Subject knowledge or pedagogical knowledge to teach? Perceptions of student teachers on effective preparation to teach primary science

Teacher Education Advancement Network Journal
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University of Cumbria
Vol 11(4) pages 57-67

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Abstract
As a teacher educator, feedback from students is important to ensure there is time for my own reflection to inform and develop my practice and curriculum design within formal expectations of initial teacher education. This paper considers the perceptions and expectations of a sample of student teachers, situated in a Higher Education Institution (HEI) in the UK, of teaching primary science and the perceived subject knowledge required. The recommendations from this paper highlight the importance of ensuring that teacher educators support the development of competent practitioners to address concerns about subject knowledge and developing confidence in teaching primary science. The findings concur with previous research into how best to support low confidence of student teachers to teach science, support the perception of the importance of what you know and what you need to know to teach, as well as a need for fixed ideas even in pedagogical knowledge. As I was able to identify similar themes from student feedback as highlighted in my review of the literature, this adds support to those studies. This paper recommends that we explore and raise awareness of pre service teachers' conceptions about what it means to teach primary science, to be more explicit about looking at and signposting the different types of knowledge involved in teaching and to consider how renaming the science subject knowledge sessions can eliminate misconceptions about their purpose.

Keywords
Subject knowledge; initial teacher education; primary science; confidence, conceptions.

Introduction
This paper will consider which aspects of subject knowledge would be effective and appropriate for preparing students to teach primary science. One of the aims of this research was to seek more clarity between subject knowledge and pedagogical knowledge required to teach as my students displayed different perceptions of what they received and what they hoped for from the subject knowledge sessions. As a former classroom teacher, I found from experience that being an expert in a particular subject does not necessarily make teaching effective (Ball, 2000). It is important to be able to deconstruct one's own knowledge as it is vital for teachers to be able to work with their students in their 'growing and unfinished' state (Ball, 2000, p. 245). A wide variety of experiences regarding our students' teaching of science was evident. Some of the student teachers who are on school placements throughout their course had gained extensive science teaching experience whereas some students do not experience science teaching during one or more phases of training. This is very much dependent on school approaches to timetabling primary science. This reflects the variability in science teaching across primary schools presented in Her Majesty's Inspectorate (HMI) monthly commentary (Ofsted 2016) and the opportunities for student teachers to observe or teach. In light of this, it could therefore be considered that some schools are not providing sufficient opportunities for primary student teachers' appropriate learning in science, however, this is very much context driven. My review of the literature also uncovered opposition to the concept of Pedagogical Content Knowledge (PCK) as Ellis (2007) highlights Shulman's (1986) framework as problematic, as subject knowledge is not fixed. I feel that this is a particularly valid point when considering the nature of teaching primary

Citation
Wilberforce, C. and Pratt, A. (2019) 'Subject knowledge or pedagogical knowledge to teach? Perceptions of student teachers on effective preparation to teach primary science', *TEAN journal,* 11(4), pp.57-67.

science where research and development of technology have enabled us to improve, update and discover new knowledge about ourselves, the world around us and beyond, and continues to move forward.

The research focus was to explore what provides student teachers with the competence to teach through a critical evaluation of the importance of subject knowledge and pedagogical knowledge to teach in the primary science context. This research will therefore consider recommendations for future practice regarding perception of subject knowledge competence in primary science and balance this with current research perspectives. Potentially the findings of my research may contribute to small changes at an institutional level, disseminated via our students into classrooms around the locality. Drawing the research together, the aim is to inform the education community on students' perceptions of subject knowledge competence to teach primary science and make recommendations on effective teaching of primary science subject knowledge within my programme.

Literature Review

Teacher subject knowledge assumes that the more knowledge of their subject that a teacher has then the better the outcomes are for their students. This is not a new concept (Ellis, 2007). Historically, teacher education courses were designed around strict criteria of which there was a focus on subject knowledge and skills needed to produce effective classroom teachers (DfE (Department for Education), 1993). Menter, Brisard and Smith (2006) examined this approach in a comparison of professional knowledge for initial teacher education where concern was expressed at teaching being reduced to a list of behaviours to be observed to meet standards. Furlong (2000) states clearly that *'*the majority of teacher initial education courses were training how to teach not what to teach' (Furlong et al., 2000, p.11). This concurs with Shulman's view (1986) that understanding of knowledge alone does not make someone a teacher. Shulman identifies pedagogical content knowledge, part of the knowledge base for teachers, as the unique knowledge of teaching that blends content and pedagogy, since *'*mere content knowledge is likely to be as useless pedagogically as content-free skill' (1986, p.8). He advocates that teachers need knowledge of strategies in reorganising the understanding of learners taking into account prior knowledge and the teachers' ability to transform their own knowledge into teaching others.

