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The development of physics subject knowledge by student science teachers

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Abstract

Inadequate supply of new secondary school physics teachers in England is a widely reported concern. One solution is the provision of Subject Knowledge Enhancement (SKE) courses intended to develop the physics subject knowledge of non-physics graduates so they can enter an Initial Teacher Education (ITE) course to become physics teachers. Although the effectiveness of SKE courses for developing students' subject understanding has been researched, little attention has been given to examining students' experiences of engaging with a subject they have perhaps not studied since A-level in school. My research explores the cases of 9 SKE course students in one English university to examine how their conceptualisations of physics subject knowledge for teaching evolve over time, and their perceptions of effective approaches for supporting its development. The aim is to develop insights that can be used to inform ITE practice and to form the starting point for a possible longer-term longitudinal study into these participants' experiences as they progress in their teaching careers. In this article I share some of the early emergent themes from initial analysis of longitudinal data from one participant.

Introduction

This article shares my EdD (Doctorate in Education) research as work-in-progress as I engage in early data analysis. My project is in the area of student teacher subject knowledge development and arose from the challenge I experienced as a novice teacher educator to support students effectively on a new type of subject knowledge enhancement course. First I will describe the national context for my research and how this manifests itself in my particular research setting. I will then outline the research approach and discuss some examples of early data analysis and the impact on my practice so far.

The Research Context

To be employed as a teacher in state schools in England and Wales, student teachers must gain Qualified Teacher Status (QTS) by demonstrating they have met a series of professional standards. There are a variety of Initial Teacher Education (ITE) routes that lead to the award of QTS, with one of the most common routes for prospective secondary school teachers being the Post-Graduate Certificate in Education (PGCE) course. A PGCE course is led by a University in partnership with local secondary schools. Of the QTS Standards, Standard 3 addresses a teacher's subject knowledge and states that a teacher should "demonstrate good subject and curriculum knowledge" (Dept. for Education, 2012), and must:

- have a secure knowledge of the relevant subject(s) and curriculum areas, foster and maintain pupils' interest in the subject, and address misunderstandings
- demonstrate a critical understanding of developments in the subject and curriculum areas, and promote the value of scholarship

Although teachers are required to have a bachelor's degree, Standard 3 does not require the degree to be in the subject the teacher is preparing to teach. There is an "accepted wisdom" (Kind, 2009, p.1531) that science teachers are more effective if they teach within their own subject specialism, and most ITE routes and schools prefer candidates to hold bachelor's degrees in the subject they will be teaching. However, the shortage of supply of new teachers in physics (Smithers and Robinson, 2008; Institute of Physics, 2001) led to the government supporting the creation of Subject Knowledge Enhancement (SKE) courses, which aim to support non-physics graduates to develop their physics subject understanding sufficiently to be able to enter a subsequent PGCE course (Dept. for Education, 2013; Ireson and Twidle, 2004). Such courses have now been running for several years in some English universities and their effectiveness at improving students' conceptual understanding, compared to student teachers who have a physics bachelor's degree, has been researched elsewhere (e.g. Angell et al., 2005).

I was a member of the science education team at an English university that developed and implemented a Physics SKE course from September 2008. This course recruited graduates with a variety of bachelor's degree backgrounds, ranging from humanities to psychology, and increasingly in recent years, biological sciences (see Inglis et al. (2013) for a detailed description of the course design and history). Working with SKE students challenged my existing notions of the physics subject understanding that is important for becoming a physics teacher, and how to support students as they engage with a subject they have perhaps not studied since A-level in school, leading to three research questions: (1) what are physics SKE students' conceptualisations of physics subject knowledge for teachers? (2) how do these conceptualisations develop during ITE? and, (3) what teaching and learning approaches do the students experience as significant for their subject knowledge development?

The Research Methodology and Methods

My research started out as a practitioner enquiry using my home institution as a case of one particular Physics SKE course. I opted for an exploratory longitudinal approach to develop insights into my participants' experiences and conceptualisations, rather than testing hypotheses through an experimental design. Six students from the 2011/12 cohort of twelve SKE students volunteered to participate as they progressed through the SKE and subsequent PGCE courses. Two of these participants withdrew from the study once they had started the PGCE year. I also recruited three participants from the 2012/13 SKE course. Data collection consisted of semi-structured individual interviews and focus groups, which were audio-recorded and transcribed (see Fig. 1). Each interview was conducted as an "'interview conversation" (Kvale and Brinkmann, 2009, p.54; Charmaz, 2006, p.25) where the participants and I discussed their definitions of physics and the physics subject knowledge required by a physics teacher, and the activities they experienced during the SKE (and PGCE) course that helped them to develop their subject understanding.

