Pre-service primary teachers' conceptions of creativity in mathematics

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Abstract Teachers in the UK and elsewhere are now expected to foster creativity in young children (NACCCE, 1999; Ofsted, 2003; DfES, 2003; DfES/DCMS, 2006). Creativity, however, is more often associated with the arts than with mathematics. The aim of the study was to explore and document pre-service[i] primary teachers' conceptions of creativity in mathematics teaching in the UK. A questionnaire probed their conceptions early in their course and these were supplemented with data from semi-structured interviews. Analysis of the responses indicated that pre-service teachers' conceptions were narrow, predominantly associated with the use of resources and technology and bound up with the idea of 'teaching creatively' rather than 'teaching for creativity'. Conceptions became less narrow as pre-service teachers were preparing to enter schools as newly qualified but they still had difficulty in identifying ways of encouraging and assessing creativity in the classroom. This difficulty suggests that conceptions of creativity need to be addressed and developed directly during pre-service education if teachers are to meet the expectations of government as set out in the above documents.

Keywords Creativity, Primary, Pre-service teachers, Conceptions, Mathematics.

1. Introduction

1.1 Creativity

Creativity has been described in many ways (Eysenck, 1996; Mayer, 1999). Treffinger, Young, Selby and Shepardson (2002) identified over one hundred definitions but a common theme is that creativity is a personal activity intended to produce something new. For instance, Bergström (1984) defines creativity as "performance where the individual is producing something new and unpredictable" (as cited by Pehkonen, 1997, p. 159). Kwon, Park and Park (2006, p. 52) define creativity as a "high-dimensional human ability or skill to think up something new". Similarly, in the UK, the National Advisory Committee on Creative and Cultural Education (NACCCE, 1999, p. 30) describes creativity as "imaginative activity fashioned so as to produce outcomes that are both original and of value". This reference to 'originality' and 'value' reminds us that there is an implicit social aspect of creativity as it is, in the final analysis, society (or some significant subset of it) which validates the product (Csikszentmihalyi, 1996; Plucker, Beghetto & Dow, 2004). Not all mathematicians would agree with the need for practical 'value' in creative work (see for example Sriraman, 2009a) and Cropley (2001) has added that the product must be ethical. In essence, this means that what is acceptable and valued depends on the context and the culture (Kwang, 2001). This meaning of creativity began to take shape in the nineteenth century in connection with artistic and poetic imagination and popular notions of the creative domain are still shaped by this association (Tatarkiewicz, 1980; Euster, 1987). The existence of creativity outside the arts and, in particular, the many ways of being creative in mathematics did not attract much attention until more recent times (Treffinger et al., 2002).

1.2 Creativity in the mathematics classroom

One notion of mathematical creativity is the 'genius' view where creative acts are seen as rare and produced quickly and effortlessly by extraordinary individuals (Weisberg, 1988). While there are people described as mathematically gifted, this does not mean that others are not also creative in mathematical ways (Sriraman, 2005). Others argue that creative acts are associated with long periods of mathematical activity and reflection and the use of deep and flexible knowledge

(Sternberg, 1988; Gruber & Wallace, 2000). Research suggests that the mathematically creative are not necessarily those who show high levels of achievement in school mathematics (Hong & Aqui, 2004). Creativity in mathematics comes from more than a sound knowledge base; it comes from the ability to break free from established mind-sets, to see possibilities beyond and to apply a broad range of mathematical knowledge in seeing opportunities (Cropley, 1992; Haylock, 1997; Sriraman, 2009b).

