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What does it take to make a
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Abstract

Trainee teachers on one year postgraduate training courses (PGCE in England) have little time to develop the required mathematical subject knowledge, yet this is expected of them. Trainees embarking on their teacher training bring a range of mathematical experiences, some of which could hamper still further their ability to acquire this knowledge. In this pilot study, two primary trainee teachers, with very different mathematical backgrounds, and their mathematics tutor explore in detail the processes through which they became confident and competent primary school mathematics teachers. From these experiences, we suggest that trainees' reflection and Dewey-ian open-mindedness are essential ingredients if they are to acquire the necessary knowledge to become confident primary mathematics teachers and that instilling these habits of mind in their trainees is an important part of role of providers of initial teacher education (ITE).

Keywords

Mathematics; anxiety; teacher education; primary; confidence; competent; subject knowledge.

Introduction

Concern about teachers' mathematical knowledge is nothing new (Cockcroft, 1982). The Williams Review of Mathematics Teaching in Early Years Settings and Primary Schools (DCSF, 2008) identified a direct connection between low levels of primary teachers' subject knowledge and poor mathematical results in primary schools and recommended the appointment of a mathematics specialist to each primary school. Developing teachers' mathematical subject knowledge was acknowledged as being too big a task for providers of initial teacher education (ITE) to do in the limited time available to them.

However, providers of ITE are not absolved from their responsibility to develop their trainees' mathematical subject knowledge. The revised teachers' standards (DfE, 2011), which now apply to all teachers and trainee teachers, are clear in their expectation that trainee teachers will

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have 'strong' subject knowledge (DfE, 2011: 5). Later, on p.5, it is asserted that this subject knowledge should be 'good' and 'secure' and while it would be possible to discuss the precise meaning of these terms, it is clear that this knowledge is essential. Research also suggests that 'subject knowledge' alone is not sufficient to produce effective primary mathematics teachers. Several studies have suggested that formal qualifications in mathematics are a poor predictor of pedagogical effectiveness (Goulding, 2003).

Hill, Rowan and Ball (2005) have sought to identify a body of mathematical pedagogical knowledge, which appears to be highly important in effective teaching. Ball and Forzani (2010) are clear that subject knowledge alone, even going well beyond 'common understanding' is not sufficient to be a teacher:

Being accomplished in a specific domain does not automatically include the capacity to break that domain down into its core components for someone who does not yet have that skill or understanding (p.41).

The knowledge of how to break a subject down into components that are understandable for a novice learner is not what would be expected of the general public and is different from simple mathematical competence. Possibly more problematic than identifying and classifying such knowledge is ensuring that all trainee teachers leave their period of ITE equipped with the required knowledge and understanding. Ball and Forzani (2010) have begun to explore the significant moments in trainee teachers' development of this knowledge during a period of initial teacher education, suggesting that there are certain 'highly leveraged' tasks that contribute significantly to the development of this knowledge.

An additional, and significant issue for providers of ITE, is the diversity of mathematical backgrounds and experiences, which trainee teachers bring to their training. Brown, McNamara, Hanley and Jones (1999) suggest that 80% of the pre-service teachers in their study had overwhelmingly negative experiences of mathematics at school. Fiore (1999) documents clearly how difficult or even traumatic experiences of learning mathematics can have significant negative effects well into adult life. They colour trainees' feelings about mathematics and how it can and should be taught. Beilock, Gunderson, Ramirez and Levine (2010) suggest that mathematically anxious teachers can unwittingly pass their anxieties on to their pupils. There is considerable evidence that anxiety about mathematics disrupts cognition (Ashcraft, 2002; Miller and Bichsel, 2004) and is associated with avoiding mathematics classes (Bibby, 2002). These experiences cannot be divorced from, and are highly likely to influence the process of becoming a primary mathematics teacher. Gresham (2008) suggests that there is a significant and negative correlation between trainees' levels of anxiety about mathematics and their pedagogical efficacy.

