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What teachers see as creative incidents in elementary science lessons.

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Abstract

Teachers are often urged to nurture creativity but their conceptions of creativity in specific school subjects may have **limitations which weaken** their attempts to do so. Primary school teachers in England were asked to rate lesson activities according to the opportunity they offered children for creative thought in science. The teachers could, overall, distinguish between creative and reproductive activities but, as predicted, there was evidence of narrow conceptions of school science creativity, biased towards fact finding, practical activity and technological design. Some teachers saw creativity in essentially reproductive activities and in what simply stimulated interest and on-task talk. Some implications and recommendations for teacher training and professional development are discussed.

Introduction

Creativity is widely valued, largely for material reasons. Beghetto (2007, p. 1) argues that it is 'The ultimate economic resource and an essential for addressing complex individual and societal issues'. It is increasingly seen as what matters in a successful economy, at least in the West (Pink, 2005). But, at the personal level, it offers a kind of empowerment which may help people cope with and lead a fulfilling life (Newton, 2000; Kind & Kind, 2007) and it can be very satisfying (Shaw, 1989). McLaren (1999), however, suggests that perpetual innovation threatens stability and conformity and risks producing an anxious, uneasy society. Nevertheless, the economic and empowerment arguments prevail and facility with creative thought is a commonly stated goal of education at all levels and in all subjects (Fleming, 2008; Walker & Gleaves, 2008). For instance, the English government's education department urges teachers to exercise young children's creativity and problem solving skills across the primary school curriculum through publications such as *Excellence and Enjoyment* (DfES, 2003). **This study interprets creative behaviour for the specific context of the elementary science classroom and predicts and explores some teachers' conceptions of scientific creativity and compares them with that interpretation. We begin with the concept of creativity in broad terms and then narrow the study to creativity in the science classroom.**

Creativity

A clear distinction between mimicry and creativity was generally not made until relatively recent times. For instance, it was not until the Age of Enlightenment that art began to be seen as potentially creative or until the nineteenth century that it became an archetype for creative activity. The creative nature of science did not receive much attention before the twentieth century and the model which art provided continues to shape popular thought (Tatarkiewicz, 1980). Definitions of creativity are now numerous (see, e.g. Taylor, 1988) but most focus on it being 'the ability to offer new perspectives, generate novel and meaningful ideas, raise new questions, and come up with solutions to ill-defined problems' (Beghetto, 2007). In an educational context, NACCCE (1999, item 29) has described it as 'Imaginative activity fashioned so as to produce outcomes that are both original and of value' - originality alone is insufficient as, during the creative process, scientists also evaluate their developing products for appropriateness (Amabile, 1998; Lubart & Mouchiroud, 2003). These definitions also have an implicit social element in that what is appropriate and valuable is, ultimately, determined by the scientific community (Csikszentmihalyi, 1996).

Children being creative in science

We cannot expect children to be creative like a scientist (Kind & Kind, 2007); a scientist's creativity and judgement of what is appropriate draws on extensive, deep subject knowledge and strategies and on what counts as an elegant solution (Taylor, Smith, & Gheselin, 1975; Simonton, 1999; NAE, 2005). Children are unlikely to produce something new to the world which is appropriate and stands scrutiny by the scientific community. Nevertheless, everyone is creative to some degree even if only to solve the problems of everyday life. As Hadamard (1954, p. xii) put it, 'life is perpetual invention'. For this reason, Boden (2004) distinguishes between historical creativity which offers something novel to the world and psychological creativity which produces something novel to the person. On this basis, children are psychologically creative when they construct, for instance, meanings, explanations, hypotheses, arguments and procedures which are new to them (Givens, 1962). Torrance (1975) found that young children are capable of such creative thought and that practice helps them develop the ability. Accordingly, it is reasonable to ask teachers to exercise children's creativity in science lessons and develop relevant habits of thought and dispositions (Newton & Newton, 2008). Although the mental events of construction are inaccessible, a teacher can provide conditions which increase the likelihood that certain mental processes will be practised and valued structures created (although, in the classroom, this generally means recreated).