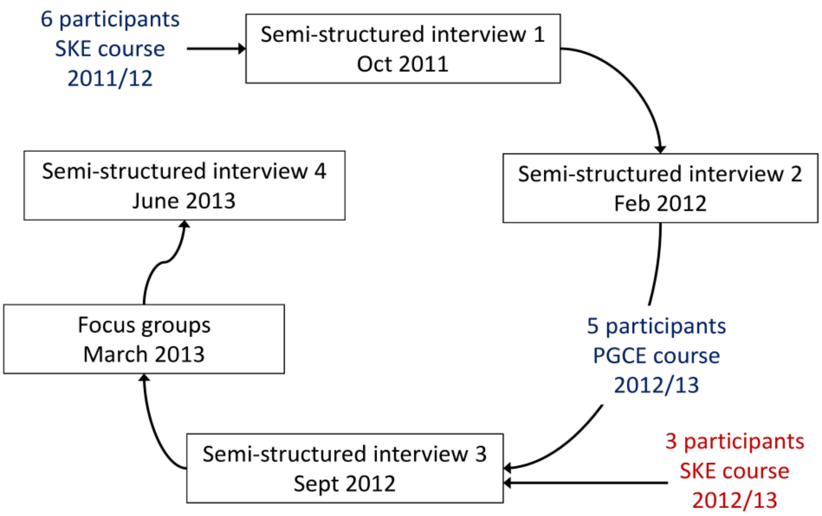

Fig. 1: Data collection schedule

Analysis

I am using some of the approaches associated with grounded theory (Gibbs, 2007; Charmaz, 2006; Strauss and Corbin, 1997; Glaser and Strauss, 1967) to analyse the interview transcripts, in conjunction with repeated re-listening to the audio-recorded interviews. I have approached grounded theory with some caution as I acknowledge the criticisms that have been made about the claims by some of its advocates for the necessity to analyse data without any preformed theoretical ideas (e.g. Thomas and James, 2006). My initial analysis has focussed on taking a longitudinal approach to each participant's data through using constant comparative method (Cohen et al., 2011; Saldaña, 2009; Thomas, 2009) via open and focussed coding (Gibbs, 2007; Charmaz, 2006) to derive possible analytical themes, which will then be used as a starting point for analysing transversely across all participants. This approach has led to the formulation of some tentative themes and *In Vivo* codes (Saldaña, 2009, p.74; Charmaz, 2006, p.55).

What follows are some examples from early analysis of data constructed with Ben, a participant from the 2011/12 cohort of SKE students who gained QTS via the subsequent PGCE course in June 2013. He is nearly 30 years old and from England; has A-levels in Biology, Physics and Computing; and, a BSc degree in Ecology from an English university. After graduating he travelled and worked abroad, and then worked in the UK in a personnel management role before deciding to become a science teacher. Ben describes his primary motivation as wanting to be a teacher of children, which he can do via the subject of science, rather than identifying himself first and foremost as a teacher of a particular subject. He enjoyed physics at school and is aware that his prospects as a teacher would be enhanced if he can present himself as able to offer a physics specialism alongside biology.

I will share a sample of themes developed from talking with Ben about the questions 'what is physics?' and 'what physics subject knowledge is needed by a physics teacher?'

What is physics?

Physics as factual knowledge vs. physics as process. Although Ben refers in the interviews to physics as consisting of "topics" to be studied, this occupies a decreasing proportion of the language he uses in the later interviews. In interview 1 Ben describes physics as learning the "fundamental physical laws of nature" and presents a view of physics as a body of knowledge to be learned. By interview 3 the language Ben uses is dominated by action words (e.g. "physics is looking at the physical world to make connections and trying to explain", "physics is an attempt to model", "attempt to describe and predict…and to try and manipulate that", "attempting to sort of make sense"). This suggests that during his ITE experience his view of physics shifts from physics as exclusively a body of content or factual knowledge towards physics as a process.