Ball (2000) ascertains that the answer to this quandary must contain elements of both, which reflects the way teacher education courses are structured to divide subject material from pedagogical approaches. This therefore leaves teachers with the difficult task of integrating subject knowledge and pedagogy into their everyday practice for themselves as a result of the limitations highlighted in the literature. Herein lies a fundamental difficulty with learning to teach 'as knowing subject matter and being able to use it is at the heart of teaching of all students' (Ball, 2000, p. 243). However, there is little factual evidence to link teachers' subject knowledge to the learning of their students (Goulding, Rowland and Barber, 2002; Appleton, 2003).

Research by the Wellcome Trust (2014) explored how science expertise was being used in primary schools. Their findings highlighted weak strategic leadership for this subject with little accessibility to high levels of science expertise in a number of schools. Despite becoming a core subject in the primary curriculum in 1989, concerns have continued to be raised about teachers' weak subject knowledge and its impact on pupils' development in science. The Wellcome Trust's 'State of the nation' report of UK primary science education (2017) and Ofsted's (2019) recent phase 3 curriculum research into primary school science have again identified issues with the provision of this core subject. Within the small number of schools sampled, teachers' subject knowledge and planning were not supporting pupils' understanding. Ofsted (2019) concluded that deeper subject knowledge is required of teachers and that curriculum design needs to be addressed amid concerns that the depth and breadth of pupils' knowledge and understanding will impact upon their interest and participation in this subject area at

secondary level. Murphy, Neil and Beggs (2007) call for Higher Education Institutions (HEIs) to play their part in preparing our future primary teachers by addressing the concerns of teachers' lack of confidence and expertise in science teaching. Confidence to teach primary science is a recurring theme throughout the literature and is inextricably linked to weak subject knowledge (Harlen, 1997; Harlen and Holroyd, 1997; Appleton, 2003 and Nilsson and van Driel, 2010). As a teacher educator with responsibility to deliver science sessions to our students, I need to address this lack of confidence to impact positively on the future practice of science teaching and learning.

Further investigation demonstrates how important the attitudes and beliefs of students are as they enter teacher education programmes relating to confidence to teach science (Gunstone and Northfield,1992 cited in Skamp and Mueller, 2001; Tobin, Tippins and Gallard, 1995 cited in Skamp and Mueller, 2001; Appleton, 1995; Parker and Spink, 1997; Appleton, 2003 and Fuentes, Bloom and Peace, 2014).The influence of students' conceptions about their own learning of science and the teaching of science revealed the importance of raising students' awareness of their own conceptions. These conceptions could then be developed and/or changed and possible problematic concepts could be challenged and addressed resulting in more effective practitioners in the classroom. There is also recognition of the role of the teacher educator being aware of their students' conceptions to support and better meet the needs of their cohort (Appleton, 1995; Harlen, 1997; Harlen and Holroyd, 1997; Nilsson and van Driel, 2010). It is therefore clear that further research into developing effective subject knowledge in our primary teachers is needed (Poulson, 2001 and Ball; Thames and Phelps, 2008) and taking into account the perspectives of the students themselves is where this research starts.

Methodology

For the purposes of this research, action research was an appropriate method for exploring the perceptions of student teachers to see if their needs are being met in terms of effective preparation to teach primary science, focused on professional change or improvement. Kemmis presents action research as 'practice -changing practice' (2009, p.464) This appropriately reflects the ongoing issue to look at not why, but how to bring about change to improve practices that impact on the teaching of primary science. This reflects Ferrance's (2000) definition of the purpose of action research.

Both Sikes (2006) and Zeni (1998) discussed the dilemmas that researchers face due to their institutional roles as they try to balance their responsibilities for their students with their research. Often referred to as 'insider research', it is difficult for any practitioner to find a neutral vantage point. As you set out to solve a problem or an issue in your everyday practice, you automatically compromise any objectivity, and tensions between your role and your well-meaning research are created. Issues such as the influence of relationships between you and your participants, impartiality, difficulties in eliminating influences of your day to day teaching role, and impact on student teacher workload can all surface as the roles of practitioner and researcher are reversed.