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Alongside trainee teachers who have had negative or even traumatic experiences as mathematics learners (Fiore, 1999) are those who have been 'successful' mathematicians and who see themselves as such. These trainees may also present challenges for providers of ITE, as they are likely to have learned mathematics in a particular way, which they may be reluctant to re-consider or change. Research suggests that confident and mathematically able trainee teachers may not give sufficient attention to planning and may well be resistant to teaching approaches that are not the same as those they experienced. There is a considerable body of research (Stipek, Givvin, Salmon and MacGyvers, 2001) that suggests that trainee teachers' beliefs are highly resistant to change. Rowland, Martyn, Barber and Heal (2000) cite examples of a number of trainee teachers who scored very well on an audit of their mathematical subject knowledge, but whose classroom performance was rated as weak.

Given this variety of prior experiences, the expectations of trainees' subject knowledge acquisition and limited time available to providers of ITE, we hope that a detailed examination of the processes that led to two trainee teachers on a PGCE course in the UK to become confident primary mathematics teachers will be helpful for providers of ITE and for trainees embarking on their own journey towards becoming primary mathematics teachers.

Research Questions and Research Design

This paper seeks to address two key questions, prompted by the situation outlined above:

1. How did a 'mathematically anxious' pre-service primary teacher seek to become a 'confident and competent' primary mathematics teacher?
2. How did a 'confident and competent' mathematician develop into a 'confident and competent' teacher of primary mathematics?

Brown (2005) suggests that pre-service primary teachers do undergo changes in their attitudes towards and even anxieties about mathematics during their course of training. In seeking to explore the processes involved in this change and therefore to address the research questions, a case study approach was chosen, as the processes involved are complex and may well be personal to the individual involved.

Each and every trainee teacher making the journey towards mathematical confidence and competence will bring a unique set of prior experiences and dispositions to the situation. The two trainees who took part in this case study were selected as they were similar to a number of other trainee teachers in their mathematical background and in terms of the factors that affected their development into confident primary mathematics teachers. In exploring their two cases together, it was hoped

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that the two participants, who were also partner researchers and co-authors, would understand their own development more fully and that this would also be of use to them in their future teaching careers.

Stake (1995), however warns against case studies as being 'sampling research'; the focus has to be on understanding the specific cases involved. In this study, the primary aim was to understand in greater depth processes involved in the development of these two specific trainee teachers, with the intention that the representative nature of the participants would enable the findings to be of interest and relevance beyond the specific cases. The small number of participants is acknowledged along with the fact that this makes generalising findings from the study more difficult, however it is hoped that this will act as an 'instrumental case study' (Punch, 2005) where the detailed examination of a particular case or cases gives insight into a particular phenomenon, which may be of interest more widely (Stake, 1995). The findings reported here represent an initial exploration and it is hoped to add further examples to a growing bank of cases in the future.

Data collection and analysis

Yin (2009) identifies at least six possible sources of evidence for case study research, although there is no injunction for researchers to use all of them. In this case, data was predominantly collected from two sources: documentation and informal interviews. Informal interviews were conducted with both trainees at different points during their PGCE year and more formally at the end prior to the beginning of their final school placement. The interviewer adopted a semi-structured approach, with specific topics to be covered, but with room in the interviews for the exploration of broad themes and the opportunity for follow-up questions. The nature of the study in trying to understand better a complex and personal process meant that too rigid an interview structure would have potentially led to important insights being missed. Yin (2009) highlights the benefits of focus and flexibility in interviews, but warns against bias and reflexivity. This was a concern, as the interviewer was also the mathematics tutor to the two participants. Honesty was expressly sought throughout and participants were encouraged to frame their answers in the context of the whole course and not to focus on the role of the mathematics tutor.

Both trainees kept reflective diaries during the year, although there was no compulsion to do this. These diaries contained entries about a range of experiences, not exclusively mathematical ones. As part of their course requirement, each trainee wrote a 'reflective commentary' detailing their developing ability to reflect within the context of a chosen, broad theme. Both participants in this case study chose to write about their developing attitude towards and relationship with mathematics. Yin (2009) highlights the precision, stability and unobtrusive nature of documented evidence as advantages. In this case, at the time of writing them, neither participant

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knew prior to the submission of their assignments, or while completing their reflective journals, that they would be used for research purposes; as the decision to compile this paper was taken later. For this reason, some of the concern about possible bias in the authors' reading of the data was lessened when examining the documentary data. Both participants did give full, informed consent to their writing being used as the basis for this paper, as detailed in the section below.