Struggling to explain/define. A recurrent theme across all interviews (and from many of the other participants) is the struggle to articulate a simple definition of physics:

> Yeah, I would struggle I think a bit actually; I've never thought about a simple definition of what it is. (interview 2)
>
> Physics is looking at the physical world and, yeah ah, I hate this question {laughs}. Has anyone given you a good answer yet? So, I'd say physics is looking at the physical world to make connections and trying to explain what happens around us but it's all so vague when you say it like that. I need something more specific. What does the Oxford English Dictionary say about it {laughs}…I should know this if I am going to be a physics teacher…I'm just going to end up listing a load of topics, err…I'm struggling. (interview 3)
>
> In the school sort of context Physics is the science of... Oh God, I should've prepared for this, I knew this was coming {laughs}…I don't think many people, unless they've thought about it quite a lot beforehand, can sort of put it concisely into a sort of box or a definition…I think it is probably a bit hard, the hardest of all of them to define. (interview 4)

This struggle seems at odds with the accuracy of Ben's explanations during all of the interviews, which contain the typical ingredients of what most physicists would accept as an appropriate description of physics.

Relating biology, chemistry, physics and science. Three features of interest stand out so far about how Ben relates the sciences to each other. Throughout the early interviews Ben consistently describes physics by first defining biology and chemistry, and then defining physics in terms of what it is *not*:

> Biology is the study of living things, so that's easy. Chemistry and physics are a bit hard to separate out but chemistry is more to do with the reactions of substances; physics is everything else really. (interview 2)

Later in his ITE studies, Ben increasingly emphasises that all of the sciences have "scientific method" in common and are differentiated primarily by the *scale* of nature under investigation, a view shared by many of the other participants:

> Yeah I think the scientific methodology is common to all three. It has to be because they are all sciences. You know, the ideas of scientific rigour and objectivity and whatnot. The differences, I think they are all different points on a spectrum really. I don't think there should be any real differences in how they think. I think they are each looking at different aspects of the same thing, on different scales perhaps. (interview 3)

What physics subject knowledge is needed by a physics teacher?

Moving from a rigid subject knowledge dualism ('factual' and 'pedagogical'). In interview 1 Ben states that subject knowledge consist of two elements "being bundled together into one sort of package": "knowledge of physics topics" (listing waves, forces, energy and nuclear physics as examples) and "how to teach it", which for Ben means specifically "conferring that knowledge onto other people". This split of subject knowledge into these two components persists in interview 2, but Ben now divides "knowledge of physics" further into what he calls "textbook knowledge" and "pub quiz knowledge":

> So what I'll say is sort of textbook knowledge…which is the subject matter for the course so as defined by curriculum and there's more of a general sort of pub quiz type knowledge I guess...it's just sort of general interesting facts or little quirks, and things like that… (interview 2)

By the time of interview 3 more complexity is apparent in Ben's responses, where knowing "how to teach physics" has been replaced by knowledge of misconceptions and the idea of "fluency" where:

> …you start to understand where the misconceptions come from. This happens once you have reached a good level of subject knowledge. Yeah I think that's part of the fluency. If anyone ever gets good enough to sort of transcend the whole thing then they will also as well as having the factual knowledge and the understanding of how it all fits together and the big picture, they will also know and understand where and why people get mixed up with stuff. (interview 3)

Over time Ben's conceptualisations of a physics teacher's subject knowledge increase in sophistication and move away from a simple content knowledge vs. pedagogical knowledge division. What is unclear to me at this stage of analysis is the extent to which his views develop as a consequence of his contemporaneous experiences in the classroom as a student teacher.

The way the course is constituted communicates what subject knowledge for a teacher is and what is important about it.

> I thought well, subject knowledge, we are just going to sit here and learn physics for a year and then learn how to teach it next year, whereas I see now that we are sort of touching on the teaching as we go as well to give us some preparation to get us thinking that way and also there is a big emphasis on thinking how science is and how it relates to the world, a bit of politics, a bit of media. (interview 1)

Ben's initial attempts to describe subject knowledge in interview 1 are tentative and are organised around what he anticipates experiencing during the course. During later interviews a theme emerges where what constitutes subject knowledge for a teacher is communicated to Ben by how he experiences the course. This is first highlighted in interview 2 where Ben introduces what he calls the “wow factor” as a component of subject knowledge, but only because this is a concept that has been articulated and made explicit by a tutor during course sessions. Ben describes the “wow factor” by drawing on the concrete examples of it he experienced on the course (such as using the Van de Graaf generator for dramatic demonstrations of electrical phenomena). An emerging idea here is that a student’s experience of the course, such as how it is structured, the way teaching is carried out, the nature of the relationships with tutors and peers, the use of assessment, etc. communicates powerful messages about what subject knowledge is and what is important about it. The extent to which these messages are explicit and planned, or implicit and accidental, is an aspect to be explored.