Research Design

The target group for this research was the Primary Postgraduate Diploma in an Education (PGDE) cohort of 128 student teachers at a university in the North West of England. Within this population three subgroups were identified: School Direct students who received their subject knowledge input off site; 3-7 primary PGDE students; and the 5-11 Primary Core PGDE students. I chose to target the 5-11 group, of which there were 30 students, as they had received the same input in terms of their subject knowledge sessions. These sessions were delivered before October half term as part of Subject Knowledge weeks, where English, mathematics and science were timetabled. The aims of the science sessions were to introduce students to key ideas and concepts, scientific vocabulary, common misconceptions and a variety of teaching strategies through some of the primary curriculum content. Despite being labelled as 'subject knowledge' there was a focus on the context and pedagogy for teaching and learning not just content. As this was a small-scale and subject focused study Denscombe

(2014) recommends a more pragmatic approach to sampling which was the approach used in this research. The questionnaire was sent out electronically as students were out on their final placements in schools and seven responses were received. As some of the questions involved reflecting on the impact of university led sessions and placement experience this seemed the most appropriate time to ask students to complete the questionnaires, but unfortunately as I was unable to discuss the aims of the research face to face, the response rate was lower than expected.

A questionnaire was used since it is a method that can collect lots of data quickly and as I had a relatively small window of opportunity to collect this data this seemed the most effective way. By using a questionnaire, no interviewer was involved and so my questions could be presented to all participants in the same way creating a controlled environment and reducing the possible factors that could influence the responses given. Both qualitative and quantitative data were captured through the questionnaire. The questions were designed due to the emerging themes of the influence of students' attitudes and beliefs and the fact that there seemed to be an observed potential divide from the literature between perceptions of training in University sessions and training while on school placement. The final questions were designed as reflective, to find out what impact the science subject knowledge sessions had on the student and their ability to teach primary science. This is a deductive approach rather than an inductive approach (Menter et al., 2011) as I am not using the data to produce theories for research but to test existing ones for my research. Since I am using key themes from the literature review in order to do this, my data analysis also has a thematic, comparative perspective.

Analysis of findings

The findings of this research will now be presented and analysed through the key themes identified from the literature review.

Student experience

Students' responses to questions regarding their background experience established a link between the level of study and time elapsed since study of science. Five out of the seven participants only studied science up to GCSE level and five out of the seven participants had not studied science for a period of five years or more. Past learning experience influences conceptions of teaching according to studies by Parker and Spink (1997) and Appleton (2003). Questions about academic background of the participants revealed that in line with these studies many of my participants had not studied science beyond GCSE and therefore had experienced a gap since studying and starting this course. This experience influenced confidence as found in Appleton's study (2003), as participants indicated they did not feel confident in primary science on starting the course. Unlike Parker and Spink (1997) the research found that the participants had a positive attitude towards science and that despite their own scientific background did not consider themselves as 'failed learners'. From their responses one reason given for this was the influence of their own teachers which was not addressed within the literature. Two of the participants clearly indicated that the role of their teachers was key to their enjoyment of their own experience of learning science due to the care, motivation and inspiration these individuals provided.

Use of subject knowledge audits

In the questions which explored students' attitudes and beliefs about science teaching (four, five and six), overwhelmingly (five out of seven) participants suggested that they would find a science subject knowledge audit useful, as is the practice with the other core subjects. Interestingly, only one response highlighted the potential difficulty in assessing knowledge in such a fixed way without a context.

Question five, which looked at confidence of the students to teach science prior to the course, found four out of seven of the participants were not confident on entry to the course and only one expressed confidence to teach science from the start. More detailed comments revealed two key themes, one

being of the importance of knowledge as one respondent expressed it as: *"*it will show what we know and what we need to know*"* (Participant A). The importance of pedagogical knowledge also came through in comments about recognising their own misconceptions and realisation that perceptions may not be that different from the children being taught.

