The importance of subject knowledge for mathematics teaching: An analysis of feedback from Subject Knowledge Enhancement Courses

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Over the last ten years, Subject Knowledge Enhancement (SKE) programmes have become an established part of the Initial Teacher Education (ITE) landscape in England, providing the opportunity for those who do not have sufficient degree level mathematics for direct entry to Post Graduate ITE programmes the opportunity to develop their mathematics knowledge prior to undertaking teacher preparation. More recently, SKE programmes have become more diverse in terms of mode of delivery with a growth in popularity of on-line provision. This session will present an analysis of feedback and evaluations from students on face-to-face mathematics SKE programmes at several institutions through consideration of Ball, Thames & Phelps' (2008) domains of mathematical knowledge for teaching. Evaluations are also considered in terms of the outcomes and benefits, in terms of both subject knowledge and other outcomes, of these programmes.

Keywords: mathematical knowledge for teaching; Subject Knowledge Enhancement courses; mathematics initial teacher education

Introduction

Over the last ten years, Subject Knowledge Enhancement (SKE) programmes have become an established part of the Initial Teacher Education (ITE) landscape in England with the National College for Teaching and Leadership (NCTL) in England suggesting that "They are widely used, with around a third of ITT places in priority subjects being supported by SKE in the academic year 2014 to 2015" (NCTL, 2015). These programmes provide opportunities for those who do not have sufficient degree level mathematics for direct entry to Post Graduate ITE programmes to develop their mathematics knowledge prior to undertaking teacher preparation.

Over time, SKE programmes have become more diverse with different types of institutions being allowed to offer SKE courses. Through funding from the NCTL, new providers, such as university subject departments, teaching schools, academy chains and online 'colleges' can now offer SKE courses in addition to university ITE departments. Courses can range from short eight week courses to much longer 36 week courses which may include school placement opportunities. In terms of mode of delivery, there has been a particular growth in the popularity of on-line provision. Short online courses often attract career changers who are in full time employment prior to starting their ITE course and such courses may be perceived to be a convenient tool for access to an ITE course. Consequently, there has also been some concern within the ITE community about potential variation in expectations, content and quality of programmes. Following concerns raised by members, the Association of Mathematics Education Teachers (AMET) recently produced best practice advice for SKE programmes (AMET, 2015). In the course of this work, SKE programme tutors shared feedback and evaluations from students on their SKE programmes. What

is presented here is an analysis of these evaluations in terms of the outcomes and benefits of these programmes.

Literature

Guidance from the National College for Teaching and Leadership (NCTL), an executive agency of the Department for Education in England, says that SKE programmes are aimed at "updating a candidate's subject knowledge so that he or she is ready to teach" (NCTL, 2015). What is not clear, however, is exactly what is understood as the appropriate level and type of subject knowledge for teaching secondary school mathematics. Given that there is a great deal of research in the area of mathematics knowledge for teaching, we base part of our analysis on the work of Ball et al. (2008), which develops the classic work of Shulman (1987) about content knowledge for teaching; Ball et al.'s (2008) classification of mathematical knowledge for teaching is shown in Figure 1.

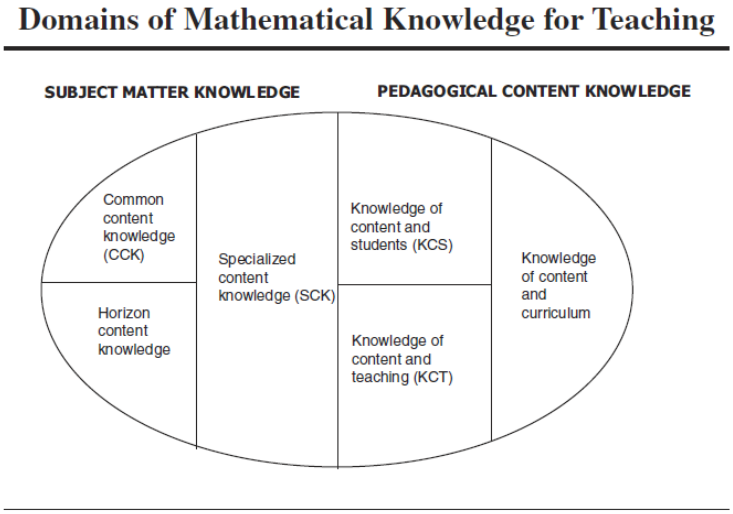

Figure 1: Domains of mathematical knowledge for teaching (Ball et al., 2008)

