall scheme of Kvale (1996) and consisted of introductory, follow up, probing, specific and interpretative questions. The majority of questions were designed and phrased ahead of time to improve the reproducibility of the interview experience across the sample; however some questions were elaborated on by trainees according to their experience. If indicated, extra questions were included, which

afforded both the researcher and trainee teacher the flexibility to probe for details and discuss issues.

The major benefit of using semi-structured interviews was to encourage mutual communication providing opportunities for detailed exploration of ideas (Kvale, 1996). To ensure that the sample of sixteen trainee teachers received a similar interview experience, researchers conducted a number of pilot interviews in order to familiarise themselves with the overall interview design and how two-way communication would be established. Following this process, researchers discussed the trial interviews to ensure a consistency of approach.

Though no recording of the conversation was undertaken, brief notes were recorded during the interview along with noteworthy quotes. Following the interview these were immediately elaborated on and transcribed into a question by question interview record. In this way specific quantitative and qualitative information from the trainee teachers was obtained in terms of the number and duration of opportunities they had been afforded to observe and teach primary science. General information pertinent to the resourcing and apparent profile of science within the school curriculum was sought. A range of insights on specific issues including science specific pedagogical input in both school and university contexts was also gained. Open questioning was used in order to probe for in-depth responses regarding how experiences of observing and undertaking science teaching and were influencing the trainees feelings of confidence and perceived professional development. At each interview questions were asked with respect to how confident in their ability trainees felt in the delivery of science as a result of their school based practice. Trainees were also asked specifically whether their experience in school had aided their motivation to teach primary science both presently and in the future.

Data analysis

Data analysis was carried out in three phases. Firstly statistical data from the questionnaires were entered into Microsoft Excel, coded and analysed alongside the descriptive data relating to the key stage taught. Following this, the analysis of open ended questionnaire responses and interview data involved the immersion of the researchers in a prolonged, repeated process of data reduction, data display and verification (Miles and Huberman, 1994). Through the researchers' use of 'constant comparative analysis' (Birks and Mills, 2011:94) and the use of both abductive and inductive thought processes, conceptual leaps were made during the analysis. This iterative approach generated an 'abstract conceptual framework' (Birks and Mills 2011:94) from what may be initially seen as raw qualitative data. Finally, methodological and investigator triangulation facilitated validation process via cross verification of key themes. In addition the responses given by the sixteen interview participants were collated electronically on a question by question basis, colour coded by hand and analysed against the opportunities each trainee was afforded to observe and teach science.

Ethics

A commitment to adhere to best ethical practice was central to the study, which prioritised the welfare of all participants including trainees, mentors, children and school staff. The BERA research guidelines (BERA 2011) acted as a point of reference, in addition to peer review by the institute ethics committee.

Findings

Emergent themes linked to the research questions

The themes that emerged from the data are linked to the research questions as shown below:

Research question: trainee teacher observational opportunities

Results from the questionnaire, showed that the majority of trainee teachers were experiencing very little opportunity to both observe and teach science. It can be seen from figure 1 that the vast majority (87%) of trainees were able to observe less than 35 minutes of science teaching on average per week, during their school experience training. In addition, a mere six percent of trainees were afforded the opportunity to observe 45 minutes or above per week. Twenty percent of trainees were not given the opportunity to observe science at all. Given that children are routinely taught mathematics and literacy lessons for 45 minutes per day, it is clear that the time allotted to science in the curriculum is significantly diminished in comparison to the other two core subjects.

On the limited number of occasions when science was seen being taught during KS 2, trainees attributed this, to the enthusiasm of the teacher for delivering this subject or because the individual was responsible for co-ordinating the subject in the school. This was reflected in the comment made by one trainee who said:

'The amount of science teaching depended on how high up you were in the school and how the confident the teacher was in teaching it.'

The majority of trainees who witnessed science teaching at KS 2 felt that, based on their limited experience, there was little opportunity for children to develop scientific investigations or enquiries. The teaching was perceived as being highly structured and somewhat didactic in its delivery. As one student noted:

'What I saw (of science teaching) was really structured, the children sat watching videos and there was little chance for them to investigate'

Trainees who observed science teaching, however, did on the whole value the opportunity; they felt it provided them with the means to reflect upon their own styles of teaching and allowed them to assimilate knowledge and skills from more established colleagues. They commented that when science was observable, the ability to see good practice modelled, as well as reflecting on something they would like to emulate in the future, was invaluable.