Ethical Considerations

As stated earlier, the two participants in the research are also co-authors of the paper. They were approached by the lead author about the possibility of documenting their experiences on the PGCE course, as they had both taken a great interest in their developing competence as primary mathematics teachers. Both gave their full, informed consent and worked together with the lead author in the preparation and writing of the paper. As such, all their reflective writings and assignments were contributed willingly and in the full knowledge that it would be used in the writing of this paper. Care was taken to ensure that the principle of informed consent was adhered to strictly. Both participants were aware that they could withdraw from the process at any time and without needing to give a reason. The writing of the paper was deliberately left until both participants had graduated. In that way, any perceived power imbalance between the lead author and the two participants/co-authors, which might have prevented them from withdrawing from the process had they wished to, was reduced. The lead author no longer had any influence on the participants' future careers in the teaching profession and therefore was in no position to influence any decision about withdrawing from the research.

In the interests of honesty and transparency, the journal entries and other reflective writing, which were often done at the end of, or during a busy day's teaching, have been left un-corrected in this paper. Additionally, great care was taken with the selection of writing that the participants/co-authors submitted that no school or child could be identified. It was hoped that the participants/co-authors would benefit professionally, both from their involvement in the writing process and from the process of undertaking a close examination of the processes that had led them to being confident and competent primary mathematics teachers.

Findings and Discussion

One of the trainees in the study (M) came to the course highly anxious about mathematics. This seemed to dominate her initial reflection about the process of becoming a primary school teacher:

'Looking back in my journal I have realised that maths anxiety seems to be the main topic in many of my journal entries.'

'Back in early September when the course started my anxiety started with the thought of having to pass an impossible test. The maths

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QTS test seemed then an impossible task. The more I practised the more irritated and annoyed and upset I became. I then began to doubt my abilities and question my place on the course. One word which seemed to keep reappearing in my entries was inadequacy. Reflecting on this, I knew I was worried and anxious I would not be able to keep up with my peers. This left me feeling deflated and more anxious.'

Initial anxieties were clearly exacerbated by the prospect of having to pass a mathematics test (all trainee teachers in the UK have to pass tests in English and mathematics before they can teach). There is a weight of research suggesting that formal testing, particularly high-stakes testing, contributes to anxiety. Cohen (1989) highlighted the negative impact of high-stakes testing on self-esteem. An interesting case was presented by Reay and Wiliam (1999), who documented a child whose experiences of high-stakes testing led to her labelling herself as a failure. This is strongly echoed in M's diary entries.

This test seems detrimental to anxious trainees, making the job of ITE providers more difficult. The test is set to become more demanding and more 'high-stakes' in the 2012-13 academic year. Ramirez and Beilock (2011) suggest that writing about anxieties prior to a high-stakes test can significantly improve performance, especially among candidates who are particularly anxious. Integrating opportunities for anxious trainees to write about their fears might represent a way of helping them to perform better. M commented that the act of writing about her anxiety during and after university mathematics seminars was helpful to her.

Teaching mathematics is clearly an important element in the development of mathematical confidence (Breen, 2004).

'One pivotal moment for me came back in November in placement where my mentor gave me 24 hours to plan my very first lesson. I had the choice of which lesson to teach but she wanted to see how I would react. My journal entry at the time recorded my feelings and I remember choosing maths. Why would someone choose a subject that they really did not like as their very first ever lesson to teach? I knew I had to challenge myself and so I did. It turned out that I was left buzzing after this lesson and I surprised myself at how liberated I felt from the experience.'