Subject matter knowledge

In Figure 1, Common Content Knowledge is the general mathematical knowledge that most educated adults would have and Specialised Content Knowledge is the "mathematical knowledge for teaching which is detailed in a way that goes beyond what is needed in everyday life and, moreover, is not necessarily known to other mathematicians" (Campton & Stephenson, 2014, p. 13) but does not require knowledge of students or teaching. Examples include being able to explain why a procedure works, presenting mathematical ideas and finding examples and representations of mathematics. Ball et al. (2008) further identify Horizon Content Knowledge as an awareness of how mathematical topics are related over the span of mathematics included in the curriculum, or the "mathematical 'peripheral vision', a view of the larger mathematical landscape" (Ball & Bass, 2009, p. 1).

Pedagogical content knowledge

The other 'half' of the picture is what Shulman (1987) terms 'Pedagogical Content Knowledge' and Campton and Stephenson (2014) further describe as the subject matter knowledge for teaching that is "the bridge between the teacher's knowledge and enabling students to know it" (p.14). Shulman views this as the ways in which the subject matter can be represented in order to be comprehensible to others along with an understanding of what makes topics easy or difficult i.e.

use of explanations diagrams and metaphors;
knowledge of students' conceptions;
knowledge of curriculum.

Such knowledge is clearly much closer to teaching than that provided by Subject Matter Knowledge. Ball et al. (2008) identify three types of pedagogical subject knowledge: Knowledge of Content and Teaching; Knowledge of Content and Students; and Knowledge of Content and Curriculum.

On the journey towards becoming a mathematics teacher, those undertaking teacher preparation need to develop all these kinds of subject knowledge because, as Ball et al. (2008, p. 400) put it: "Teaching requires knowledge beyond that being taught to students" and that teachers require what they call 'unpacked' mathematical knowledge which they use to teach 'decompressed mathematical knowledge' to learners so that students eventually "develop fluency with compressed mathematical knowledge". SKE courses are one step on this journey for beginning teachers, principally focusing on all three types of Subject Matter Knowledge, but also with the intention of beginning some learning of the three types of Pedagogical Content Knowledge. Such an approach is mirrored in the advice in Association of Mathematics Education Teachers' best practice advice leaflet (AMET, 2015).

Benefits and outcomes of SKE

Stevenson (2008) cites the work of Seabourne over the period of 2004-2006 as finding that SKE courses led to "improvements in subject knowledge, attitude, understanding and confidence" and that student evaluations found an "awareness of the importance of understanding the subject in depth and making connections; the value of collaborative working; enjoyment of engagement in mathematical activity" (Stevenson, 2008, p. 106). Gibson, O'Toole, Dennison & Oliver's (2013) report on SKE courses across all subjects in which SKE is offered finds that levels of subject knowledge and confidence in the subject are dramatically enhanced on completion of SKE course. Gibson et al. (2013) make specific note of the variation in content, design and delivery of SKE courses; something that has increased more recently with encouragement from the NCTL for ITE providers to consider a wide range of models of provision (National College for Teaching and Leadership, 2015) and it is in this context that this study was conducted.

Methodology

The data from this study is drawn from seven universities representing the views of over 85 SKE students and took the form of course evaluations, where students had been asked questions about what they had found useful and how they felt they had benefited from the course. Whilst we acknowledge that the data is limited in that it was not all collected at the same point in time using the same tool, we argue that it nonetheless provides valuable insight into the benefits of these programmes from the

perspectives of participants. The data was analysed by the authors separately looking both for key themes and for examples of different types of content knowledge for teaching. It therefore provides insight into the benefits and outcomes of SKE from a student perspective across a number of university providers.

Findings and discussion

Content knowledge

It is clear from the data analysis that those studying on SKE programmes can identify aspects of development of their Common Content Knowledge, Specialised Content Knowledge and Pedagogical Content Knowledge, as illustrated by the examples from the data shown in Table 1.

