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Some Student Teachers' Conceptions of Creativity in School Science

Douglas P. Newton and Lynn D. Newton, Durham University, UK.

Corresponding author: Professor D. Newton, Durham University, School of Education, Leazes Road, Durham, DH1 1TA, UK.

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Abstract

Creativity is generally considered to be something to encourage in young children. It is, however, popularly associated more with the arts than with the sciences. This study used phenomenographic analysis to identify some primary school student teachers' conceptions of creativity in school science lessons (a class of sixteen final year students on a degree course leading to qualified teacher status in the UK). Their conceptions were narrow, focused mainly on practical investigations of matters of fact, and included misconceptions. Teacher trainers are advised that student teachers' conceptions of creativity can be grossly inadequate in several ways and they may omit significant opportunities for creativity involving, for example, the imaginative processing of scientific information and the construction and testing of explanations. As conceptions may be shaped by creativity in the arts, it is suggested that science educators might loosen the connection by introducing students to the broader term of 'productive thought' that is, a combination of creativity and critical thought which is particularly relevant in science.

Introduction

Creativity

Creativity has been described in various ways but they often amount to the same thing (Eysenck, 1996; Mayer, 1999). Common to most is the notion that creativity is successful personal activity intent on producing an appropriate new idea or object. For instance, NACCCE (1999, item 29) describe it as 'Imaginative activity fashioned so as to produce outcomes that are both original and of value'. Csikszentmihalyi (1996) drew attention to a social element implicit in these definitions. Society validates the product by ruling upon what is appropriate and valuable. But Boden (2004) points out that everyone is creative to some degree. For instance, we make sense of a description, construct a lie, make a joke, think of an explanation, compile a plan, thoughtfully adjust behaviour in a changing situation, and make mental connections to construct an understanding (Newton, 2000). These everyday acts generally lack social validation but they do produce something new, at least to the person concerned.

Creativity in the classroom

The view that schools tend to ignore creativity is long-standing (Fisher, 1990; Craft, 2002; Garner, 2007). In the UK, the Plowden Report (CACE, 1967) argued that imagination and inventive thought could be fostered through play. Although criticised for weak thinking about what counts as worthwhile, it highlighted the possibility that creative thought might be practised in the classroom (Barrow & Woods, 1975). Subsequently, criticism of its recommendations contributed to a National Curriculum in which children were to think creatively *across* the curriculum (Craft, 2002; DfEE/QCA, 1999). Later, six Early Learning Goals for the under-fives were added, one being the use of imagination or creativity, largely in art and craft (Newton, 2005). An attraction to creativity is evident across the UK where it is often described as a thinking, key or life skill (SEED, 2006). An interest in fostering creativity is also apparent in, for example, Australia, Cyprus, Japan, Korea, New Zealand, Singapore, and the USA (AAAS, 1990; Schwartz-Geschka, 1994; Ritchie & Edwards, 1996; Diakidoy & Kanari, 1999; Tan, 2000; Park *et al.*, 2006, Milne, 2007). Perceptions of the desirability of creativity, however, depend on the culture and may not be encouraged in the classroom (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) and Piaget argued that the principal goal of education is to produce creative people (see Fisher, 1990, p. 30). From a philosophical point of view, it can be argued that, 'A meaningful life is a creative one' (Taylor, 1999, p. 9) but, more mundanely, a creative mind can contribute to personal independence, autonomy and the ability to cope in new situations (Craft, 2002; NACCCE 1999). In classrooms, creativity can improve behaviour, social skills, self-esteem, motivation and achievement (QCA, 2003, 2005; Ofsted, 2006). Against this background, the DfES (2003) urges primary teachers to foster creativity and problem solving skills. (Craft (2002) and SEED (2006) offer useful accounts of the adoption of creativity as an educational aim.)