[Figure 1 near here]

Trainees who were fortunate enough to observe science being taught in their school were mainly found in an Early Years Foundation Stage (EYFS) setting (where 72% observed some science). These trainees felt that during the Foundation Stage there was a considerable amount of science being taught and planned for, and that it was being integrated into topics which aided children in their 'Understanding of the World' element of the EYFS curriculum. As pupils moved into Key Stage one (KS 1), science was also being taught as part of wider ranging topics and, from trainees comments, was still being taught on a regular basis. However over half of trainees interviewed felt that as pupils moved from KS 1 into KS 2 the amount of science being taught diminished significantly.

Overall, it was clear from both quantitative and qualitative data that trainees as a whole had been afforded very little opportunity to observe or teach science. The exception was a very small number of trainees whose class teachers were the science coordinator or a senior member of staff with a particular interest in science.

Research question: Training opportunities and confidence

When asked to reflect upon their initial feelings at the start of the course, the majority of trainees interviewed (75%, n=12) clearly indicated that they lacked confidence in their ability to teach primary science. They felt they were unable to structure pupil's learning experiences and scientific enquiries and did not know where to start in order to promote science teaching and learning. As one trainee on the Early Years Foundation Stage (EYFS) pathway noted:

'I didn't feel confident to teach science, I was really worried about it.'

It appears that there were very few opportunities not only for trainees to observe science but also to teach it, as illustrated in Figure 2. Eighteen percent of trainees were afforded no opportunity to teach science and only four percent were afforded the opportunity to teach 45 minutes per week.

[Figure 2 near here]

Those trainees given the opportunity to teach science during their placement valued this aspect of their school experience in relation to developing their own practice as well as receiving feedback on their teaching from the professionals around them. As trainees suggested:

'I think it is good seeing someone teach since it helps you model your own practice and it helps you reflect upon what they are getting right and how they can improve.'

'I found it hard to know if I am doing the right thing without seeing anyone else teach.'

'I would have valued having the opportunity to see more science teaching. I felt it was very superficial since there was not enough time spent on the activities.'

It is, however, interesting to note that despite very limited experiences of observing and teaching primary science in school being reported, trainees were reluctant to rate their training experience as unsatisfactory (see table 2).

The perceptions of trainees with respect to training efficacy can be roughly divided into three subpopulations; just over one third (35%) of trainees felt that their science teacher training was poor/very poor and less than a third (26%) were satisfied with their training. A further third (39%) of trainees felt that they were afforded good/excellent training opportunities.

[Table 2 near here]

Trainees as a whole initially reported to have low levels of confidence in teaching primary science. This was improved throughout their training, largely as a result of taught sessions at university where they had the opportunity to learn through modelling by their science tutors. With the exception of the trainees who found themselves in EYFS settings, the trainees did not report that school training opportunities supported them to increase their confidence levels.

Profile of science in the curriculum

On reflection, at the end of their final school experience, three quarters of trainees felt the profile of science was diminished compared to the more consistent levels of numeracy and literacy. As one trainee in KS 1 said:

'I felt the profile of science was considerably lower than the two core subjects of Maths and English.'

Over two thirds of trainees felt the lowering of the science profile was attributed to the pressure of trying to cover all areas of the curriculum, over what was already a "packed day", but also as a result of science not now being statutorily tested at KS 2. As two trainees commented:

'I think teachers are so busy and that they think it is just another subject they have to fit in. I don't think it is seen as a core subject anymore now it is not taught as much.'

'Science was valued in school it's just that Maths and English got a much greater share of time available.'