Indeed, learning itself may be seen as a creative process in which meaning is constructed by the learner (Von Glasersfeld, 1984; Lerman, 1990; Ernest, 1994). Boden (2004) usefully distinguishes between historical creativity which offers something novel to the world and psychological creativity which produces something that is new to the person. On this basis, children are being creative in the mathematics classroom when they produce something new to themselves, as when they construct meaning for symbols, signs and operations, make sense of a mathematical problem, devise a way of solving it, and think of a way of testing the reasonableness of the solution (Haylock, 1987). Even very young children can be creative in this sense, as when a 4½ year-old child felt the need for a symbol for a half and so depicted the figure 4 and invented a representation of a half by adding a half of the 4 (Worthington & Carruthers, 2003; Carruthers & Worthington, 2005). Similarly, a child may create meaning for 5 + 6 by analogy with the spots on dominoes, counting the dots to arrive at the sum. Children may similarly be creative when they split a problem into sub-problems and formulate a plan to work through them. A mathematics student may also construct meaning in grasping for the first time why some standard algorithm works and invent a variant of that algorithm or improve it (Haylock, 1987).

To summarise, creative opportunities in the mathematics classroom are in, for example, the need for mathematical expression and communication, the construction of meaning and development of personal understandings, the generation of ways of solving problems, hypothesising about mathematical situations and outcomes, constructing tests of those hypotheses, and in formulating plans for solving complex problems. Mann (2006) usefully discusses and relates some of these in his study of indicators of mathematical creativity. He also sums up the way in which, all too often, mathematics teaching stifles creativity in schools and suggests a way forward:

> Frequently, all students, including those who met or exceeded the test goals, simply receive more of the same methods of instruction that yielded the results under examination. If mathematical talent is to be discovered and developed, changes in classroom practices and curricular materials are necessary. These changes will only be effective if creativity in mathematics is allowed to be part of the educational experience. (Mann, 2006, p. 237)

There is a concern to provide this experience in the UK (where creative thought is often described as a thinking-, key- or life-skill (SEED, 2006)) and in many other parts of the world (e.g. Diakidoy & Kanari, 1999; Tan, 2000; Kwon et al., 2006; Mann, 2006). This concern is not, however, universal as creativity may not be considered to be a desirable trait in all cultures (Kwang, 2001). The perceived value of creativity stems from its potential to contribute to personal effectiveness, culture and the economy (NACCCE, 1999; QCA/DfEE, 1999). More fundamentally, creativity can contribute to personal independence, autonomy and the ability to cope in new situations (Craft, 2002; NACCCE, 1999). In classrooms, it is claimed that creativity can improve behaviour, social skills, self-esteem, motivation and achievement (QCA, 2003, 2005; Ofsted, 2006). Against this background, the DfES (2003) in the UK urges primary teachers to foster creativity and problem-solving skills. There is also a clear distinction in the literature between 'teaching for creativity' in children and 'teaching creatively' by the teacher (NACCCE, 1999). Here, concern is with teaching which might foster children's creativity in mathematics (A useful collection of relevant articles can be found in Sriraman, 2008).

1.3 Teachers' conceptions of creativity

Aiken (1973) argues that the teacher is the key to creative thinking in the classroom. At the general level, teachers' notions of creativity are very similar in various parts of the world. For instance, Fryer and Collings (1991) found that UK teachers see creativity as producing original, independent work. Similar beliefs were found amongst Swedish and Cypriot teachers (Bjerstedt, 1976; Diakidoy & Kanari, 1999). Runco and Johnson (2002) studied parents' and teachers' beliefs about the traits of creative children in the USA and in India. They found that both agreed that creative

children are artistic, imaginative and inventive. However, some subjects are seen as offering fewer opportunities for creativity than others and mathematics is often considered to be one of them (Pehkonen, 1997; Davies, Howe, Rogers & Fasciato, 2004). Teachers of young children claim to believe mathematics is creative in the classroom but closer inspection shows that they refer to the opportunities mathematics sessions provide for creative activities in construction, art, and songs and rhymes rather than in mathematics itself (Worthington & Carruthers, 2003; Carruthers & Worthington, 2005). Teachers of older children may routinely dismiss creative thought (Kennedy, 2005), particularly in subjects like mathematics where they may see the acquisition of algorithms as paramount and creativity as a distraction (Beghetto, 2007).