Creativity in science

Science creates ideas through imaginative thought governed by rationality (Osborne, *et al.*, 2003; Kind & Kind, 2007). Scientists, in constructing theories, analogies, models and similar explanatory devices, in articulating them to view the world in new ways and in testing them, are creative. But what creativity means in the context of school science is unclear. Some talk of the 'child as scientist' but others see the analogy as over-stretched because scientists have a breadth, depth and connectedness of knowledge and experience which children lack (Kind & Kind, 2007). They warn against simplistic attempts to have learners imitate what scientists do and urge caution in expecting children to be creative exactly like a scientist (Klahr *et al.*, 2000; Kind & Kind, 2007; Milne, 2007). Kind and Kind point to the importance of imagination and its potential to empower. Imagination is a creative, mental resourcefulness which can add to a child's self-reliance and autonomy. On this basis, creativity in school science means taking opportunities in science contexts which foster empowering, imaginative thought in the children. This does not mean, of course, that school science has no other aims or that empowerment stems only from creativity.

From a constructivist perspective, meaningful learning is inherently creative (see Newton, 2000; Howe, 2004; Ovens, 2004). A teacher might support the making of mental connections to build understandings but the connecting is something children must do for themselves. We try to help them when we ask children to:

§1. *Make scientific sense of the world.*

This includes opportunities for creativity, such as:

§1.1 constructing more or less tentative descriptions of, for instance, properties, scenarios, trends and patterns, structural models and analogies *(as when a child 'sees' a pattern in data or uses scientific information to imagine living on Mars or describes a rock as being like cinder toffee)*;

§1.2 constructing more or less tentative explanations involving, for example, reasons, causes, hypotheses, theories, functional models and analogies *(as when a child thinks of a reason for the appearance of an image in a mirror or connects a ball bouncing off a wall with a light ray reflecting off a mirror)*.

Given the purpose of schooling, the descriptive and explanatory understandings the children create (or recreate) are likely to be novel to the learner. Included are opportunities for creativity afforded by extending or articulating descriptive and explanatory understandings to produce new possibilities *(as when a child uses a grasp of the reflection of light to explain why paper does not behave like a mirror)*.

Children also have opportunities to be creative when asked to:

§2. *Gather and evaluate scientific information and evidence.* This second field is commonly referred to as doing 'experiments' or 'practical investigations' and includes opportunities, such as:

§2.1 constructing a practical way to find reliable, descriptive information *(as when a child devises a way to see if sound travels through water, if light bounces off a mirror like a ball off a wall, or if this shoe has more grip than that shoe)*.

§2.2 constructing a practical way to test a tentative explanation of an observation or event *(as when a child devises a practical investigation to see if roughness increases friction or 'light for its size' is what matters for things which float)*.

Opportunities in these two fields (§1 and §2 above) are not mutually exclusive. For example, a child may extrapolate from observations in §2.1 to arrive at a causal explanation (§1.2) *(as when a child speculates that shoes with studs will have more grip than those without studs)* or might revise an explanation after examining the results in §2.2 *(as when a child decides that more wheels do not make a toy car go faster)*.

These opportunities may be cast in the form of problems or challenges (Simon, 1977). *(For instance, after the story of the Titanic, children may be set the problem: 'Does it*

matter if the hole is just below the water line or at the bottom of the ship? Find out'.)
Where science is broadly interpreted to include applied science or technology (as in elementary science in Scotland) children may also be creative when asked to:

§3. *Apply science.*

This includes opportunities for creativity, such as:

§3.1 solving practical problems *(as when children use knowledge of the properties of materials to make a waterproof roof for a model house)*.

This opportunity may, of course, be attached to those above.

As Howe (2004, p. 15) has pointed out, scientific creativity is 'more than having fun and coming up with wacky ideas' or 'doing your own thing' (Fisher, 1990, p. 33). Creative thought has to be subject to some form of quality control. This is provided by evaluative thought and, sometimes, practical ability to translate a novel idea into a product (Sternberg and Lubart, 1995, 1999). Some evaluation could occur in the above examples (as when a child alters an account of living on Mars to bring it in line with new information or when s/he sees the limitations of a practical test and improves it). Implicit in the list is scientific problem solving which can entail constructing tentative explanations and tests. It is, of course, possible for children to be creative in other ways in their science lessons. They may, for instance, create a poem or a painting to express their feelings about what people are doing to their world. We do not say that these opportunities should be ignored but they should be seen as instances of creativity with language and art.