The final stages of the programme and developing confidence

After three terms of taught University science sessions and training in school, trainee interview responses clearly indicated improved levels of confidence and subject knowledge. As well as developing science specific pedagogy, the trainees also reported they were now supported by an increased awareness of how to structure cross-curricular learning for primary children. They indicated that the taught element of the science course had helped them to appreciate children's misconceptions in science and design appropriate remediative strategies. This was supported, in their view, by being able to engage pupils in meaningful learning and by an increased knowledge of how to probe children's understanding by structured open-ended questioning. Though this research was undertaken during the study of the "old" National Curriculum (N.C.) (DfEE 1999), the new N.C. (DfE 2013) was being implemented, which meant references to both sets of documentation were necessary during

training. Trainees indicated that they felt they had started to become familiar with this documentation and its relevance to their teaching and pupils learning. Comments which were typical of the value the trainees placed on their training were:

'I found university sessions so useful. They gave me so many practical ideas and such a positive feeling of how to teach science. It really boosted my confidence.'

'I feel confident to teach primary science in contrast to the beginning of the course when I was really worried about it'

and:

> *'At the beginning I did not have had the confidence or knowledge, to design the teaching activities myself from scratch without the university sessions. Having the opportunity to plan and design my own experiments has enabled me to see how teaching activities could be designed to engage and motivate children.'*

Trainees appeared to be empowered by their university based sessions, despite their lack of classroom based experience. Probing additional questions during interviews showed that in the majority of cases (88%, n=14), university teaching had instilled in trainees a strong sense of commitment to ensure that they taught equitable amounts of science, rather than be left offering limited scientific experiences, they had only too often witnessed in school. As trainees said:

'I feel really motivated to teach science but it's from my science sessions in university and not from what I have seen or learned in school."

'I will be proactive in bringing science into the classroom as the freedom for children to discover things about the world around them is very important.'

Resourcing the science curriculum

Responses from the questionnaire in terms of resourcing for primary science teaching were very positive, (73%) rated the resources in schools as satisfactory or above. This was heavily corroborated by the interviews where trainees described most schools having a designated science equipment store. Some trainees said they had to be "creative" with respect to utilising equipment for several different purposes, but no trainee cited lack of resources as a limiting factor for science teaching.

Research question: Training opportunities and developing professional identity.

There were data to suggest that trainees' developing professional identity was impacted upon by the low profile of science on the curriculum in school. During the interviews they frequently expressed wishes to see more science in order for them to develop their practice and see themselves as teachers who could teach science. In the case of trainees in EYFS settings they expressed satisfaction at being afforded opportunities to develop this facet of their practice and were able to reflect on how this had impacted on their sense of teacher identity.

Discussion

Opportunities to observe science teaching on placement in school

In an ideal training scenario, trainees would be afforded numerous opportunities to shape their developing values and beliefs as advocated by Koskela and Ganser, (1998) and reviewed by Izadinia (2013). However this research clearly shows that this is far from the current reality for this sample of trainees. Flores and Day (2006) refer to "the gap between ideals" and the "real world" of schools and classrooms; it is clear from this study that the majority of trainee teachers did not find their experiences of school based science teaching ideal. Since trainee teachers spend much more time with their class teacher compared to that of their university science mentors, it is essential that relationships between trainee and class teacher provide a 'rich opportunity for guided growth' (Weasner and Woods, 2003:681) within the sphere of science pedagogy. For as McCullagh & Doherty (2016) note such rich collaboration between student and teacher is invaluable in the development of a student's class based practice.

Thus, one of the most concerning aspects of this study was how trainees' limited opportunities to observe science in schools influence their pedagogical specific training. Their feelings regarding what may be seen as science's reduced profile compared to numeracy and literacy supports research by the Wellcome Trust (2011), Ofsted (2013) and the Wellcome Trust and CFE Trust (2017) who similarly highlight the 'backseat' science now plays in its importance to the senior leadership of a school. It is however heartening to find that oasis of enthusiasm and time given over to this subject were detected from teachers who felt confident about teaching the subject. This resonates significantly with the work of Appleton and Kindt (1999) and more recently with that of Knaggs and Sondergeld (2015) who found high performing beginning teachers' self-confidence increased with greater teaching experience of science. This research suggests that, in order for trainee teachers to realise their full potential, and develop self-confidence it is essential that they are provided with opportunities to engage with the full range of curricular subjects and not just see a mainstay diet of literacy and numeracy. If we are truly to counter the reported lack of confidence of those teachers who have limited science qualifications and that of less than five years of teaching (Wellcome Trust CFE Research, 2017) then the increased profile of science must be seen as being of paramount importance in our schools. Not only to protect its future profile in our current school curriculum but to counter the reported huge reduction of girls now studying STEM subjects and the implication this has for the future take up of degree and level 4 science qualifications as reported by WISE (2017). Such diminished level of science qualifications must surely only be seen as being detrimental to the quality of our future student science teachers.