Whether such beliefs are important in shaping practice depends on the context and specificity of the conception in that context. Some studies have found little relationship between teachers' conceptions of the nature of mathematics and their teaching (e.g. Schraw & Olafson, 2002). Others find that such beliefs shape classroom strategies (e.g. Lerman, 1983; Thompson, 1984; Hofer & Pintrich, 1997). The link between teachers' conceptions of mathematics and their practices is neither direct nor simple but is mediated by the pressure to cover content, a lack of teaching experience, preferred teaching approaches and student reactions to them (Fryer & Collings, 1991; Askew, Brown, Rhodes, Johnson & William, 1997; Bolden, 2006). Furthermore, when teachers' conceptions are accessed at the general level, broad views of the world may be too vague to shape planning and teaching. But, when accessed at a level that ties it to classroom practices, there can be a closer relationship between conceptions and teaching (e.g. Strauss, 1993; Beswick, 2004). Strauss (1993) points out that teachers need to consider such beliefs and, if necessary, address them. On this basis, teachers' conceptions can matter and knowledge of them has the potential to be useful to teacher trainers.

1.4 Aims

It is not enough for a teacher to know what constitutes creativity in general. Like understanding, the nature of creativity varies with the subject so teachers need to know what constitutes creative thought in a particular context if they are to foster and

assess mathematical creativity in a systematic and deliberate way (Newton, 2000). This study aimed simply to explore and document pre-service teachers' conceptions of creativity in mathematics, particularly in relation to primary school mathematics. The purpose was to comment on how appropriate these conceptions are for teaching mathematics at the primary level (i.e. to 5 to 11-year-old children) and ultimately inform thinking about pre-service teacher education in this context.

2. Method

At the beginning of their course (see below) pre-service teachers were asked to complete a questionnaire[*] to elicit their conceptions about creativity in primary mathematics. The questionnaire used both closed (with a Likert scale) and open-ended items. For an example of the latter, "Could you give an example of a mathematics lesson you have observed which demonstrated creativity? Try to say what was creative about it". The questionnaire responses provided the initial data pool.

Closely following the phenomenographic procedure for identifying conceptions of lived experiences devised by Marton (1981), responses in the data pool describing teaching behaviours considered by the respondents to be creative were sorted into groups. This sort was iterative, particularly at the outset when groups may be abandoned, refined or replaced until they reflect a particular kind of teaching behaviour.

For example, the responses *"fractions, as it is often a topic children find difficult but it can be related to pizza slices"* and *"It's much easier when it comes to space, shape and measures because you can get kids to be creative through doing practical things…"* led to the initial group representing the category called, tentatively, *areas of mathematics*. As later responses were added, e.g. *"measuring data – can get children to physically undertake investigations – using scales, measuring lengths/widths of objects in classroom",* this led to the renaming of the category as *pupils undertake practical activities and investigations*. Similarly, the category *teachers' imaginative use of resources and technology* was identified from a number of responses including

[*] The full questionnaire is available from the lead author at d.s.bolden@durham.ac.uk.

"*maths bingo for learning the 6 times table. A more interactive and fun way of learning tables"* and *"children were working with shapes such as hexagons, circles, pentagons and triangles…"* but again as more responses were analysed this category was considered to be inadequate and another category was identified, *teachers apply mathematics to everyday examples*. This and *teachers' imaginative use of resources and technology* then became sub-categories of a larger category called *creativity as creative teaching*. Ultimately, from the entire data pool, self-consistent and mutually exclusive groups evolved.

Each group was given a descriptive label, its attributes were listed and the group was exemplified to form a 'category of description'. Each category described a conception of creativity (for a full account, see Marton, 1981). It cannot be said, however, that the list of categories is exhaustive: interviews with other pre-service teachers may add to it and it should not be assumed that other conceptions do not exist amongst other pre-service teachers. In practice, this is not an obstacle to using the results to inform discussion about certain questions relating to pre-service teachers' conceptions.