Teaching mathematics successfully boosted M's confidence. Brown, Westenskow and Moyer-Packenham (2011) draw a distinction between mathematics anxiety and 'mathematics teaching anxiety'. Despite M's anxiety about mathematics itself, she was prepared to 'have a go' at teaching, which allowed her to take brave decisions, which were ultimately pivotal in the development of her confidence. What is striking is that, for trainees who are anxious about mathematics, teaching this

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subject appears to give an added frisson of achievement and excitement. M talked animatedly about the excitement she felt in preparing to teach mathematics. This was connected with the fact that she was learning alongside the children and with a sense that she was facing down her fears.

'I got a real kick from preparing the lessons.'

'Planning my maths lessons has been very exciting for me, locating resources that would stimulate and motivate along with the pace of the lesson as it has been so rewarding being able to teach a subject where I feel I have grown in my own subject knowledge.'

Johnson (2003) suggests that a certain amount of anxiety can be exciting and liberating. The research referred to above suggests that formal mathematics qualifications are a poor predictor of pedagogical efficacy. However, possession of specialist knowledge for mathematics teaching is highly predictive of pedagogical efficacy (Hill et al., 2005). M seemed excited about the prospect of acquiring a new body of knowledge and then being able to put this to good use in the classroom.

Hayes (2004) documented the emotional responses of trainee teachers as they embarked on teaching practice and found a mixture of emotions, some of which were anxious, others of which were highly affirming. There is a genuine opportunity for providers of ITE to capitalise on the positive experience that teaching mathematics in a supported way can give to anxious trainees. While some trainees clearly don't have universally positive experiences of teaching mathematics, M drew considerable confidence and excitement about mathematics from her teaching experiences. A possible role for providers of ITE is to capitalise on the excitement anxious trainees may have in facing their fears and enabling them to have successful experiences of teaching mathematics early on.

A further sense of excitement and motivation became apparent from looking at M's reports from her own schooling:

'The comment my maths teacher made at the time truly reflects the position maths played in my life not only then but years later, "Melanie always tries although she finds this subject difficult, she is keen to do well and this sometimes makes her over anxious". Reflecting on this now at the age of 41 I am astounded that no one bothered to address this. Why could I not have the support I needed from my education? I don't recall anyone trying to intervene and offer me extra assistance in this subject I found so difficult.'

M reflected on her own schooling and on ways that she might turn this experience to her advantage as a trainee teacher.

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'My hope would be that I can correct the past a little by finding intuitive ways to work with a pupil who was struggling or lacked confidence in this subject. It does very little to improve an individual's confidence by writing down words that signify what they already are aware of.'

This determination was expressed very practically in M's classroom practice where she saw some advantages in her lack of confidence with mathematics. Her determination not to repeat the mistakes that her own teachers made with her coupled with an open-minded approach (Dewey, 1933; Pollard, 2008) to the acquisition of pedagogical knowledge gave her more confidence to teach mathematics.

'If you know a lot of maths and you're good at a lot of maths, you know one way of delivering it, or telling someone. So you're kind of in a zone where you can only teach it one way, whereas I'm open to any way of teaching it, because that's how I'm learning it.'

M was also aware of her own sensitivity to children and also her ability to sense children in the classroom who are, or could become anxious about mathematics. In this respect she was demonstrating confidence in her pedagogical skills in a mathematical context, although her anxieties about mathematics remained. She reported having a sympathetic, physical reaction to a situation in the classroom where another teacher's behaviour had put a child in a potentially anxiety-producing situation.

M herself identified the importance of her relationship with her mentor, who was an experienced teacher and also someone whose mathematical confidence was not high. This was a source of reassurance to M, who was able to see an experienced and highly effective teacher who also had concerns about mathematics. While it is hoped that trainees on ITE courses are exposed to the highest quality mathematics teaching both in school and at university, the exemplary mathematics teaching they see in university is done by tutors whose special interest is mathematics and whose level of mathematical knowledge and understanding may seem unattainable. Having a role-model who is also, or who has been apprehensive about mathematics is potentially hugely beneficial. This clearly has implications for the placement of mathematically anxious trainees.