Trainees' confidence in teaching primary science

Postgraduate trainee teachers involved in this study clearly indicated the value they placed on appropriate school-based opportunities to observe and teach science during their initial training year, perceiving these to have direct impact on their confidence in teaching primary

science. They aspired to see context-specific modelling of science teaching in order to effectively reflect upon their own levels of efficacy. It is established that trainees require a breadth and depth of training opportunities both in and out of the classroom (De Juanas Olivaa et al., 2009; Marusic, Jugovic and Loncaric, 2017) so as to develop their confidence and enhance their level of pedagogy (Caires, 2012; Byrne, Rietdijk and Cheek 2016).

Findings indicate that the limited opportunities to experience and deliver primary science has perceived impact upon trainee confidence to teach science, as well as developing and extending their pedagogic skills.

Trainees' sense of professional identity

The minority of trainee teachers who were able to witness a variety of teaching approaches were often located in Foundation Stage settings. They reported strong feelings regarding the positive impact these opportunities had on their developing professional identity. For trainees to develop aspects of professional practice it seems evident that without these social interactions between trainee and class teacher, there is a limit to a trainee's ability to co-construct meaning relating to their science teaching. Such ideas have clear resonances with the work of McCullagh & Doherty (2016). Researchers such as Sammons et al. (2007) and Kington (2008) suggest that it is the situations in which trainees find themselves, that can shape (positively or negatively) an individuals' sense of professional identity. Pillen, Beijaard and den Brok (2013) describe in-depth the tensions beginning teachers experience as a result of shaping their professional identity, therefore it is not unreasonable to postulate that what they perceive as a deficit in their science training will exacerbate these struggles. Linked to this Davis and Smithey (2009:747) revealed that beginning teachers show a desire to "engage, interest and motivate" their learners, as well as themselves (Tonna and Shanks 2017); if these wishes are in conflict with what they see as school priorities this will further impede facets of their developing identity. This could suggest that the ability to not only experience high quality science teaching within a professional context but also feel that science teaching is a core subject within the curriculum is vital in influencing this aspect of trainee teacher's sense of emerging professional identity.

Towards a model of primary science preparation

The findings of this study, clearly portray how trainees are placed at the centre of many influences in terms of their school-based practice, university training and the wider school context which is often buffeted by external governmental influences. This complex interaction of the social, emotional, situational and regulatory arenas, has resonances with Bronfenbrenner's (1979) bio-ecological model. Findings from research such as the Wellcome Trust (2011) clearly indicate that changes in assessment requirements as determined by government policy (macrosystem), in turn contribute to a diminished profile of primary science in the curriculum (exosystem). This reduced profile of science is witnessed by trainees in terms of a reduction in the frequency and nature of primary science delivered in

schools (mesosystem) which ultimately results in the provision of little, if any, opportunities for trainee teachers to practice science pedagogy (microsystem).

[Figure 3 near here]

With this model in mind, if the current situation persists, there is a risk that a downward spiral will develop, characterised by the creation of newly qualified teachers who do not feel confident in their ability to deliver primary science. The implication could be that the professional development of these teachers in terms of science specific pedagogy could lag behind that of numeracy and mathematics, leading to a negative spiral for the maintenance of science teaching. Together with a constant pressure on curriculum time, this could lead to a further lowering of the profile of science in primary schools due to diminished teacher agency which, in turn, could influence teachers' positive sense of developing professional identity.