Follow-up interviews with a volunteer sample of ten pre-service teachers allowed us to check our interpretations and explore these responses further through such questions as, "In your examples of mathematics lessons in which children would be creative, what would the children do that was creative?" "Is there another way children might be creative in mathematics?" Most interviews lasted approximately twenty minutes and had a quality control purpose and elicited, for instance, views on the accuracy of the interviewer's perceptions of their beliefs, specific instances of mathematics lessons believed to provide opportunities for children to be creative in mathematics, clarification of what children did that pre-service teachers considered creative, and what was seen to be worthy of high (or low) marks for creativity in these lessons. The interviews were conducted individually, after the analysis of the data pool, and on two consecutive days toward the end of their course.

2.1 The sample

The questionnaire was completed by a convenience sample of thirty-eight pre-service teachers on a 38-week postgraduate teaching course. The interviews sample

comprised ten volunteers who had previously completed the questionnaire. The interviews were conducted towards the end of their course as this was convenient for the pre-service teachers and the purpose was not intended to track change over time.

The course caters for those wishing to qualify to teach in primary schools in the UK and who already hold an undergraduate degree. As qualified primary teachers they are expected to teach across the curriculum in English primary schools (5-11 year-old) and had followed a broad course covering the range of subjects generally taught in England at that level and which included generic instruction on lesson planning (but no specific instruction on support for creativity). Over the duration of the course, these pre-service teachers had observed, planned and taught lessons for some twenty-one weeks in local primary schools. This included a significant amount of mathematics teaching, often on a daily basis. They were quickly expected to plan lessons without detailed support. Although the course population tends to be an academically able group only one had an undergraduate degree in mathematics and many tend to have concerns about their mathematical subject knowledge. Thus the sample comprised mainly 'non-specialists' in mathematics as the majority had not studied mathematics beyond the GCSE/GCE 'O' level[ii]. In this respect the pre-service teachers in this sample can be described as typical of many other primary school pre-service and practising teachers in the UK.

The aim of the mathematics element of the course is to develop an understanding of the subject knowledge relevant to teaching 5-11 year olds. It emphasised the importance of the connections between mental representations of any mathematical concept (see for example Harries & Barmby, 2007). The course involved no instruction about mathematical creativity.

3. Results

We present the findings from the questionnaire and interviews together, first in broad terms and then by reference to the conceptions held by the pre-service teachers. The rationale for this combined presentation is that we viewed the questionnaire responses as providing the bulk of the data pool with the interviews providing useful

supplementary data. That is, the interviews allowed the authors to access pre-service teachers' conceptions from a different angle and verify that their questionnaire responses were being interpreted as they were meant.

3.1 Some background beliefs

The responses to the questionnaire indicated that most pre-service teachers believed that mathematics was not a creative subject (a median response of 2 from a 5-point, Likert-scale where 1 is not very creative and 5 is very creative). There was also the view that it was difficult to encourage creativity in mathematics (a median response of 4). Given this, it was not surprising to find that other subjects, such as English, Art and even Science were seen by pre-service teachers as offering more opportunities for creativity. In general, these subjects were perceived to offer much more scope for 'discussion and exploration of ideas', 'freedom of choice', involved greater use of 'the imagination', had 'fewer set goals' or 'no correct answer'.

3.2 Pre-service teachers' views about creativity in mathematics

Drawing on responses to the questionnaire and also in the interviews, pre-service teachers had a number of conceptions of creativity in mathematics classrooms. These were eventually organised into broad categories related to teaching, learning and assessment. The sections below discuss these categories and associated sub-categories and Table 1. gives details of their prevalence within the sample of pre-service teachers.

3.2.1 Creativity as creative teaching

There were essentially two sub-categories that matched pre-service teachers' comments within this broad area. Firstly, creativity was viewed in terms of the resources that were used to teach mathematical topics – both the types of resources used and the way in which they were used. Secondly they discussed creativity in terms of the way in which real life examples were used to explore mathematical concepts.