In science lessons, this creative process may be exercised in constructing notional scientific knowledge such as speculative descriptions of situations, tentative explanations, hypotheses and imagined, possible alternatives. For brevity, this is referred to here as, *Field 1*. The creative process may also be practised in constructing empirical ways of gathering knowledge and evaluating ideas, such as devising a procedure to collect reliable, descriptive information or an empirical test of a tentative explanation (Spearman, 1931; Givens, 1962; Metcalfe, 1983; Barron, 1988; Lubart & Mouchiroud, 2003; Beghetto, 2007). This is referred to here as, *Field 2*. Within these fields, an epistemic distinction can be made between *descriptive* and *explanatory* science. Descriptive science deals with fact-like information while explanatory science deals with causes and reasons. Creative thought can produce *description* and *explanation* in both fields (Newton, 2000).

Creative thought may also be exercised in applying scientific knowledge to solve a practical problem, referred to here as *Field 3*. In England, this is currently the principal concern of the subject, Design & Technology, but elsewhere, as in Scotland, it may be an integral part of elementary science. It is possible to distinguish between creativity in science (popularly called 'discovery') and creativity in the application of science (popularly called 'invention', see, for example, Hadamard, 1954) but both involve novel mental constructions, one to describe or explain the world and the other to support effective action in it. Table 1 exemplifies children's creative thought in the three fields (Newton & Newton, 2008). It also contrasts *creative* thought with its antithesis, *reproductive* thought, the recalling, recycling of information, the following of instructions, using algorithms and gathering information without materially altering or adding to it (Moseley, Baumfield, Elliott, Gregson, Higgins, Miller, & Newton, 2005). (Curiously, the exemplification of scientific creativity in *Excellence and Enjoyment* (DfES, 2003) in England is confined to practical problem solving, that is, Field 3.)

<<Table 1>>

Teachers' conceptions of creativity

Western teachers tend to see being creative as producing something novel, largely epitomised by creativity in art, reminiscent of the popular notion of creativity (e.g. Bjerstedt (1976) in Sweden; Fryer and Collings (1991), Davies, Howe, Rogers, and Fasciato (2004) and Edmonds (2004) in Britain; Diakidoy and Kanari (1999) in Cyprus; Dickinson, Abd-El-Khalik and Lederman (2000) in the USA). In the USA and elsewhere, some teachers claim to support creative thought but, in reality, they provide little opportunity for it (Aljughaiman & Mowrer-Reynolds, 2005; Cropley, 2001). Others routinely dismiss creative thought (Kennedy, 2005), particularly in subjects like mathematics where they may see it as secondary to the acquisition of established procedures and a distraction from the purpose of the lesson (Beghetto, 2007). Another determinant of what happens in the classroom is the teacher's conception of creativity at the specific level of the classroom activity. What teachers see as scientific creativity in the context of school science is likely to shape whatever activities they provide for children. Teachers may come to know what counts as creativity in a subject through experience but science has often not been a strong feature in the prior education of many primary school trainee teachers in England (Newton & Newton, 2009a). Even when students have this experience, conceptions can still be mixed, vague and inaccurate (Howell, 2008; Walker & Gleaves, 2008; Newton & Newton, 2008, 2009b).

People's conceptions of scientific creativity are a combination of their conceptions of science and their conceptions of creativity and comprise what people see as diagnostic, essential attributes of both (for combined conceptions, see Costello & Keane, 1992). Limitations in either conception are likely to make themselves felt in the combined conception. While primary teachers may conceive of creativity in the classroom as children producing something which is novel to themselves, the teachers' conceptions of school science can be narrow, centring on factual description and practical activity to do with fact-like information (Newton & Newton, 2000). With these notions, teachers are more likely to see opportunities for scientific creativity in work to do with description and practical activity than with explanation and, say, discussion. At the same time, there can be a conflation of science and the appliance of science (Newton & Newton, 2008, 2009b). Such a notion suggests that teachers are likely to see opportunities for scientific creativity in children using scientific knowledge to solve essentially technological problems. It should be said, however, that the link between teachers' conceptions and what they do in the classroom is not always simple or direct but they can contribute significantly to what happens (or does not happen) in a lesson. (e.g. Fryer & Collings, 1991; Brickhouse & Bodner, 1992; Waters-Adams. 2006).