Common Content Knowledge:	*new areas of mathematics which I did not cover in my A level; problem solving skills and overall fluency;* *an insight into the raw fabric of mathematical knowledge;* *re-ignited a passion for mathematics*
Specialised Content Knowledge:	*an understanding that knowing 'why' is just as important, if not more important, than knowing 'how';* *bringing things together than you didn't realise were related;* *see maths in a different way*
Pedagogical Content Knowledge:	*I found the opportunity to look at topics that I had always approached in a traditional way in different ways and to make the connections between them most useful. I believe this will help me to teach in different ways to meet the needs of different learners;* *In the sessions at university, it was helpful to consider each topic from the point of view of a pupil;* *I always knew children struggle with maths. However, now I have a much better idea into why they struggle and more importantly, what I can do as a teacher to mitigate this*

Table 1: Content Knowledge examples

Students demonstrated that they had learned Specialised Content Knowledge through the development of their own understanding of mathematics and their learning about the connections between topics and, in their comments, that they saw this as distinct from their Common Content Knowledge learning gains. Comments about improved subject knowledge were commonly part of the evaluations, and, to some degree, reflect Gibson et al.'s (2013) findings that it was only after completing an SKE that students recognised that they had over-estimated their levels of understanding of the subject initially.

The development of Pedagogical Content Knowledge is a clear outcome of SKE and students benefit from seeing that mathematics can be taught in a way that is not largely procedural and that they learn through discussing different methods. This development of Pedagogical Content Knowledge may be because the students are taught in 'pedagogically appropriate' ways but it may also be because students look for this because they all intend to follow their SKE with an ITE programme. It is possible that such an outcome is a distinctive of face-to-face SKE. Much of our analysis focused on what it was SKE students thought that they had learnt on their course in terms of their mathematics subject knowledge. Whilst comments about both

Pedagogical and Subject Content Knowledge are not surprising to tutors, they firstly demonstrate the dual nature of tutors' intentions in the type of subject knowledge covered on SKEs but also that this message is clear to students on completing their course.

Other findings

In addition to analysing the feedback for content knowledge benefits we also looked for evidence of the additional benefits of face-to-face SKE courses, not directly related to subject knowledge. A sample of student feedback indicates some of this evidence:

confidence and good friends to keep in touch with in a variety of universities and schools;
found confidence in my ability;
helped with my confidence, in terms of presenting and speaking in front of a class;
lots of ideas, resources and materials;
prepared me in terms of the pressure;
I wouldn't have completed the first term of the PGCE without the MEC course;
prepared me for the workload and expectations.
....the fact we didn't just learn maths but by observing different lecturers' techniques, how to teach maths.
... the tools lecturers used, the various methods and approaches they took to describe each problem/theory was an excellent way of not only learning maths but also a bit about how to teach it as well....
I appreciated the variety of teachers contributing in the course, as they provided an insight to us, as students, to the variety in teaching approaches.

Having undertaken a face-to-face SKE course, students could clearly identify the benefits of doing so in terms of the opportunities for collaborative work, peer and tutor support, experiencing a range of teaching styles and levels of engagement. Students enjoyed the welcoming environment of SKE classrooms where a variety of lecturers shared their passion for the subject. Students stressed how the courses helped them to develop confidence, both in their ability and in terms of presenting and speaking in public.

The structure of the face-to-face courses prepared students for their PGCE year in many ways. They recognised how the courses had given them many opportunities to present to their peers and school pupils, so improving their presentation skills. Their communication, organisational and time management skills were also developed as assignment deadlines had to be met. SKE courses that incorporate a school placement were highly valued as students had experience of planning and teaching lessons, they had the experience of working with other mathematics teachers so improving their team player skills. SKE students were unanimous in agreeing that this aspect of the course gave them a head start in their PGCE year.

What next?

We have two ideas for further work in this area. Firstly we intend to collect data next summer (2016) from students using a common survey across the participating providers. Secondly, we wish to explore further the longer-term impacts of SKE courses, such as opportunities for career development and retention, by interviewing ex-students who completed SKE courses some time ago. We acknowledge that the

data set we have used here is not robust. The first of these ideas would allow for higher quality data with a larger data set and therefore the findings will have a greater degree of reliability and validity.

Conclusion

The data analysed here provides evidence as to the importance to students of such courses in developing subject knowledge for teaching as well as the value of face-to-face programmes in supporting student learning across a range of learning outcomes of value to beginning teachers. The data also provides further evidence of the high levels of student satisfaction with regard to university provision and of face-to-face SKE provision, in particular. Such courses have a valued place in continuing the supply of high quality mathematics teachers in England and, as such, the quality of provision needs to be assured.

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