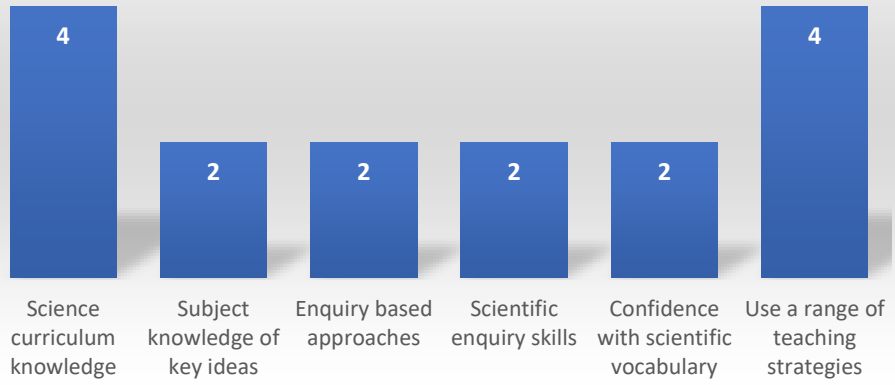
It is evident that despite being a core subject science is not given the same focus in primary schools as discussed in reports from the Wellcome Trust (2014) and Ofsted (2016). The role of audits in subject knowledge to teach is discussed in the literature, and despite policy advocating that HEIs audit student knowledge appropriately, Goulding, et al. (2002) do not view them as a favourable tool to measure subject knowledge as they can negatively reinforce a lack of confidence in the student if gaps are identified in their knowledge. This overall response to the use of audits confirms the focus highlighted by Loughran and Russell (2014) that practitioners, early in their careers, focus on what they need to know as audits do not incorporate pedagogical knowledge and perhaps there needs to be a consideration of both.

Preparation to teach

Student teachers were asked (question six) to identify aspects of the course that helped to develop their subject knowledge to explore a possible divide between university led parts of the course and the school placement. This question divided opinion as four out of seven participants said both university subject knowledge sessions and school placement were important to their subject knowledge development whereas the remaining participants (n=3) attributed their subject knowledge development to placement only. Despite the differences in opinions, the same themes emerged; that planning and teaching on placement are key to their subject knowledge development. This highlights the divide between university and placement which concurs with studies such as Shallcross et al. (2002) where the school experience is more highly valued by students over university-based learning. Participants indicated that planning and delivery of lessons while in school helped more in their subject knowledge development, again supporting the findings of Shallcross et al. (2002). While four out of seven recognised that the 'what' and the 'how' of teaching were of equal importance, the remaining three participants felt the 'how' was more important while they were on placement, which agrees with Ellis (2007). Interestingly some (n=2) identified that university subject knowledge sessions raised common misconceptions and enabled them to revisit and consolidate their knowledge and highlighted the link to school as the place to put it into action.

How subject knowledge sessions supported the experience while on placement were considered (question seven). There was a range of responses that indicated that there was no significant gap in any aspects of the sessions. The most popular choices the participants made were subject knowledge of the curriculum and the range of teaching strategies as shown by figure 1.

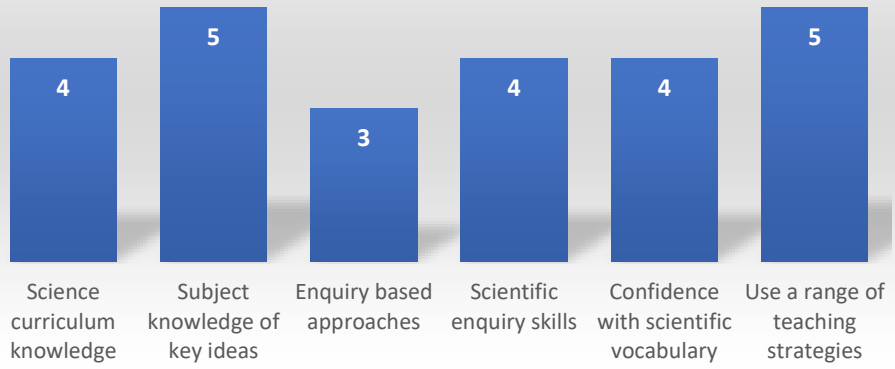
Figure 1 shows responses to question 7 : Did the science subject knowledge sessions support your experience of teaching on placement in schools in the following aspects?



Participants indicated a variety of aspects of the subject knowledge sessions that supported them on placement – how to present ideas, pedagogical strategies, how to find out and understand for themselves, to gain lesson plans and structure to their teaching – all highly valued. Which aspects had most impact on the students' preparation to teach science were considered and the importance of understanding 'how to teach' was a strong theme to emerge. Other themes that supported this research included the understanding of what they know and what they need to know which also corroborates with the positive response to the use of a science audit in question four. By looking at these responses in more detail participants indicated the importance of being able to convey knowledge over their own understanding of the subject alone supporting Shulman's (1986) view and reinforcing Appleton's statement that teachers with more subject knowledge will be better teachers as too simplistic (2003).