Could these opportunities foster self-reliance or autonomy? (Re)creating descriptions and explanations of the world (§1) can make the world less chaotic, more predictable and more susceptible to action. An ability to take such knowledge beyond its original context, manipulate it and relate it to other knowledge to produce something new to the learner is also enabling (§1, §3). Similarly, being able to construct an explanation of a situation or event from data and experience (§2) facilitates independent thought and action. These exercise the imagination to generate new possibilities and alternatives.

Young children can be creative (e.g. Torrance, 1975) but can they be taught to be creative in science? Being creative is something learners must do for themselves.

What teachers can do is provide conditions which increase the likelihood that children will make, for instance, appropriate connections and so experience being creative (Weisberg, 1988; Nickerson, 1999; Newton, 2000). This may enhance children's self-esteem, motivation and achievement but to enhance their self-sufficiency and coping capacity (what Eysenck (1996) calls private novelty, Boden (1996), personal creativity and Craft (2002), small c creativity) children must also be creative in the absence of a teacher. In other words, they should develop tendencies and behaviours which increase the likelihood that they will be creative unaided. There are programmes which claim to enhance problem solving and creative abilities. An early instance is Osborn's (1957) training in 'brainstorming'. For technologists, Altshuller (2000) compiled a set of resources to structure and guide practical problem solving. Better known is De Bono's thinking hats approach (de Bono, 1985). Such orderly approaches to enhancing creative thought can work (Osborn, 1957; Torrance, 1975; Shneiderman, 2000; Moseley *et al.*, 2005) but they are not devices which *make* someone creative. Instead, they practise routines which make creative thought more likely. As a consequence, skills, traits and habits of thought may be established which support children's creative thinking. Children may vary in creative capability, particularly in their independence, in the scope of their creative acts, in their interest in the detail of how to produce what is desired, and in their departure from common or stereotypical responses (Nystrand & Zeiser, 1970). Tasks also vary in difficulty. A teacher may choose to reduce the demand by drawing attention to relevant matters. It is worth adding that there can be pressures which act against creativity. Torrance (1975) saw children react negatively towards others who were being creative.

Teachers' conceptions of creativity

Teachers' beliefs about creativity in different parts of the world are similar, at least at the general level. For instance, Bjerstedt (1976) found Swedish teachers to see creativity as original, independent work, practised largely in subjects like art. Fryer and Collings (1991) found similar views amongst British teachers, as did Diakidoy and Kanari (1999) amongst Cypriot student teachers. 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 tended to agree that creative children are artistic, imaginative and inventive. But some subjects are seen as offering fewer opportunities for creative thought than others and science can be one of them. Pre-service teachers in the USA believed that, ‘there is no creativity after data collection because a scientist has to be objective’ (Dickenson *et al.*, 2000, p. 12). In the UK, primary teachers were found to have a narrow, arts-based view of creativity. Science was seen as relatively uncreative and training programmes may neglect this conception (Davies *et al.*, 2004).

Do such beliefs matter? Hardy and Kirkwood (1994) argue that only through deep-seated change in teachers’ beliefs, values and feelings about learning and teaching will their practices change. Some studies, however, find little relationship between teachers’ conceptions of the nature of science and their teaching (e.g. Duschl & Wright, 1989; Mellado, 1997). Others find that such beliefs can determine classroom strategies (e.g. Pajares, 1992; Hofer & Pintrich, 1997; Water-Adams, 2006). The link between teachers’ conceptions of science and their practices is neither direct nor simple. It is mediated by such matters as the pressure to cover content, a lack of teaching experience, preferred teaching approaches and student reactions to them (Fryer & Collings, 1991; Brickhouse & Bodner, 1992; Bell *et al.*, 2000). Moreover, when teachers’ conceptions are accessed at the general level, views of the world painted with a broad brush may be too vague to shape planning and teaching. When accessed at the specific level, however, there can be a closer relationship between conceptions and teaching (e.g. Strauss, 1993; Lunn, 2002; Beswick, 2004). Strauss (1993) points out that teachers need to consider their beliefs and, if necessary, confront them. On this basis, teachers’ conceptions do matter and knowledge of them has the potential to be useful in teacher training.