Limitations of the study

Inherent limitations

The authors acknowledge that there are some inherent limitations to the study; for example due to local and regional needs there may be some variations in training within ITE providers and school settings. In other geographical areas trainees may teach in settings with a higher or lower percentage of children with SEN or in areas where there are only primary and secondary schools. Alternatively some areas contain regional science learning centres which may alter the profile of science on the curriculum and hence change trainee classroom experiences. For these reasons it may not be possible to extrapolate the findings of this study to all areas of the U.K.

Methodological limitations

The main methodological limitation is that this research was undertaken with trainees enrolled at a single ITE provider, although this provider works in partnership with over four hundred different schools. In terms of the chosen data collection tools questionnaires rely on the respondents being honest although this is encouraged by the fact they are anonymous. Closed questions within questionnaires are thought to risk lack of coverage and authenticity, for this reason, open questions were included. It is possible that some questions might be misinterpreted by trainees, this was minimised by the researchers going through the questionnaire with trainees and clarifying questions before completion. The questionnaires were designed to be straight forward in structure and used language appropriate for a cohort of trainee teachers.

It can be argued that data derived from semi-structured interviews may be compromised by interviewer bias. In this case this was minimised by the researchers accepting their positionality, whilst making concerted efforts to not seek answers that supported their preconceived notions. Follow up questions were used to ensure interviewers understood what the respondents were saying. There may also be a tendency for trainee teachers due to their

inexperience to “acquiescence” (Breakwell, 2000:254) whereby they answer questions according to how they believe the interviewer would like them answered, regardless of their true feelings and ideas.

Using this study as a basis, future longitudinal research could explore the evolving professional identity of these trainee teachers as they complete their first induction year and the early phase of their teaching career. A larger nationwide study involving a range of training models including undergraduate, PGCE and School Direct provision is key to corroborate these findings and determine to what degree they represent primary science training provision in the UK. It is hoped that future research into this area will afford initial teacher preparation providers and partnership schools greater insight into what effective science-specific training entails.

Conclusions

At heart of this study was an exploration of science education within the context of the primary curriculum, and how its profile in schools is perceived to influence PGCE trainees’ developing professional identity. In agreement with Hong (2010) and Akerson et al. (2014) it has been demonstrated that trainees develop subject-specific knowledge, confidence and pedagogical ideas from their practice at university. However this is not enough and the lack of meaningful and successful school-based experiences not only limits trainees’ ability to embed and secure their practice but impacts negatively on their professional identity formation. The findings contribute to the growing awareness of the importance of training high quality science teachers across the entire science curriculum in order to produce scientifically competent learners. It should be of interest to teachers, schools, local authority policy makers, teacher educators and educational science trusts and governmental review bodies as it highlights the challenges and achievements of trainee teachers in this area of professional development.

Withstanding economic concerns, we presently find ourselves arguably at a time of huge societal pressure with respect to evolving technological capability and its concomitant ethical use. If well informed decisions and policy are to be made, it is essential that we foster and promote a high degree of scientific understanding throughout our society starting with our youngest learners. In the words of the French bacteriologist Pierre Emile Duclaux (1840-1904), ‘Science is a series of judgments, revised without ceasing’. If we are to ensure valid and well informed judgements in the future we must ensure all members of society receive effective science teaching throughout all phases of their education. This will only be achieved by ensuring training provision produces confident and competent teachers with a positive sense of professional identity with respect to science teaching, especially those practicing during the important formative years of young children’s learning.

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Figure captions:

Figure 1 shows the amount of science observed by trainees. It can be seen than overall the amounts are low, with 60% of trainees observing 15 minutes or less of science on average per week. It is notable that 20% of trainees were not able to observe any science at all.

Figure 2 shows the amount of lesson time spent science teaching by trainees. It can be seen that trainees' opportunities were limited, with only 18% being allowed to teach science for a mean amount of 35 minutes or above per week. A significant number (18%) were not allowed to teach any science at all.

Figure 3 shows the factors influencing the emerging professional identity of trainee primary teachers.