Which aspects from the science subject knowledge sessions students felt more confident about now they were near to completing the course were explored as shown by figure 2.

Figure 2 shows the responses to question 9: Now you are near to completing this course, how confident do you feel about teaching science? Identify the aspect of science you fell MOST confident with.

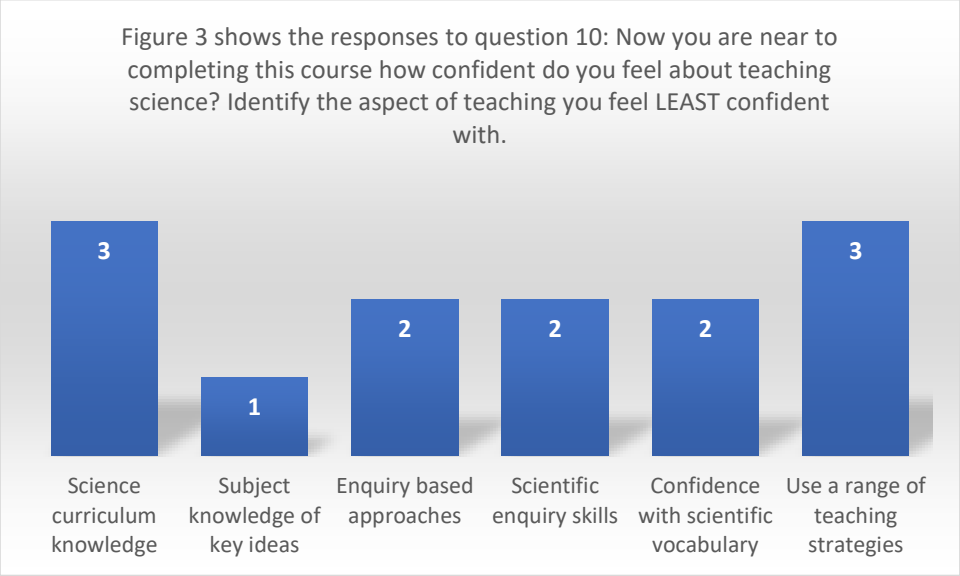


The variety of answers given indicates that there are no significant gaps in the provision of the sessions, which is reassuring. However, this could indicate a lack of meeting individual needs or

awareness of what those needs are and therefore needs cautious interpretation. Several themes emerged – confidence, knowledge, grades, pedagogy, divide between university and school – many of which were also evident from the literature considered earlier in this paper. Intriguingly two of the participants linked their confidence to the grades they gained for the teaching practice element of the course. They used the outcome to confirm their feelings of confidence and not the other way around. This was the only theme not identified from the literature review and was an interesting response.

Responses regarding which aspects of the subject knowledge sessions were not useful in supporting students on placement were very varied indicating the range of individual needs that perhaps are not being met or even addressed. Once again, reasons for some of the responses revealed similarities in studies conducted about student teachers' perceptions of subject knowledge. One participant felt enquiry- based approaches were most beneficial as it allowed them to *"*find out answers for ourselves*"* (Participant D) allowing them to be involved in the construction of their own knowledge as advocated in Nilsson and van Driel's study (2010).

It was interesting to see that for the aspect they were least confident about (question ten) most participants only ticked one response. There was a range of different responses from my participants, which may show that there are no significant gaps in the sessions, but this may also mean we are not catering for individual needs as shown by figure 3.



Consideration of less positive views of their experience were also explored, the least confident aspect and the theme to emerge from reasons for their choices was the lack of time they had to teach science while on placement. Identifying their least confident aspect of science teaching again produced a variety of answers reflecting individual needs. However, when looking at the reasons behind their choices, common themes emerged about the lack of confidence linked to the amount of time they had teaching science on placement. Limited experience of teaching science may be due to issues of time available for science in the curriculum and teacher confidence as highlighted in reports by Harlen (1997), Wellcome Trust (2014), Ofsted (2016). This also reflects differences yet again in our students' experience in science teaching while on placement.

Participants were invited to outline any changes and or improvements they would make to the subject knowledge delivered on the course. The most common theme was that of knowledge of the National Curriculum (DfE, 2014), which highlights their need to know what they need to teach, as discussed earlier in the literature review aspect of this paper, reflecting the importance of knowledge and fixed

knowledge of the student. Interestingly, one participant asks for more planning opportunities for units of work which Appleton (2003) suggests would be more beneficial for students in developing conceptual understanding of science and its teaching and is a timely link at the inception of the new Ofsted framework (2019) and the focus on curriculum.