Aims of the study

This study aims to collect evidence to inform discussion of the following questions:

1. Can teachers generally recognise classroom incidents which offer opportunities for scientific, creative thought?
2. Does practising teachers' ability to recognise such incidents depend on the kind of science, **favouring description (fact-like information) over explanation (causes and reasons)?**
3. Is their ability to recognise such incidents greater in one field than in another, **favouring Field 2 (empirical ways of gathering knowledge) and Field 3 (the application of scientific knowledge in practical problem solving)**?
4. Does their ability to recognise such incidents depend on the topic in science?
5. Can the teachers discriminate against non-scientific opportunities for creative thought which might occur in a science lesson?

It does this by testing some teachers' ability to recognise various classroom incidents in science which offer opportunities for creative thought.

Method

The instrument

A conception is a cognitively economic structure which represents attributes of some aspect of the world and guides interaction with it. In particular, it enables someone to judge whether or not something is a specific instance of that aspect (Eysenck & Keane, 2000). Conversely, someone's selection of specific instances can say something about the conception which guided that selection (e.g. Kruger, 1990; Skamp, 1995). In this context, this means teachers may reveal something of their conceptions of scientific creativity in what they recognise as opportunities for scientifically creative thought in the classroom. A comprehensive taxonomy of the kinds of thought involved in the production of something novel varies with context and purpose but the essential ingredient is creative thought (Moseley, *et al.,* 2005). The other side of the coin is reproductive thought.

Accordingly, an instrument comprising 36 short classroom incidents in three, dissimilar science topics was constructed. The topics were: Earth, Space and Gravity; Electricity; Plants and Animals. These related to the requirements of the English National Curriculum for 5 to 11 year old children and so provided meaningful, specific classroom contexts for teachers in England (DfEE, 1999). Furthermore, notions of learning relate to practice more closely when they are accessed at such a specific level (e.g. Flanagan, 1975; Thompson, 1984; Trigwell, Prosser, & Waterhouse, 1999).

Twelve of the incidents favoured creative thought in science and twelve were biased towards reproductive thought in science. Of the twelve creative incidents, six related to descriptive science (concerning itself with fact-like information) and six to explanatory science (dealing with reasons for situations or events). Of the six descriptive science incidents, three were located in Field 1 and three in Field 2. Similarly, the six explanatory science incidents comprised three in Field 1 and three in Field 2. The twelve reproductive incidents were distributed in the same way. This accounted for 24 of the 36 incidents.

Six additional items related to incidents in Field 3. Typically, these were about children designing solutions to practical problems and were divided equally between reproductive and creative thought. The items with a creative bias reflected the model in Table I. There were six further incidents, two for each topic, involving creative thought which was not essentially scientific in nature. For example, Item 30: *When learning about plants, the children visit a garden centre and then paint pictures of bouquets of flowers they would like to give their mothers.*

The various categories of incidents appeared equally in each topic. Within each topic, the incidents were arranged in random order for rating on a five point scale to indicate the extent to which each offered an opportunity to exercise creative scientific thought in the context of the primary school. The topics were collated so that each appeared about the same number of times in the first, second and third positions to counterbalance any tendency for favour to accrue to any one of them (Rutherford, 2001). The instrument was trialled on several teachers and their responses used to improve the clarity of the description of each incident. The final version appears in the Appendix.

Sample of teachers

The questionnaire was completed by the twenty-three primary school teachers of a rural, a small town and a large town primary school in the North-East of England with roughly equal numbers of teachers in each school. Schools like these teach science to 5 to 11 year-old children. The teachers were evenly distributed across the working age range and included four men (17%), closely reflecting the characteristics of the national primary teaching workforce in England as described by the Department for Education and Skills (DES, 2005, 2006). The most recent inspections of these schools by the government’s quality control agency (Ofsted) found planning to be thorough, teaching to be generally good and, where science was mentioned, comments were favourable. All teachers rated all incidents in all topics.