Teachers' imaginative use of resources and technology

This view saw creativity in the primary mathematics classroom as residing predominantly in the teacher rather than in the pupil. One aspect of this creativity was bound up with teachers' use of a variety of different resources. The use of resources here seems to be related to the pupils having fun with little real consideration of the way in which the resource might enhance the learning of mathematical concepts. For instance, below are three examples of responses to the questionnaire item which asked pre-service teachers to provide an example of a mathematics lesson which they had observed and which they believed demonstrated creativity.

> *Maths bingo for learning the 6 times table. A more interactive and fun way of learning tables. The teacher used the interactive whiteboard.*

> *Children were working with shapes such as hexagons, circles, pentagons and triangles. The teacher gave them the task of making a picture out of their shapes, e.g. spaceships, Christmas trees. The children had to name the shapes they used.*

> *There are a lot more resources in school now. There weren't dice at school [in my day], there weren't number fans, there weren't the interactive whiteboard with all the resources that has on it, you know, the countdown games, the silly things, but they really do make a difference … it makes maths more exciting.*

Here it is clear that "fun" is paramount in the pre-service teachers' minds. There is little if any view that the resources themselves could be used to represent concepts in different ways and possibly give young learners better access to ideas. Further it is important to recognise that resources have specific uses. For example whilst number fans are an excellent resource for helping young learners see how numbers are built up in our denary system, they are difficult to use to perform calculations on numbers. For this, other resources are valuable. Thus, there is a need to understand the limitations of the resource being used.

Teachers apply mathematics to everyday examples

The second sub-category here was seen as the teachers' ability to apply mathematical topics to a variety of everyday examples. One pre-service teacher described it as, 'finding a hook' with which to grab the pupils' interest.

> *I think it's about finding a hook, find something that's interesting to the children like I had one child who was only interested in fishing so if you could relate anything to fishing he could do it and if you couldn't, he couldn't do it, he had a sort of mental block. So I was making up these ridiculous questions about how many carp are there in a pond, just tailoring the question to their interests, using your creativity to interest them.*

Here it could be said that the pre-service teacher is recognising the need for context when learning mathematics. This is an important consideration but it is also necessary to understand the range of contexts within which the young learner can give meaning to mathematical concepts. Some may be real contexts such as the one mentioned but it is also possible to develop contexts which are more abstract such as puzzle contexts which would allow the learner to explore an idea.

3.2.2 Creativity in learning

The second broad area identified by the pre-service teachers concerned the way in which young learners constructed their own learning. There were two sub-categories here – the type of activity experienced and the development of flexibility in performing calculations.

Pupils undertake practical activities and investigations

Creativity here is seen as pupils undertaking practical activities and investigations in the classroom. In these activities there are no set ways of working and so young learners are able to develop their own methods for approaching problems and are encouraged to explore ideas rather than just seek an answer. Certain mathematical topics were perceived by pre-service teachers to offer more opportunities for creative learning in this respect. For example, shape, space and measures, fractions, division, data gathering, were all identified as opportunities for pupil creativity in learning, e.g.

> *Measuring data – can get children to physically undertake investigations – using scales, measuring lengths/widths of objects in classroom.*

Fractions, as it is often a topic children find difficult but it can be related to pizza slices.

It's much easier when it comes to space, shape and measures because you can get kids to be creative through doing practical things whereas when it comes to using the four operations it becomes harder to develop creativity.

These comments show the pre-service teacher view that active learning is to be encouraged but again it could be questioned as to how clear they are about the way in which the activities can help to give meaning to concepts. For example whilst pizza slices might help to illustrate the "part-whole" idea of fractions, whether it can be extended to help young learners to see fractions as numbers and whether it helps to give meaning to calculations with fractions is unclear.

Pupils develop computational flexibility

Creativity here is seen as pupils' ability to develop flexibility in their computational methods. However, the origin of this aspect of creativity was much less clear, That is, although pre-service teachers saw this flexibility as representing creativity in pupils, i.e. creative learning, they also saw it as representing creativity in teachers, i.e. creative teaching (See *creativity as creative teaching* above). This overlap can be discerned from the following comments:

It's about giving them a variety of different ways of approaching different concepts, not to just go down the one route but giving them different ways of working something out so that they can understand the concepts from different angles, so they can approach them and have a bit of background knowledge to say 'well, I can't do it that way but I can do it this way'.