The problem

It is not enough for a teacher to know what constitutes creativity in general. Creativity is polymorphic, that is, its nature varies with the subject. To foster and assess scientific creativity in a systematic and deliberate way, teachers need to know what constitutes creative thought in the context of primary science. Further, knowing only a subset of the possibilities is not enough. This study aimed to identify some student teachers’ conceptions of creativity in primary science and comment on how appropriate they are for teaching science.

Method

The collection and processing of a data set

Marton's phenomenographic method for eliciting conceptions was used. Generally, this requires interviews with between twelve and twenty people. Here, students first completed a questionnaire about creativity in primary science (see Appendix). This preliminary step was to increase the likelihood that subsequent interviews would be productive by informing such questions as, 'In your examples of science lessons in which children would be creative, what would the children do that was creative?' 'Is there another way children might be creative in science?') Most interviews lasted between twenty and thirty minutes and elicited:

- Specific instances of science lessons believed to provide opportunities for children to be creative in science;
- Clarification of what children did which students considered was creative;
- What the students considered to be worthy of high (and low) marks for creativity in these lessons;
- The students' views on the accuracy of the interviewer's perceptions of their beliefs.

The responses to the questionnaire were clarified, extended and supplemented in the interviews. The interviews were conducted by one of the authors who was known to the students. Responses (questionnaire and interview together) which purported to describe creative lessons were transcribed and printed as individual items to form a data pool. (This pool included, for example: *'The children need to pool all their ideas from teaching to design a vessel which will sail'*, *'Absorbing water in different types of paper to find the best to use to make a hat for the school chef'*, and *'A lesson on testing materials for strength'*). The data pool was sorted into groups on the basis of similarities in the kind of creativity the students considered the lessons to support. This was done jointly by the authors and was iterative. As the sort progressed and new groups formed, earlier groups were re-sorted and items were re-allocated so that self-consistent, 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 certainly complete: interviews with additional students may add to it. Here, as data from students at the end of the list were added, no new categories appeared. Nevertheless, it should not be assumed that other groups do not exist amongst student teachers. In practice, this is not an obstacle to using the results to inform discussion about certain questions relating to student teachers' conceptions.

The sample

The questionnaire was completed by sixteen, final (third) year students on a first degree course which also led to qualified teacher status. These students would 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 and which included generic instruction on lesson planning. Over the previous two years, these students had observed, planned and taught lessons for some twenty weeks in four primary schools. As required by the National Curriculum for England, this included the teaching of science. By this stage, these students were generally expected to plan lessons without detailed support. At the time of the study, these students had elected to take a science education option to give them some insight into science leadership in schools. The group comprised mainly 'non-specialists' in science as the majority (11) had not studied science beyond the age of sixteen years in school. Five had pursued some aspect of science, mainly biological, at A or AS level of the General Certificate in Education. They were interviewed individually over three successive weeks. The topic of creativity in primary science was to be a part of their course but none had formal instruction on creativity at this stage.

Results

We present the findings first in broad terms and then in the specific context of science teaching where we describe five categories of conceptions held by these student teachers. More briefly, students' thoughts on how to assess and foster creativity in science and on the opportunities for creative activity afforded by various aspects of science conclude the account.

Some background beliefs

According to their responses to the questionnaire (Q1-5), none of these students believed science is uncreative. Nevertheless, Music (14), Art (16), and Drama (16) tended to be seen as offering more opportunities for creative thought than science (the number of endorsements is in brackets). Design & Technology also attracted similar attention (10). Responses in the interviews showed that these students generally saw Design & Technology as offering problem solving opportunities which required creativity in designing solutions. Together, these subjects were generally seen as more 'open-ended', 'less theoretical', involving 'less writing', more open to 'self-expression', 'imagination', 'independent activity', 'your own ideas rather than explaining ones that already exist', and did not involve 'right answers'. Seen as offering fewer opportunities than science were modern foreign languages (16), geography (16) history (16), mathematics (15), and religious education (8). These were described as 'presenting facts' and subject knowledge' which had to be acquired before creativity was possible and as having 'right or wrong answers' and 'rules and patterns to follow' where children were 'told what to do'. Collectively, these students appear to have general conceptions of creativity which, although favouring the arts, can be related to accepted descriptions of creative thought. What this means in the more specific context of the science lesson was revealed by the phenomenographic analysis.