Results

Table 2 shows the mean scores for the test items relating to descriptive and explanatory science (standard deviations in brackets). **Pairwise comparisons suggests that the teachers tended to award creative incidents higher scores than reproductive incidents. Similarly, it suggests that Field 2 (briefly, empirical ways of gathering knowledge) tended to attract higher creativity scores than Field 1 (briefly, constructing notional scientific knowledge) incidents. Other differences and interactions between these variables are less easy to see in the table so** the raw data were subject to four-factor analysis of variance with repeated measures (see, for instance, Rutherford (2001)). The factors were: field of science (Fields 1 and 2), kind of thought (reproductive and creative), topic (Earth, Space and Gravity; Electricity; Plants and Animals) and kind of science (description and explanation). The model included all main effects and interactions. The outcome is summarised. in Table 3 **which shows that there are effects and interactions which are unlikely to be chance occurrences, notably to do with the kind of thought (creative versus reproductive) and the kind of science (description versus explanation). These and other effects are discussed later.**

<<Table 2 and Table 3>>

The mean responses to the six items relating to practical problem solving (Field 3) are shown in Table 4 (standard deviations in brackets). **The means suggest that the**

teachers tended to score creative incidents more highly than reproductive incidents. The raw data were subject to two-factor (kind of thought (KOT) and topic) analysis of variance with repeated measures. The model included all main effects and interactions. Table 5 summarises the outcome **and shows the above difference to be statistically significant and that the size of the difference could depend on the topic (KOT*Topic)**.

<<Table 4 and Table 5>>

Table 6 shows the responses to the incidents that were biased towards non-scientific creativity. **The mean scores conceal the wide range of scores which each item can attract so those ranges have been included here. They show that some teachers scored items as very reproductive while others scored them as very creative.**

<<Table 6>>

Discussion

There was a significant main effect (Table 3, kind of thought (KOT), $p<0.00$) which showed that the teachers tended to score scientifically creative incidents higher (2.54, on average) than those which called for reproductive thought (1.74, on average). In other words, as a group, they showed some ability to recognise such opportunities in the incidents provided (a moderate effect size (Cohen, 1988) of 0.68).

There was a significant main effect (kind of science (KOS), $p<0.00$) in which the teachers tended to see more opportunity for creative thought in descriptive science (mean score, 2.25) than in explanatory science (mean score, 2.03; effect size 0.16). While there was no strong evidence for an effect of the field of science alone (p=0.11), there was an interesting and relevant interaction between field and kind of thought (Field*KOT, p=0.02). This showed a tendency for the teachers to see more opportunity for creative thought in Field 2 (practical activity, mean 2.71) than Field 1 (non-practical activity, mean 2.37, effect size 0.33). These tendencies were predicted. Regarding the application of science (in Field 3), there was a significant effect associated with kind of thought (p=0.00). In other words, items describing incidents of the application of science in practical problem solving tended to attract significantly higher scores (mean score, 2.62) than those exercising reproductive thought (mean score, 1.78; p<0.00; a large effect size of 0.77). Again, this tendency was predicted.

There was no strong, statistical indication that one topic was favoured more than another in the scoring but, given that the probability approached significance at the 5% level (Topic, p=0.07), there may be topics which would contradict this. Similarly, while the pattern of scores is comparable in each topic (Figure 1), the interaction between topic and kind of thinking hints at a tendency for less discrimination between reproductive and creative incident scores in Electricity (KOT*Topic, p=0.07). Most primary teachers are not science specialists and knowledge in topics like Electricity is not always as secure as it is elsewhere (Jarvis and Pell, 2004) which may reduce their ability to discriminate between the incidents. It could, however, be an artefact of the particular incidents offered in *Electricity* although they tended to parallel those offered in the other topics. A similar effect was noted in the interaction between field and topic (Field*Topic, p=0.00). Given the earlier effects and interactions, those of a higher level are not surprising and do not add greatly to the discussion.