Mathematically anxious individuals will go out of their way to avoid mathematical situations (Bibby, 2002; Brown et al., 2008). M had experienced this and had thought that, having left school, she would not really need to engage with mathematics again in life. Wanting to become a teacher, and having a huge desire to do so, meant that she came to her course of ITE highly motivated to conquer her previous mathematical difficulties. She was aware of the huge amount of work she had put in to become a teacher and the fact that she didn't want mathematics to

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prevent her from becoming a teacher. She identified the importance of being open about her mathematical anxieties from the beginning of the course and being able to access tutor support. M, who was a mature student, expressed some concern that younger trainees might feel less able to admit to weaknesses in mathematics and therefore be less able to access tutor support. The implications for prospective trainee teachers is clear; admitting to mathematical anxieties and turning this to advantage as a teacher are key elements to their training.

M also identified her own depth of reflection and having opportunities to write about her mathematical anxieties as significant factors in overcoming her fears and becoming a competent and confident teacher (Pollard, 2008; Tigchelaar and Korthagen, 2004). She identified strongly with Dewey's (1933) exhortation that reflective practitioners should be open-minded. She was candid about the commitment needed to become a successful primary mathematics teacher who has anxieties about the subject. M was clearly aware of Dewey's exhortations and had cited him in her reflective diary:

'Dewey (1933) states "There is no greater enemy of effective thinking than divided interest. A genuine enthusiasm is an attitude that operates as an intellectual force. When a person is absorbed, the subject carries him on" (cited in Pollard, 2008:20).'

Her own experience shows how this commitment, coupled with an open-minded attitude towards learning can lead to a genuine enjoyment of teaching mathematics, even if anxiety remains.

'My journal reflects how I carried on with my teaching practice and gained some valuable experience in teaching maths which I thoroughly enjoyed. January 24th my entry recorded, "Numeracy is great, even though I am still scared of what it actually is. I do enjoy the concept of teaching and am learning as I teach".'

Recording her own reflections at the end of taught mathematics sessions was also important in communicating her anxieties and progress to her mathematics tutors. An initial disclosure of anxiety about mathematics enables tutors to act sensitively. However, research (Brown, 2005) shows that trainees' feelings about mathematics change during a period of training. M had a number of 'ups and downs' during the year. An open channel of communication between trainee and tutor enables tutors to celebrate with a trainee when significant progress is made and to offer appropriate support when there are difficulties.

C came to his PGCE with no anxieties about mathematics. He had been a relatively successful mathematical learner, although he had 'never found mathematics easy.' He had an A level in mathematics and had used statistics extensively in his psychology degree. During his psychology

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degree, he had become interested in what he described as 'the underlying workings of mathematics'. Clearly, C had different challenges and requirements on the way to becoming a confident primary mathematics teacher to M's. Confidence in mathematical ability does not necessarily translate into pedagogical confidence. The challenge for providers of ITE is to expose trainees with very different mathematical experiences to appropriate and meaningful mathematical experiences.

While M's predominant goal through the period of her training was to conquer her fears of mathematics, C realised early during his training that he was not always able to relate to people who found mathematics difficult. He was surprised by the level of anxiety among some of his fellow trainees and his own difficulty in relating to their fears. Knowing that he would meet children in school with similar concerns and difficulties about mathematics sparked an interest in anxiety.

'However, I have been surprised by the amount of anxiety which mathematics has caused in my peers and how difficult some find it.'

C was aware of the fact that anxiety is often born of comparison with other people. This had been a feature of his own mathematical experience and was something that C had noticed about the test-based culture of schools.

A challenge for C and for those working with him during his course of ITE was to capitalise on his excitement about and interest in mathematics and turn this into something special in the classroom. C himself realised this and made a pro-active decision to develop his knowledge. He arranged a meeting with his mathematics tutor:

'Throughout the course I had come to the realisation that I had a strength in mathematics and the aim of the meeting was to see how I could develop this. My original thought was that I needed to build up my bank of high quality mathematics activities to be used in the classrooms. During the meeting I talked about my experiences of mathematics teaching so far and also about my interest in the subject at university. My tutor challenged me on my initial idea of that I needed to increase my knowledge of mathematics tasks but instead suggested that I should develop my own understanding of how I think, as someone who is confident in the subject, when solving problems.'