I think it has to come from the teacher but from my point of view it's about the teacher encouraging the students to be creative in their maths. I mean I've been working with Year 2 children and it's about getting them to use different methods and finding out which is best for them, and get the right answer doing that, as long as they can do it, that's the key.

Here we can see the pre-service teachers moving away from a purely answer-based view of mathematics with a specific algorithm learnt in order to obtain this answer. They are encouraging the young learners to see mathematics as more open and that the way in which calculations are performed is at least as interesting as the answer. This orientation suggests that pre-service teachers saw flexibility as a key element of creativity.

Table 1. Number of pre-service teachers holding identified conceptions of creativity.

Categories and subcategories of conceptions	***N***
Creativity as creative teaching:	27
a) Teachers' creative use of resources.	17
b) Teachers apply mathematics to everyday examples.	10
Creativity as creative learning:	18
a) Pupils undertake practical activities and investigations.	12
b) Pupils develop computational flexibility.	6

3.2.3 Creativity and assessment

Results from the questionnaire showed that all but one of the pre-service teachers (*N*=37) thought encouraging creativity in primary mathematics classrooms was generally a difficult thing to do. Interviews showed that pre-service teachers found it difficult to be explicit about identifying and categorising creativity in the classroom.

> *I think it would be quite hard … maybe just being a little bit different, hmm … it's quite difficult! Perhaps if you saw a child really engaged in the activity and trying to work their way through it but also a little bit … different.*

> *They'd have to show their working out and the structure and how they'd done it.*

> *It would be easier if you had the children from the word go. For instance, I've been teaching Year 2 children and when they come into Year 2 they have already been taught 'this is how you do addition' or 'this is what addition is' and they think there is only one to do it and you have to think, well how else could you do it.*

In order that children can be creative in the classroom they first need to be presented with opportunities to display their creativity. For instance, activities need to be

designed that allow the young learners to be creative and to have opportunities to communicate their findings. Further, the way we think about assessment needs to develop so that the mechanisms we use for assessment are appropriate.

An assessment system predicated on a behaviouristic view of teaching and learning is one that is currently used in the centralised National Curriculum for England (DfES, 1999). Assessment of learning by paper-and-pencil, 'objective' tests, with the aim of determining *how much* of the core curriculum has been learned from the teacher, is still an important part of the National Curriculum in England. Shepard (1991, 2002) argues that this measurement approach to classroom assessment reflected by standardised tests and teacher-made emulations of those tests is essentially incompatible with the central ideas underpinning constructivism and only serves as a barrier to the implementation of the ideas of constructivism. This scientific measurement approach is more theoretically consistent with earlier forms of the curriculum and their associated beliefs about learning, e.g. rationalism and behaviourism.

If assessment practices are to be better able to assess creativity then we need to get creative in the ways we assess. That is, creative assessment is likely to require children to illustrate their mathematical understanding and this will require very different modes of assessment than we currently have in operation in England. When knowing is viewed as an understanding of the overarching principles of a subject domain rather than the ability to produce algorithmic answers then assessment practices will need to assess that understanding across a wider range of the domain, which means assessments will need to be larger in their scope. For instance, some alternative assessments that are being devised in the United States include larger projects that may take several days or weeks to complete (Greeno, Collins & Resnick, 1996). More recently Cropley (2001) has argued that recent work in assessing creativity suggests it is far less difficult to assess than one might think.

3.2.4 Narrow conceptions of mathematics and its creativity

Questionnaire responses suggested that pre-service teachers held narrow, absolutist views of mathematics as a subject. That is, the data suggested that most (N=31)

conceived mathematics as a subject as a set body of knowledge which offered little or no room for freedom of expression, imagination, and independence.