In general, the teachers were not overly generous in their scores, only two means in Table 2 exceeding 3.00. A score of 2 corresponds to ‘a moderate opportunity’ while 3 is ‘a good opportunity’. While this may reflect a tendency to see relatively low levels of opportunity for creative thought in science, scores for other subjects are not available for comparison and it may also be that other incidents in science may have attracted higher scores. A second observation is that the scores often had a wide range. For example, in the first topic, the mean score for the reproductive thought item: *Children use information from books and the Internet and find a description of what it is like inside a torch bulb* received a mean score of 1.74 but six teachers scored it as 3 or 4. The creative thought item: *The children learn that gravity on the Moon is much weaker than on the Earth and they think of examples of what that will mean* received a mean score of 2.43 but four teachers scored it as 1. In short, some see creativity where others do not. An incident in *Electricity* is also worth a closer look, namely, item 20: *The children find a book which shows how to make a battery from salty water, blotting paper and washers made from different metals. The teacher lets the children try it and they find it interesting and engage in a lot of on-task talk*. Intended as a reproductive incident, it attracted an average score of 2.52, comparable with several of the mean scores associated with more creative incidents. It may be that the children’s interest and on-task talk tempted the teachers to score it more highly than in other reproductive incidents in general. This mirrors some trainees’ notion that an activity which attracts, motivates and excites is also a creative one (Newton and

Newton, 2008, 2009b). It could also be that teachers envisaged children being creative in their on-task talk, although on-task talk is not, necessarily, creative.

Regarding the incidents of non-scientific creative thought (Table 4), all except one had mean scores of less than 2.00, not unlike the scores awarded reproductive thought in description and explanation. This suggests that these practising teachers could, in general, distinguish between these examples of non-scientific and scientific creativity. Once again, however, the variation from one person to another was marked. For example, *The children make papier-maché models of imaginary worlds to hang up in the classroom*, attracted a mean score of only 1.69 but seven teachers scored it at 3 or 4. It may be that some teachers saw the juxtaposition of *imagination* and *worlds* as implying creative thought necessarily constrained by science knowledge.

Some comments on limits of the study, although fairly obvious, are appropriate. First, it may be possible to recognise incidents which afford opportunities for scientific creativity but be unable to construct them. Even with the ability to construct them, a teacher may not include them in lessons, so this says nothing about these teachers' practices. It seems reasonable to assume, however, that those who cannot recognise such incidents are less able to provide them deliberately in a coherent form and are less able to provide explicit guidance for trainees on their provision. Second, the instrument presented incidents drawn from three science topics but teachers may respond differently to other topics. These topics were dissimilar yet the pattern of teachers' responses was broadly similar (Figure 1). On this basis, a similar pattern might be found for other topics. It must be mentioned that the incidents themselves could have been different and, perhaps, responses to them may then have been different. Nevertheless, the teachers' responses resonated well with those obtained in a qualitative, phenomenographic study of trainees' conceptions (Newton & Newton, 2009b) and this adds some confidence in the data. We do not, however, suggest that the instrument has the virtues or rigour of a standardised psychometric test**.** Nor do the 36 items cover every conceivable opportunity to be creative in science. Rating more items, however, takes more of teachers' time and risks inattentive scoring and refusals.

<<Figure 1>>

Regarding the sample, the size is adequate for analyses of variance but, as pointed out by Bacchetti (2002), it is not sample size which is paramount – statistical **tests** incorporates and reflects sample size **(some, indeed, are intended for very small samples**) – what matters more is the extent to which the sample is representative of the population concerned. In this instance, these teachers shared features with English primary teachers in general. Caution is needed, however, if this is to be applied to a given group of teachers – they should not differ greatly from those in this group. For instance, a group of primary science coordinators with a strong background in science or secondary school science teachers may respond differently. On the other hand, where trainers recognise characteristics amongst those they train (what Bassey (2001) describes as the 'relatability' of research findings to specific contexts) they may find the results relevant to the training they provide. **In particular, they may see conceptions of creativity and science combined to produce limited (and limiting) conceptions of scientific creativity.**