References

Appleton K. and Kindt I. (1999) Why teach primary science? Influences on beginning teachers' practices. International Journal of Science Education. 21 (2) 155-168. DOI: 10.1080/095006999290769

Avraamidou, L. (2014) Studying science teacher identity: current insights and future research directions. Studies in Science Education. 50(2) pp. 145-179 DOI:10.1080/03057267.2014.937171

Beauchamp, C. and Thomas, L. (2009) Understanding teacher identity: an overview of issues in the literature and implications for teacher education. Cambridge Journal of Education 39 (2) pp. 175-189 DOI :10.1080/03057640902902252

Beijaard, D., Meijer, P. and Verloop, N. (2004) Reconsidering research on teachers' professional identity. Teaching and Teacher Education 20 pp. 107–128

BERA (2011) Ethical Guidelines for Educational Research. https://www.bera.ac.uk/researchers-resources/publications/ethical-guidelines-for-educational-research-2011

Beyer, J. and Davis, E. (2011) Learning to Critique and Adapt Science Curriculum Materials: Examining the Development of Pre-service Elementary Teachers' Pedagogical Content Knowledge. Science Teacher Education 96 (1) pp. 130-157. DOI: 10.1002/sce.20466

Birks, M. and Mills, J. (2011). Grounded theory: A practical guide. Los Angeles, CA: Sage.

Boyle, B. and Bragg, J. (2006) A curriculum without foundation. British Educational Research Journal (24), pp. 569-582. DOI: 10.1080/01411920600775225.

Breakwell, G. (2000) Interviewing. In G. Breakwell, S. Hammond and C. Fife-Shaw (eds) *Research Methods in Psychology* (second edition). London: Sage, pp. 239-50.

Bronfenbrenner, U. (1979) The ecology of human development: Experiments by nature and design. Cambridge, MA: Harvard University Press.

Bryan, L. (2003) Nestedness of Beliefs: examining a prospective elementary teacher's belief system about science teaching and learning. Journal of Research in Science Teaching, 40(9), pp. 835-868. DOI: 10.1002/tea.10113.

Byrne, J., Rietdijk, W. and Cheek, S. (2016) Enquiry-based science in the infant classroom: 'letting go', International Journal of Early Years Education, 24:2, pp. 206-223 DOI:10.1080/09669760.2015.1135105

Caires, S., Almeida, L. and Vieira, D. (2012) Becoming a teacher: student teachers' experiences and perceptions about teaching practice. European Journal of Teacher Education volume (35) pp. 163-178. DOI:10.1080/02619768.2011.643395

Cochran, K. (1997) Pedagogical Content Knowledge: Teachers' integration of subject matter, pedagogy, students, and learning environments.
https://www/narst.org/publications/research/pck.cfm

CBI (2014) Gateway to growth. CBI/Pearson Education skills survey 2014
http://www.cbi.org.uk/media/2807987/gateway-to-growth.pdf.

Davis, E and Smithey, J. (2009) Beginning Teachers Moving Toward Effective Elementary Science Teaching. Science Education 93(4) pp. 745-770. DOI 10.1002/sce.20311

Danielsson, A. and Warwick, P. (2014) "You have to give them some science facts'; primary student teachers' early negotiations of teacher identities in the intersections of discourses about science teaching and about primary teaching. Research in Science Education 44 pp. 289-305 DOI 10.1007/s11165-013-9383-9

Day, C. and Kington, A. (2008). Identity, well-being and effectiveness: the emotional contexts of teaching. Pedagogy, Culture and Society. 16(1), 7-23.
DOI:10.1080/14681360701877743

De Juanas Olivaa, A., Fernández Lozanoa, P., Martín del Pozoa, R.,, González Ballesterosa, M., Pesquero Francoa, E. and Sánchez Martína, E. (2009) Comparative study of the evaluation of professional competencies by experienced and trainee Spanish primary teachers. European Journal of Teacher Education (32), pp. 437-454
DOI:10.1080/02619760903005823

Denzin, N. (2001) The reflexive interview and performative social science. Qualitative Research. 1(1) pp. 23-46. DOI: 10.1177/146879410100100102

DfE (2011) Guidance: Teachers' standards.
https://www.gov.uk/government/publications/teachers-standards

DfE (2013) National curriculum in England: science programmes of study.
https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study

DfEE (1999) The National Curriculum: Handbook for primary teachers in England Key stages 1 and 2.
http://www.educationengland.org.uk/documents/pdfs/1999-nc-primary-handbook.pdf

Evans, L. (1998) Teacher, morale, job satisfaction and motivation. Thousand Oaks, CA: Sage.