Categories of conceptions about creativity in the science classroom

Most of the students said they found it difficult to think of examples of creativity in science lessons. From their responses to Q6-11, explored in the interviews, these students had the following conceptions.

Category 1

1a Children experience the world and generate explanations.

In this sub-category, direct experience of some scientific phenomenon is generally provided and the children are asked to explain it. Creativity is seen as being in the generation of a causal explanation.

e.g.

(After children had a period of self-directed activity making circuits) 'Ask them why do lights go dimmer when you add more to a circuit?'

1b Children experience the world, generate explanations and test them.

This sub-category is an extension of 1a in which children are also asked to test their explanations practically.

e.g.

‘The children try out lots of different objects to see if they would float or sink in water. They try and guess which would float and say why.’ (Followed by testing to see if the outcome is in accordance with prediction.)

Category 2

Children imagine using scientific information.

In this category, the teacher aims to make facts more interesting, memorable or meaningful by having the children integrate them using their imaginations to make, for example, mental pictures. Creativity is seen as being in the use of imagination.

e.g.

‘Visiting planets using imagination.’

Category 3

3a Children do fact-finding practical investigations to answer given scientific questions.

Here, the emphasis is on finding a way to collect relevant data which answers a factual question. Explanations of underlying phenomena or events are not required. Creativity is seen as being in designing the investigation.

e.g.

‘Do different surfaces have different amounts of friction?’

‘What are the best conditions for seeds to germinate?’

3b Children apply scientific knowledge to solve a given practical problem.

This sub-category represents the practical application of scientific knowledge. Creativity is seen as being in applying that knowledge in the design of a solution (often an object) to solve what is, in essence, a technological problem.

e.g.

(Children are asked to find a way of cleaning dirty water to make it usable.) ‘They devise their own way of doing it.’

‘Children use past knowledge and initiative to make a boat.’

3c Children do fact-finding practical investigations and apply what they find to solve a given practical problem.

This sub-category is a combination of 3a and 3b. The practical problem calls for fact-like information which must be found through practical investigation. Explanations of underlying phenomena or events are not required. Creativity is seen as being in both designing the investigation and in designing a solution to the problem.

e.g.

'Absorbing water in different types of paper to find the best to use to make a hat for the school chef.'

'What material would be the best to use to make a set of ear muffs to block out the sound? Then making and testing the ear muffs.'

Category 4

Children's positive feelings about science are aroused by the lesson.

Here, a science lesson is provided to excite, enthuse or surprise children. The events tend to impress children, arouse comment and attract their attention. Creativity is seen as being largely in the atmosphere and engagement which the lesson generates.

e.g.

(Referring to a lesson involving demonstrations with bottled gas) 'Very little writing involved. Getting them thinking. Getting a Wow!'

Category 5

Children make or do things in science.

In this category, the children produce or make something following a teacher's detailed instructions. The task is generally a way of making information more concrete, memorable or meaningful.

e.g.

'Children to create the planets (e.g. in card) and stand to scale in order of planets. Demonstrate the movement of the earth around the sun, etc.'

Assessing creative thought

Responses to Q12-14 gave some indication of how assessing creativity is perceived in general terms. Children showing creative thought were seen as 'thinking for themselves', 'giving reasons', 'asking questions', 'expressing in their own words' and, more specifically, making choices of equipment and method, interpreting results and applying knowledge (9 responses). Two students thought evidence of creative thought was in a child's 'participation' and 'interest and enjoyment'. Absence or poor quality creative thought was seen as being indicated by rote learning, the absence of reasons for thought and action, and 'just getting results, not meaning' (9). Lack of participation was proposed by two students as indicating an absence of creative ability. The balance (5) said they felt unable to assess creative thought, good or bad.

Encouraging creative thought

Responses to Q19 and 20 expressed the view that encouraging creative thought in science was difficult (11). The minority said it depended on the child and the topic. The reasons given for the perceived difficulty were diverse. Three said that creativity in science was 'hard to define' and three felt that primary school children had an insufficient grasp of science to be creative. Three thought that children were not aware that they were allowed or expected to be creative. Another thought it was the nature of science, dealing with 'the invisible', which made the task difficult. One student wrote that creativity was more relevant at the Foundation Stage and at Key Stage 1 (children aged 3 to 5 years and 5 to 7 years, respectively). One felt it depended on resources and 'how well the children relate to the topic' and one believed that creative thought was 'beyond the teacher's control'. The balance (3) were unable to supply reasons.