Conclusion

Practising primary teachers showed they can, as a group, broadly distinguish between incidents which favour scientifically creative thought and those which favour scientifically reproductive thought. They did, however, favour fact-seeking practical work and the application of such information to solve practical, technological problems as opportunities for creative thought. At times, individuals disagreed considerably in the extent to which they perceived opportunities for creativity: some saw very good opportunities when others saw none. Some may not have a clear conception of what scientifically creative thought is and be unable to distinguish it clearly from reproductive thought. On the other hand, teachers generally could discount incidents offering non-scientific creative thought but, again, some failed to do so and rated them as scientifically creative. While the same pattern of response was evident in different topics, it was more marked in some than in others, perhaps reflecting a general variation in teachers' quality of knowledge across topics in science.

Similar predispositions have been found amongst trainees who have not had specific instruction on creativity in science teaching. Given these findings, guidance from practising teachers may not eliminate them without additional instruction and practice. It is also likely that some teachers would be unable to provide detailed support for trainees when planning opportunities for creative thought. For practising teachers, in-service training which illustrates a wide spectrum of scientifically creative thought in the classroom could help some recognise opportunities better, help many provide a wider range of opportunities for their pupils, and equip them to support and guide trainees in this aspect of their work. **There are indications that**

conceptions of scientific creativity stem, at least in part, from conceptions of science and from conceptions of creativity. Accordingly, trainees might usefully address the more complex, combined conception of scientific creativity by exploring trainees' and teachers' conceptions of its components, recognising that narrow views of either are likely to produce narrow views of scientific creativity. For instance, a clear distinction between creativity and mimicry still needs to be made for some teachers while others may need widen their view to see constructing an scientific explanation as a creative act.

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Appendix

The codes in brackets did not appear in the list when given to the teachers. They indicate a bias towards: reproductive (Rep) or creative thought (Cr), descriptive (Des) or explanatory science (Exp), knowledge, enquiry or practical problem solving (Fields 1, 2 or 3: F1, F2, F3), or non-scientific activity (O), as these terms are described above.

Being scientifically creative

We are interested in opportunities for children to be scientifically creative in the primary classroom. Consider each of the following incidents. Some may offer more opportunity for children to be creative in a scientific way than others. How much of an opportunity does each of these incidents offer? Please use the 0 to 4 scales to indicate what you think about each incident (circle one number for each incident). Note that:

0 = no opportunity, 1 = a small opportunity, 2 = a moderate opportunity, 3 = a good opportunity, 4 = a very good opportunity.

In work on *Earth, Space and Gravity*:

1. The children see the dents that marbles make in a sandpit and then are asked to explain the craters on the Moon. (Cr/Exp/F1) 0 1 2 3 4
2. After hearing how rough the surface is on the Moon, the children draw their ideas for a Moon buggy explorer which can cope with the Moon's surface. (Cr/F3) 0 1 2 3 4
3. The children ask if a feather will reach the floor before a hair so you ask them to think of how to make a fair test in order to try it for themselves. (Cr/Des/F2) 0 1 2 3 4
4. You explain why the children's model spaceship keeps falling over and you give them instructions for an experiment which shows that wide bases are more stable than narrow bases. (Rep/Exp/F2) 0 1 2 3 4
5. The children are asked to use books to find the reason why meteorites burn up when they enter the Earth's atmosphere. (Rep/Exp/F1) 0 1 2 3 4

6. Children collect information from science books about Mars to put together a description of the Martian landscape. (Rep/Des/F1) 0 1 2 3 4

7. You show the children how to test different parachutes fairly and they do so to find the one which takes the longest time to reach the ground. (Rep/Des/F2) 0 1 2 3 4

8. The children learn that gravity on the Moon is much weaker than on the Earth and you have them suggest examples of what that will mean for someone on the Moon. (Cr/Des/F1) 0 1 2 3 4

9. You explain why aeroplanes are streamlined and then have the children think of how they would test the explanation. (Cr/Exp/F2) 0 1 2 3 4