Flores, M. and Day, C. (2006) Contexts which shape and reshape new teachers' identities: A multi-perspective study. Teaching and Teacher Education 22 pp. 219-232.

Freese, A. (2006) Reframing one's teaching: Discovering our teacher selves through reflection and inquiry. Teaching and Teacher Education 22 (2006) pp.100–119.

Galton, M. (1995) Crisis within the Primary Classroom. London: David Fulton.

Hargreaves, A. and Goodson, I. (2006) Educational Change Over Time? The Sustainability and Nonsustainability of Three Decades of Secondary School Change and Continuity. Educational Administration Quarterly 42, (1) pp. 3-41

Hong, J. (2010) "Pre-Service and Beginning Teachers' Professional Identity and Its Relation to Dropping Out of the Profession. Teaching and Teacher Education: An International Journal of Research and Studies, 26 (8) pp.1530-1543

Koskela, R., and Ganser, T. (1998) The cooperating teacher role and career development. *Education,* 119 (1), pp.106-114.

Knaggs, C. M. and Sondergeld, T. A. (2015), Science as a Learner and as a Teacher: Measuring Science Self-Efficacy of Elementary Preservice Teachers. School Science and Mathematics, 115: pp.117–128. DOI:10.1111/ssm.12110

Kvale, S. (1996) Interviews and introduction to qualitative research interviewing. London SAGE, chapter 7: The interview situation pp. 124-135.

Lasky, S. (2005) A sociocultural approach to understanding teacher identity, agency and professional vulnerability in a context of secondary reform. Teaching and Teacher Education. (21) pp. 899-916. DOI:10.1016/j.tate.2005.06.003

Lee, H., Longhurst, M. and Campbell, T. (2017) Teacher learning in technology professional development and its impact on student achievement in science.
International Journal of Science Education 39 (10) pp. 1282-1303

Lieber, E., and Weisner, T.S. (2010). Meeting the practical challenges of mixed methods research. In Tashakkori, A. and Teddlie, C. (Eds.), Sage handbook of mixed methods in social & behavioral research (2nd ed.), pp. 559-579. Thousand Oaks, CA: SAGE

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. Eds. (1999) *Examining Pedagogical Content Knowledge*. Dordrecht: Kluwer Academic Publishers pp. 95–132.

Marušić, I., Jugović, I. and Lončarić, D. (2017) Approaches to learning of first-year and fifth-year student teachers: are there any differences? European Journal of Teacher Education 40 (1) pp.62-75.

McCullagh, J. and Doherty, A. (2016) Innovative approaches within Initial Teacher Education to develop emergent science leaders. The Journal of Emergent Science, Issue 12, pp. 55-63

Miles, M. and Huberman, A. (1994) Qualitative Data Analysis (2nd edition). Thousand Oaks, CA: Sage.

Mulholland, J. and Wallace, J. (2003) *Facilitating* primary science teaching: a narrative account of research and learning, Teachers and Teaching: Theory and Practice, 9(2), pp. 133-155. DOI:10.1080/13540600309374

Nias, J. (1989) *Primary teachers talking: A study of teaching as work.* New York: Routledge.

Ofsted (2013) Maintaining curiosity: a survey into science education in schools. http://www.ofsted.gov.uk/sites/default/files/documents/surveys-and-good-practice/m/Maintaining%20curiosity%20a%20survey%20into%20science%20education%20in%20schools.pdf

Ofsted (2016) HMCi's commentary: science and foreign languages in primary school. https://www.gov.uk/government/speeches/hmcis-monthly-commentary-may-2016

Pellett, T., Strayve, K., and Pellett, H. (1999) Planning for Student-Teaching Success: A Guide for Cooperating Teachers. Journal of Physical Education, Recreation & Dance. 70(5), pp. 50-54. DOI:10.1080/07303084.1999.10605935