Parts of science and opportunities for creativity

There was very little agreement amongst the students in their rankings of areas of science listed in Q15 (the Kendall coefficient of concordance was only 0.06 and was statistically insignificant (Siegel, 1956)). For example, Earth in Space and Changing Materials were considered to provide the best opportunities for scientific creativity by one student, the worst opportunities by another, with the other students spread between them. This lack of agreement could indicate that the areas are seen as fairly equal as far as creative opportunities are concerned. Earth in Space, however, was treated slightly more favourably and was seen as offering opportunities for imaginative thought about other worlds. Keeping Healthy, on the other hand, was treated slightly less favourably on the grounds that it offered fewer opportunities for practical activity. The perceived presence or absence of opportunities for practical activity was the most common reason given in Q17 and 18 for the rankings (6 responses).

Discussion

The approach identifies categories of conceptions but it can never be certain that the set is complete – there may be others out there being expressed by would-be teachers who were not in the sample. Furthermore, while the prevalence of particular categories is interesting, the sample is too small to permit much beyond speculation about the relative prevalence of the categories in the general population of student teachers. Nevertheless, these students share attributes with many other primary school trainees. For instance, most had not studied science after the age of sixteen years, other than as a part of their teacher training course. Consequently, teacher trainers may recognise these students amongst their own and be able to relate the students' views to those of their students (see 'relatability' in Bassey, 2001). These students had, however, opted for a science education course. Presumably, science found favour with them. It may be that their lesson planning skills in science were generally better informed than other students because of this. Given that, this may be a slightly optimistic account of conceptions of creativity amongst student teachers in general.

There was evidence that creativity in the broad sense was seen as others tend to see it. For instance, there was reference to 'self-expression', 'imagination', 'own ideas', 'thinking for themselves' which suggested an expectation of novelty in thought. These students also saw creativity as centred more on the arts which parallels the findings of Diakidoy and Kanari (1999), Davies *et al.*, (2004) and Edmonds (2004). This 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, five main categories of conception were identified. In the first, creativity was seen as having children construct explanations of scientific events and phenomena, sometimes going on to test their causal explanations. This relates well to creativity in making scientific sense of the world (especially opportunities §1.2 and §2.2). In the second category, creativity is in using the imagination to construct mental images, such as what it would be like to live on Mars. Often, this involves processing and relating information to construct descriptive understandings of the scientific world. This relates to opportunity §1.1. In the third category, creativity was seen as having the children construct fair tests to produce fact-like information (as in §2.1), having them apply fact-like information to solve given practical (technological) problems (§3.1), and having them do both. This category also reflects an interest in pursuing facts (albeit experimentally) and parallels the attention teachers give to them in primary science (Newton & Newton, 2000). It was the most frequent category of conceptions (10 students) although it may be a specific attribute of this group of students. The fourth category sees creativity in the engineering of a shared, positive feeling about some topic in science. This may conflate or confuse the creative act with its possible effects, such as, stimulating attention, generating interest and excitement, and prompting on-task talk. A lesson which generates emotions is not necessarily one which stimulates creativity (Barrow & Woods, 1975). It may also confuse a teacher's creativity with that of the children. Both of these would be misconceptions. Another misconception lies in the final category which sees creativity in making things by following instructions. 'To create', in an everyday sense, can simply mean to reproduce without novelty and this is implied here.

Taken together, the first three categories map onto the suggested opportunities for creative thought reasonably well. However, the students tended to confine themselves to one category, mainly the third. Given a tendency to judge the potential of topics for creative thought by their opportunities for investigations, opportunities may be narrowly focused on fact-finding investigations and knowledge application in technological problem solving. Other opportunities, such as the construction of explanations, are likely to be overlooked by these students and where technology is a separate subject in the curriculum, scientific creativity may hardly be exercised at all.