10. The children are puzzled about how to make a model spaceship which flies. They find pictures on the Internet which shows them what to do and they use them successfully. (Rep/F3) 0 1 2 3 4

11. The children look at pictures of planets while listening to the *Planet Suite* then use a xylophone to make tunes which suit the Earth, Jupiter and Mercury. (Cr/O) 0 1 2 3 4

them use the xylophone to make tunes which suit the Earth, Jupiter and Mercury. (Cr/O)

12. The teacher has the children write a diary about a long journey on a spaceship giving attention to the tensions of living together. (Cr/O) 0 1 2 3 4

In work on *Electricity*:

13. Children use information in books to compile a description of what it is like inside a torch bulb. (Rep/Des/F1) 0 1 2 3 4

14. The children know that metallic objects conduct electricity. The teacher ask them how they might make a circuit work without using wires. (Cr/Des/F1) 0 1 2 3 4

15. Following instructions in a book, the children use torch bulbs and batteries to make a set of light bulbs to decorate a small cardboard tree. (Rep/F3) 0 1 2 3 4

16. The teacher tells the children that a bulb will not work if the thin wire inside is broken because the electrical current cannot flow through it. She gives the children magnifiers, shows them how to make a test circuit, and has the children check that what she says is correct. (Rep/Exp/F2) 0 1 2 3 4

17. After hearing how important it is to be seen when crossing the road, the children 0 1 2 3 4

think up ways of using electrical lights on coats so that motorists will see them. (Cr/F3)

18. The children are asked to use the Internet to find out why the wire inside a light bulb glows when connected to a suitable battery. (Rep/Exp/F1) 0 1 2 3 4

19. The teacher tells the children that some things let electricity through and some do not. The children have to devise a way to test materials to find which conduct electricity. (Cr/Des/F2) 0 1 2 3 4

20. The children find a book which shows how to make a battery from salty water, blotting paper and washers made from different metals. The teacher lets the children try it and they find it interesting and engage in a lot of on-task talk. (Rep/Des/F2) 0 1 2 3 4

21. The teacher shows the children that several bulbs connected in parallel can be lit by one battery. This looks like more light for nothing but the teacher explains that the battery will lose its power more quickly because it has to pass electricity through more bulbs. The children have to use the bulbs and batteries to find out if this is true. (Cr/Exp/F2) 0 1 2 3 4

22. The children see that a weak battery, left to rest, recovers some of its power for a short while. They think of several explanations for this. (Cr/Exp/F1) 0 1 2 3 4

23. The children draw pictures of thunderstorms to make a Storm frieze for the classroom. (Cr/O) 0 1 2 3 4

24. The teacher introduces the phrase ‘bright spark’ and has the children think up five sentences in which they use it. (Cr/O) 0 1 2 3 4

In work on *Plants and Animals*:

25. The children are given a short list of what mammals have in common and, using a set of mammal pictures, they check that they have these features. (Rep/Des/F1) 0 1 2 3 4

26. Children see squashed hedgehogs on the road in Spring and the teacher asks them why it happens more in Spring than in other seasons. (Cr/Exp/F1) 0 1 2 3 4

27. The teacher shows the children how to use a classification chart to identify leaves. They develop the chart to include another leaf which they found and was not on the original chart. (Cr/Des/F1) 0 1 2 3 4

28. After the children learn about some endangered animals, they choose one of them 0 1 2 3 4

and design a poster to draw people’s attention to its s plight. (Cr/O)

29. After hearing what hibernation is, the children think about how they will test places to find the best one for a hedgehog to spend the winter. (Cr/Des/F2) 0 1 2 3 4

30. When learning about plants, the children visit a garden centre and then paint pictures of the bouquets of flowers they would like to give their mothers. (Cr/O) 0 1 2 3 4

31. The teacher shows seeds in a packet and explains that they do not begin to grow in the packet because they are dry. She describes how to use some compost in pots to show that this is true and the children try it. (Rep/Exp/F2) 0 1 2 3 4