Pillen, M., Beijaard, D. and den Brok, P. (2013) Tensions in beginning teachers' professional identity development, accompanying feelings and coping strategies. European Journal of Teacher Education. 36 (3) pp. 240-260 DOI/10.1080/02619768.2012.696192

Sammons, P., Day, C., Kington, A., Gu, Q., Stobart, G. and Smees, R. (2007). Exploring variations in teachers' work, lives and their effects on pupils: key findings and implications from a longitudinal mixed methods study. British Educational Research Journal. 33(5), 681-701. DOI:10.1080/01411920701582264

Sammons, P., Taggart, B., Sylva, K., Melhuish, E. C., Siraj-Blatchford, I., Barraeu, S. and Manni, L. (2006) Effective Pre-school and Primary Education 3-11 Project (EPPE 3-11): Variations in Teacher and Pupil Behaviours in Year 5 Classrooms and Associations with School Characteristics. London: Institute of Education, University of London http://www.ioe.ac.uk/schools/ecpe/eppe/eppe3-11/eppe311pubs.htm

Serrett, N., Harrison, C., Correia, C. and Harding, J. (2016) Primary Teachers' Understanding of Science Inquiry: Influences On Their Teaching and Formative Assessment Practice. https://www.researchgate.net/publication/301198012_PRIMARY_TEACHERS%27_UNDERSTANDING_OF_SCIENCE_INQUIRY_INFLUENCES_ON_THEIR_TEACHING_AND_FORMATIVE_ASSESSMENT_PRACTICE

Smith, R. (2007) Developing professional identities and knowledge: becoming primary teachers. Teachers and Teaching: theory and practice. 13(4), pp. 377-397. DOI:10.1080/13540600701391937

Sjoer, E. and Meirink, J. (2015) Understanding the complexity of teacher interaction in a teacher professional learning community. European Journal of Teacher Education. 39(1) pp. 110-125 DOI10.1080/02619768.2014.994058

Sydnor, J. (2016) Using Video to Enhance Reflective Practice: Student Teachers' Dialogic Examination of Their Own Teaching. The New Educator 12(1) pp. 67-84 DOI:10.1080/1547688X.2015.1113346

Tashakkori, A. and Teddlie, C. (2010) "Epilogue: current developments and emerging trends in integrated research methodology", in in Sage Handbook of Mixed Methods in Social & Behavioral Research, Tashakkori, A. and Teddlie, C. (Eds) 2010, Sage, California, pp. 803-826.

Tonna, M. and Shanks, R. (2017) The importance of environment for teacher professional learning in Malta and Scotland. European Journal of Teacher Education 40 (1) pp. 91-109 | DOI:10.1080/02619768.2016.1251899

Wellcome Trust (2011) Primary Science Survey Report. London: Wellcome Trust.

Wellcome Trust (2014) Primary Science: Is It Missing Out? https://wellcome.ac.uk/sites/default/files/primary-science-is-it-missing-out-wellcome-sep14.pdf

Wellcome Trust CFE Research (2017) 'State of the nation' report of UK primary science education. London: Wellcome Trust. https://wellcome.ac.uk/sites/default/files/state-of-the-nation-report-of-uk-science-education.pdf

Weasner, J. and Woods, A. (2003). Mentoring: Professional development through reflection. The Teacher Educator, 39(1), pp. 64 -77. DOI:10.1080/08878730309555330

Wilson, E., Bradbury, L. and McGlasson, M. Integrating Service-Learning Pedagogy for Preservice Elementary Teachers' Science Identity Development (2015) Journal of Science Teacher Education 26(3) pp. 319-340 DOI: 10.1007/s10972-015-9425-4

WISE (2017) The STEM Education Pipeline 2017. https://www.wisecampaign.org.uk/resources/2017/11/from-classroom-to-boardroom-the-stem-pipeline-2017

Van Driel, J., Verloop, N. and De Vos, W. (1998) Developing science teachers' pedagogical content knowledge, Journal of Research in Science Teaching, 35, pp. 673–695. DOI: 10.1002/(SICI)1098-2736(199808)35:6

Volkmann, M., and Anderson, M. (1998). Creating professional identity: Dilemmas and metaphors of a first-year chemistry teacher. Science Education, 82(3), pp. 293–310.