> *I don't feel [mathematics] is creative in the way that Art or English or Music are; it is not easy to express yourself in maths.*

> *[Mathematics] is all facts, figures, and definite answers. No personal element.*

This was corroborated later in interviews. That is, all the pre-service teachers interviewed admitted that they had not viewed mathematics as a creative subject.

> *Before commencing this course, I would have said that maths was not creative at all.*

> *Maths does not seem to be creative. It deals more with numbers, calculations, and problem-solving. Much of maths seems to be based on rules.*

Moreover, these narrow conceptions of mathematics were thought to be an inevitable result of the way in which pre-service teachers experienced mathematics during their own schooling, which was often laden with negative feelings.

> *I didn't view mathematics as creative at school. I hated it actually…because of the teacher approach, to be honest. He didn't really want to be there, he rattled through it regardless of whether you understood it or not, he would move on to the next section and I'd think 'I haven't understood that yet'.*

> *In my school the emphasis was firmly on the Arts rather than maths and science. I knew it was important but it was mostly just chalk and talk and rote learning and I never felt like I understood maths. I could do it but I worked hard and literally learnt all the formulae, because I've got a great memory, and I'd regurgitate it onto the exam paper so I always did okay but hand on heart I'd have to say I didn't really understand it, even now there's things I don't understand.*

> *It was just textbook, textbook, textbook all the way through primary school, and secondary school. The answers were in the back…the teacher displayed them*

and then it was textbook and check your own answers and then move on to the next. That was secondary school but primary school was very similar, it was very limited…but I used to love maths.

These experiences inevitably shaped pre-service teachers' views of creativity within mathematics. It is not surprising then that pre-service teachers also felt that mathematics was not a creative subject and that all but one of them felt there were other subjects more amenable to creativity. Consequently, pre-service teachers' views of creativity were very much arts-based with English, art, music, dance, and design and technology being identified as much more creative subjects than mathematics.

Maths is pretty regimented, you either get a right answer or you get a wrong answer, so that cuts it very short but if you are given something in dance or PE you can create your own dance or rhythm whereas it's difficult to get that freedom of expression in maths…at the end there's always a right answer.

Although the timing of the interviews was not designed to measure change in pre-service teachers' conceptions of creativity the data suggested that their conceptions of mathematics and of creativity within it had widened since completing the questionnaire earlier in the course.

Now I know that maths is much more for understanding than for knowing and whilst you can still teach children the old, conventional ways it's nice to be able to offer them a couple of solutions, you know, to solve a mathematical problem. Yes, I think now it's a lot more creative.

I think you have to try and get children involved. You just can't sit them in front of a textbook all day but they also need that solid knowledge … so they definitely know what they are doing. So in that sense, it has changed. I did think it was really regimented but now I think it is more creative than I first thought.

Now that I've done the course and seen things from the teacher's perspective I would say that mathematics can be much more creative, it just needs the right person to make it creative. I saw scope for creativity in maths before but I see much more scope for it now, there is much more happening now to develop

creativity than when I was at school so my vision of mathematics as a creative subject has definitely increased since I've come on the course.

This was not intended to be a longitudinal study of conceptual change in pre-service teachers. Nevertheless, we have shown that our pre-service teachers' conceptions of mathematical creativity were still limited as they prepared to enter their first teaching posts. This is evidenced by their inability to be explicit about what mathematical creativity might look like in the primary classroom beyond their tendency to associate creativity with the teacher's use of resources and technology.

4. Discussion

This research identifies categories of pre-service teacher conceptions of creativity in primary mathematics but we do not suggest that they represent an exhaustive taxonomy. It is possible that pre-service teachers not in this sample would hold different conceptions. Furthermore, the sample is small and self-selected so while the prevalence of particular conceptions is interesting, we can only speculate about the relative prevalence of the conceptions in the general population of pre-service teachers. Despite this limitation, the pre-service teachers described here are typical of many other primary school pre-service teachers in the UK. For instance, most had not studied mathematics beyond GCSE/GCE 'O' level. Consequently, teacher educators are likely to be able to relate the findings described here readily to their own pre-service teachers' conceptions (see Bassey (2001) for the concept of relatability of research results).