The meeting proved to be an important moment in C's journey to becoming the kind of mathematics teacher he had been striving to be. It led to wider questions about the purpose of mathematics teaching.

'A key part of my motivation to meet with my tutor was that I felt that my teaching needed to be different from what I had observed in

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other classrooms. It wasn't from the need to solve a problem but more to start a process of me not wanting to settle for giving children a mathematics education that is bound by schemes of work and technically easy for the teacher. It began a larger process of me trying to address some of the moral questions behind education, such as the aims of consequences of how we chose to teach.'

Reflecting back, I wasn't expecting my tutor to suggest that I focus on learning more about my own thinking.'

For people who are keen mathematicians and who are confident in the subject, a closer examination of themselves as mathematical learners might enable them to build up ideas for teaching. This has clear implications for providers of ITE and for prospective trainees. For C, the motivation to do this was an unwillingness to simply repeat the mathematics teaching that he was seeing in school.

Concluding Thoughts

Both trainees successfully became confident primary mathematics teachers, but this success was largely down to their own temperaments and dispositions. Both showed Dewey-ian open-mindedness and wholeheartedness in their approach to their different questions and difficulties. This manifested itself in different ways. For M, wholeheartedness took the form of an honesty about her own difficulties with mathematics and a determination not to let past anxieties and difficulties, which had been a significant part of her own schooling, prevent her from reaching a greater goal. In discussion, M said that she thought the most important thing in overcoming mathematical anxiety and becoming a confident mathematics teacher was commitment. C's wholeheartedness took the form of a determination to move beyond what was comfortable and easily achievable and to challenge his own views of primary mathematics teaching. Having made a pro-active choice to seek out further guidance, his open-mindedness enabled him to respond to the advice he was given, which was not the advice he had been expecting.

For providers of ITE, the experience of these two trainees suggests that a 'one size fits all' approach will not effectively meet the needs of the variety of trainees that they seek to prepare for teaching. The approach taken with these two trainees needed to be different and they represent two of a number of different mathematical pasts that trainees bring to their training. The case studies also suggest that relationships between trainees and mathematics or personal tutors are at least as and possibly more important than the development of trainees' intellectual understanding of mathematics. Providers of ITE, in particular mathematics tutors, might try to find time to get to know their trainees, not only in a mathematical way, but also on a personal level, so that informal lines of communication are open and crucial conversations that might lead to the sharing of important information are established.

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Anxiety about mathematics is very real and, for some trainees, may dominate the mathematical part of their preparation for teaching. Inevitably, this spills into all the other areas of their mathematical preparation. Ashcroft et al's (2002) finding that anxiety about mathematics has a debilitating effect on cognition suggests that trainees whose thinking is dominated by anxiety may fail to learn pedagogical skills. For providers of ITE, the early identification of and support for trainees whose preparation for teaching might be damaged by anxiety seems paramount. Establishing systems that enable mathematically anxious trainees to identify themselves and to let tutors know of their anxieties seems important.

The experience of these two trainees suggests that there are a few highly significant moments during the course of a one-year PGCE, which can have a profound effect on the trainee's mathematical confidence. Providers of ITE can and should be responsive and flexible, but these significant moments may only come about if trainees are open-minded and reflective about their mathematical experiences. Engendering these habits of mind may be the most important role of providers of ITE.

It is hoped that this initial case study exploration of the processes involved in two trainee teachers becoming confident and competent primary mathematics teachers has led to insights that are useful to all providers of initial teacher education. However, due to the highly personal and therefore diverse nature of this process, and the limited number of cases explored here, a wider bank of such case studies, detailing the processes of different trainee teachers with different initial experiences of and attitudes towards mathematics would be of benefit to the sector as a whole. The Teacher Education Advancement Network may be a good place for providers of initial teacher education to record and collate such information.

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