The final question returned to the original research question where there was overwhelming agreement from all students that both subject knowledge and knowledge to teach makes teaching effective. So, despite expressing that both are of equal importance to effective teaching, their answers actually reveal that subject knowledge is of greater value to them. In the same way, other answers reveal that participants see pedagogical knowledge to teach of more value, and, in trying to justify their answer, contradict themselves by discussing the importance of both elements.

By giving the participants the opportunity to explain their answers, their reasoning can give a further insight into responses. For example, one participant discussed the importance of using sessions to pick up, take away and deliver lessons in school despite clearly stating in another question that to understand how they need to teach had the most impact on preparing them to teach. This shows that their understanding of 'how' is fixed and knowledge based rather than pedagogical in focus. In contrast to this point of view another participant found the range of teaching strategies from the subject knowledge sessions most useful but from their more detailed response they interpreted this as the number of different lessons that were used as contexts in the sessions. They found that the fact that they were able to take one lesson into school and copy was useful, supporting Ellis' (2007) idea that the 'how' to teach may in fact not mean the pedagogical idea it implies but more fixed ideas that they can replicate for themselves.

Conclusion

The aims of this research were to identify the perceptions of student teachers on effective preparation to teach primary science, and to explore as a teacher educator how we can support the development of our students through the subject knowledge sessions we provide. This research, while not statistically significant due to the small number involved, provided my practice with data to support some of the themes regarding student perceptions on effective preparation to teach primary science. My key findings support my knowledge of working to develop low confidence of student teachers to teach science at the start of the course. This low confidence is informed perhaps by a lack of recent study experience in science and supports the perception of the importance of what you know and what you need to know to teach and considered through use of audits by students. However, some student teachers expressed that it is the 'how' of teaching that has had most impact on their preparation to teach due to their need for fixed ideas even in pedagogical knowledge just as some focus in on subject knowledge.

Parker and Spink (1997) call for ITE programmes to consider the attitudes and beliefs of students about teaching in order to challenge perceptions, ensuring we are developing effective practitioners as little has changed in addressing this over time (Ofsted 2016). The theme around student teachers' attitudes and beliefs about teaching emerged from several studies, confirming to me how important it is for us as teacher educators to consider and challenge their conceptions if we are to support their development. I personally found the concept of 'filter' reasoning by student teachers (Skamp and Mueller 2001) of particular interest to consider as an influential factor on their attitudes and beliefs about teaching and will take this forward in my research and teaching.

The key findings from this research support that there is low confidence of students to teach science at the start of the course, this is due to a lack of recent study experience in science and is justified. This therefore supports the perception of the importance of what you know and what you need to know to teach. And, although considered through the use of audits by student teachers, some express

that it is the 'how' and pedagogy of teaching that has had most impact on their preparation to teach. In conclusion, therefore, this small-scale research has highlighted the importance of finding out about the conceptions of student teachers about science and science teaching at the outset of the course and not exemplifying what they do not know to undermine this confidence. However, it is necessary to challenge attitudes and beliefs. My research revealed the student teacher perceptions of the importance of what you know and what you need to know to teach through use of audits is valued. Expression that it is the 'how' of teaching that has had most impact on their preparation to teach in this study is due to their need for fixed ideas, even in pedagogical knowledge just as some focus is on subject knowledge, to support their development as an effective teacher of primary science. Therefore, a balance is required considering early perceptions and individual needs of the student teacher.

Recommendations

This small-scale study has signposted a few issues that will be useful to inform not only my own future practice but would be beneficial to other teacher educators too:

- It is recommended that the starting points of student teachers regarding their own level of study, time since study and confidence to teach science and their prior learning are captured as a baseline assessment in order to support the needs of all students with their subject knowledge development.
- Encourage student teachers to share their values, beliefs and attitudes of teaching in order for us to challenge and support their development as practitioners. By raising their own awareness of what it means to teach primary science this will counteract the 'filter effect' (Skamp and Mueller, 2001) that their conceptions may have on how they interpret information about teaching primary science.
- Separate subject knowledge sessions should be rebranded to bring pedagogy into focus and create a more cohesive approach, avoiding misconceptions of subject knowledge sessions to consider the 'what' and the 'how'. Through more explicit signposting regarding the different types of knowledge acquired during teaching of primary science this will help to bridge the perceived university and placement divide.

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