The students were generally uncertain about how to assess creative thought in science lessons. It could be that they would 'recognise it when they saw it' (McPherson, 1975, p. 27) or be able to judge it intuitively (Boden, 1996, p. 115) but this would only be for the limited opportunities they were likely to provide. Discussion about assessment centred on the presence or absence of creative thought and nothing was said about degrees of creativity. But these students acknowledged that they found thinking about creativity difficult.

This study suggests that the meaning and assessment of creativity in primary science may not be common knowledge amongst would-be teachers. Teacher trainers may need to give it explicit attention so that weaknesses are addressed and confronted (Strauss, 1993). They are likely to meet both misconceptions and narrow conceptions of creativity in science education. Furthermore, a tendency to associate creativity with the arts may inhibit thought about it in other contexts. In science education, it is tempting to avoid the word ‘creativity’ with its art-centred connotations and have students think in terms of ‘productive thought’. Productive thought includes creative and critical thinking and relates well to thought which could be fostered in science lessons. Creative thought involves, for instance, imagining situations, generating new perspectives, producing tentative explanations, planning actions and solving problems while critical thought considers its soundness and potential (Moseley *et al.*, 2005, p. 313). Together, they offer more to empowerment than either alone. But, productive and reproductive thought would still have to be distinguished.

Conclusion

Creativity does not always receive much attention in teacher training in the UK (Davies *et al.*, 2004) and elsewhere (Diakidoy & Kanari, 1999). In the context of science education, teacher trainers should check for both narrow conceptions and misconceptions of creativity. In particular, they should be sensitive to conceptions which make it only a descriptive or fact-finding exercise, technological problem solving, emotional event, or manufacturing activity. A general tendency to associate creativity with the arts may incline students to neglect it elsewhere, particularly when they find difficulty in grasping its meaning at the classroom level. These students found it even more difficult to be specific about assessing creativity in science lessons. What counts as poor, moderate and good creativity when speculating about descriptions, explanations and investigations may need to be clarified. It could be useful to link the word ‘creativity’ with ‘productive thought’ in science education to draw attention away from unhelpful connotations and towards a wider view of what creativity of a scientific nature can entail and offer.

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Appendix

(N.B. Spaces for responses have been omitted.)

1. Do you think of science as a creative subject? Yes/No/Sometimes/Don't know

2. Which subjects offer more opportunities for creative thought than science?
(Select from this list and tick)

English	Drama	MFL	Maths	RE
History	Geography	Music	Art	PE
ICT	D&T	Any other subject? (Please specify)		

3. What makes these have more opportunities?

4. Which subjects offer fewer opportunities for creative thought than science?
(Select from this list and tick)

English	Drama	MFL	Maths	RE
History	Geography	Music	Art	PE
ICT	D&T	Any other subject? (Please specify)		

5. Why do these have fewer opportunities?

6. Give me an example of a science lesson which involves scientific creativity? (Topic and a brief description)

7. Which was the creative part?

8. What was creative about it?

9. Which topic would you like to teach or enjoy teaching in science?
Suppose you taught this topic. Are there opportunities for scientific creativity in it?

10. If so, what are they?

11. Please state what is creative about them.

12. If you wanted to give more marks to someone who showed scientific creativity in the topic you chose in 9 above, what would you give the highest marks for?

13. What would you give the lowest or no marks for?

14. What would you look for as evidence of creative thought in the topic you chose?

15. Here is a list of aspects of science. Which of them do you see as offering the best opportunities for scientific creativity?
(Put them in order from 1 (best) to 13 (worst))

Ourselves and other living things	Keeping healthy
Variety of life	Environments for living things

Materials and their properties	Changing materials
The Earth beneath our feet	Magnetism
Electricity	Light
Sound	Forces
Earth in Space	

17. Looking at your list, what makes ‘number 1’ the best?

18. What makes ‘number 13’ the worst?

19. Do you think that encouraging creative thought in science is easy or hard?

20. Why do you think this?

21. Do you see problem solving as being related to creativity?

22. If so, in what way?

23. Please give me an example of a problem which children might solve in science?

24. What would be the creative part of the problem?

25. Is there anything you want to add about creativity in science? Have I missed something out?