Discussion

I am in the early stages of data analysis and the above examples are intended to show a sample of tentative emergent themes. It is too early to say if any of these themes will form the basis of a generalised theoretical framework, but I propose some initial responses to my first two research questions.

Ben’s conceptualisations of physics subject knowledge are complex and have evolved throughout his ITE course. His view of physics evolves away from a simple static model of related facts towards a more dynamic model of a body of factual knowledge that changes with time through the application of a set of processes Ben calls “scientific method”. Although there appears to be increasing stability in this view as he moves through his ITE course, he is never satisfied with his own responses to the question *what is physics?*, despite consistent external validation of his competence in the subject and his teaching of it.

During the SKE course Ben talks about his subject knowledge development as something that is done *to him* and is driven by course tutors, as if he is operating with a transmission view of learning in mind. It is when he has experienced school-based placements during the PGCE course that he starts to talk about his subject knowledge development as a process of active construction in response to immediate need (a common driver of subject knowledge development reported by Lock et al. (2011)), and as a result of working with experienced teachers who themselves are explicit about their own subject understanding changing with time. A significant experience for Ben was co-developing A-level Physics lessons with his school-based mentor, who himself did not have a physics background, as they “both sat down and worked through stuff together” (interview 4). When I embarked on this research I initially expected to ‘see’ in action some of the commonly-discussed models of teacher subject knowledge in the literature (e.g. Banks et al., 1999; van Driel et al., 1998; Shulman, 1987; 1986). Many of these models suggest a view of subject knowledge as objective, static and universally accepted by scholars. Such models present the development of a teacher's subject knowledge as an individual context-independent affair. This is in contrast to models that attempt to frame subject knowledge as contested, and its acquisition by teachers as a dynamic process of *knowing* (Cochran et al., 1993) that is situated and socially-constructed through participation in an educational community of practice (Ellis, 2007; Wenger, 1998). Such socio-constructivist models of subject knowledge and its development are perhaps hinted at when Ben refers to knowing when he has sufficient subject knowledge as a teacher. He does not refer to objective tests of his physics knowledge, but instead talks about being "confident" and "fluent". For Ben, confidence is being able to deal with the "awkward questions kids come out with" while fluency means:

> …less of a conscious effort to talk about or describe concepts. It just rolls off your tongue almost without thinking about it. There's an unconsciousness to it. That's the aim. (interview 3)

A general criterion for subject knowledge competence, of being able to deal with unanticipated questions from learners by constructing unrehearsed explanations in response, appeared during several interviews with other participants.

Implications for Practice

The original impetus for my research was a need to inform *my* practice with *my* SKE students, and as such, was an example of practitioner research and 'insider research' (Sikes and Potts, 2008). This is also why I did not pursue a comparative study between SKE and non-SKE PGCE students. As an 'insider researcher' I had valuable insights into the participants' experiences, but also had to consider critically the reflexive nature of my interaction with the student-participants, especially when touching on students' negative experiences of the course. Although I no longer work as an insider in the research setting, there is considerable scope for impact on my practice as an ITE tutor and as an early-career researcher.

As reported above, there is evidence that student teachers' subject knowledge development is enhanced when called upon to use it in realistic contexts. Although not discussed above, many of my research participants report that peer-teaching activities (where students take it in turns to teach their peers) during the SKE course were very effective at enhancing their deep understanding of concepts (Biggs and Tang, 1999), as well as developing their pedagogical content knowledge (van Driel et al., 1998; Shulman, 1986). As a teacher educator, this has had a significant impact on my practice with all ITE students as has my raised awareness of the subtle messages communicated to students by the way they experience a course. As a researcher, engaging with grounded theory analysis approaches has raised many issues, not least around choosing to focus on the content of Ben's responses as if they reveal hidden 'truths' about his inner mental world rather than as socially-situated stories created during an interaction between us.

At present I am continuing with analysis with the aim of comparing my emerging themes across all participants' data. I will also commence analysis of the focus group data, which should allow me to give more attention to what might be learned from the interactions between the students as they discuss their experiences of preparing to teach physics. The eventual aim is to use the cases of these particular SKE course students to inform physics teacher ITE practice. Once this project is completed, I plan to extend this research to follow my participants' and explore their experiences of joining an educational community of practice as they embark on their teaching careers.

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