There was evidence that creativity in the broad sense was viewed as others tend to view it. That is, there was reference made to 'freedom of expression', 'imagination', 'independence', which suggested an expectation of originality. These pre-service teachers also saw creativity as centred more on the arts which parallels the findings of Diakidoy and Kanari (1999) and Davies et al., (2004). This resonance gives some confidence that the term was being understood as others understand it. Nevertheless, broad brush conceptions may bear little upon practice. What is more likely to count is how these are interpreted, if at all, in the specific context of the classroom.

In this respect, several conceptions were identified:

Creativity originated in the teacher before the pupil. Pre-service teachers felt that teachers as the expert adults and the orchestrators of the pupils' experience needed to have a creative approach to mathematics that they could share with the pupils. Otherwise the pupils would tend to adopt a more staid approach.

Creativity was bound up with the use of resources and new technology (teaching creatively rather than teaching for creativity). Here the pre-service teachers seemed to think of the use of resources in terms of creating a "fun" environment. Clearly this is an appropriate approach but it needs to be developed further so that the pre-service teacher is aware of the pedagogical potential of different resources for giving young learners access to mathematical ideas.

Although there was a general consensus that creativity ought to be encouraged in primary mathematics there was also a degree of uncertainty about how one might do that in the classroom. This emanated very much from the pre-service teachers' own school experience of mathematics which tended to be somewhat unimaginative. But there was also a feeling that they did not want to perpetuate this view and were keen to develop more open approaches to mathematics – even if they were not clear what this might mean for their own learning.

Also, pre-service teachers generally found it difficult to suggest ways of assessing creativity in mathematics in the classroom. The difficulty here seemed to be that they were thinking in terms of old assessment methods whereas if we are to assess such skills as creativity we need to think afresh about assessment mechanisms and how they can be appropriately developed.

The findings discussed here suggest that the meaning of creativity in primary mathematics is unlikely to be well understood by beginning pre-service teachers. This situation is likely to be amenable to improvement if the meaning of creativity in mathematics is explicitly explored. Teacher educators are likely to meet both misconceptions and narrow conceptions of creativity in mathematics. Furthermore, a tendency to associate creativity with the arts may inhibit thought about it in other contexts. Consequently, teacher educators may need to give creativity in mathematics

much more explicit attention so that such weaknesses are addressed and confronted (Strauss, 1993; Tillema, 1997).

5. Conclusion

Although we have seen a recognition of the importance of supporting creativity in primary-aged school children in England and Wales (DfES, 2003), creativity has not always received much attention in teacher education in the UK (Davies et al., 2004) and elsewhere (Diakidoy & Kanari, 1999). In the context of mathematics education, a general tendency to see mathematics as the acquisition of algorithms (Kennedy, 2005; Beghetto, 2007) and to associate creativity with the arts may incline pre-service teachers and newly qualified teachers to neglect it in mathematics, particularly when they also struggle to understand how it may work in the classroom. These pre-service teachers found it difficult to be specific about encouraging and assessing creativity in mathematics lessons. A worst-case scenario would involve newly qualified teachers entering the classroom unable to recognise creativity, ultimately discouraging those creative pupils from pursuing mathematics or, at least, from being mathematically creative.

It is important then that pre-service teachers develop adequate conceptions of mathematical creativity and of creativity as it may appear in the classroom if mathematics teaching is to improve in this respect. However, programmes of pre-service teacher education may have to be much more explicit in exploring what it means to be creative in primary mathematics if newly qualified teachers are to meet the government's expectation and develop creativity in their mathematics classrooms.

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[i] In the United Kingdom, pre-service teachers are referred to as 'trainee' teachers.

[ii] One trainee stated that there was no subject more creative than mathematics. He had a degree in mathematics.

[iii] GCSE stands for General Certificate in Secondary Education and is the standard examination taken by pupils at approximately sixteen years of age. GCE 'O' level stands for General Certificate in Education Ordinary level and was the GCSE's predecessor.

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