32. The teacher explains the origin of fossils and the children write about it. (Rep/Exp/F1) 0 1 2 3 4

33. The teacher tells the children that some places are better for some plants than others. The children follow instructions on a worksheet and confirm that this is true for wet and dry places. (Rep/Des/F2) 0 1 2 3 4

34. The teacher explains that dandelion seeds spread farther because they have ‘parachutes’ which keep them floating in the breeze. The children are set the task of devising an experiment to test the explanation. (Cr/Exp/F2) 0 1 2 3 4

35. The children read about wild guinea pigs and design a home for the class guinea pig which they believe will be better for it. (Cr/F3) 0 1 2 3 4

36. The children find instructions for a bird table on the Internet and follow them to make a bird table in the science lesson to attract birds to the school garden. (Rep/F3) 0 1 2 3 4

Table 1: Some examples of reproductive and creative thought in elementary science lessons

Reproductive Description

Field 1: *The child watches a recording showing what living on Mars would be like.*

Field 2: *A child follows worksheet instructions to see if sound travels through water.*

Reproductive Explanation

Field 1: *A child finds out from a book why the image on a mirror is laterally inverted.*

Field 2: *The child copies what the teacher did to show that roughness causes friction.*

Reproductive practical problem solving

Field 3: *The children are set the problem of making a toy from wood. They are given lots of designs to choose from.*

Creative Description

Field 1: *A child uses scientific information to imagine what living on Mars would be like.*

Field 2: *A child devises a way to see if sound travels through water.*

Creative Explanation

Field 1: *A child thinks of a reason for the appearance of an image in a mirror.*

Field 2: *A child devises a practical investigation to see if roughness increases friction*

Creative practical problem solving

Field 3: *A child uses knowledge of the properties of materials to design a roof for a model house.*

Table 2: The mean scores awarded the incidents for Fields 1 and 2 (the higher the score, the greater the perceived opportunity for creativity).

	Kind of Science			
	Description		*Explanation*	
	Kind of Thought		Kind of Thought	
	Reproductive	*Creative*	*Reproductive*	*Creative*
	Topic: *Earth, Space and Gravity*			
Field 1	1.65 (0.93)	2.43 (0.94)	1.61 (1.12)	2.17 (0.83)
Field 2	2.04 (1.19)	3.13 (0.87)	1.87 (0.97)	2.74 (0.86)
	Topic: *Electricity*			
Field 1	1.74 (1.05)	3.04 (0.88)	2.43 (1.20)	2.35 (0.78)
Field 2	2.52 (1.08)	2.27 (1.32)	0.96 (0.98)	2.39 (1.12)
	Topic: *Plants and Animals*			
Field 1	2.09 (1.24)	2.09 (1.20)	0.87 (1.06)	2.13 (0.92)
Field 2	1.17 (1.11)	2.78 (0.85)	1.87 (1.36)	2.96 (0.91)

Table 3: ANOVA summary table (the number of interactions is large so only main effects and statistically significant and near significant interactions (p<=0.05) are listed).

Source	df	SS	MS	F	p
Field	1	4.17	4.17	2.71	0.11
Kind of Thought (KOT)	1	89.28	89.28	32.39	0.00
Topic	2	5.66	2.83	2.88	0.07
Kind of Science (KOS)	1	6.52	6.52	14.03	0.00
Field*KOT	1	3.83	3.83	5.99	0.02
Field*Topic	2	19.71	9.85	12.40	0.00
KOT*Topic	2	3.55	1.78	2.77	0.07
Field*Topic*KOS	2	18.00	9.00	11.59	0.00
Field*Topic*KOS*KOT	2	34.90	17.45	18.46	0.00
Error	44	41.60	0.95		
Total (overall)	551	771.54			

Table 4: The mean scores awarded to the practical problem solving incidents (Field 3). The higher the score, the greater the perceived opportunity for creativity.

	Kind of Thought	
Topic	*Reproductive*	*Creative*
Earth, Space and Gravity	1.96 (0.93)	2.70 (1.02)
Electricity	1.43 (1.08)	2.83 (0.89)
Plants and Animals	1.96 (1.15)	2.35 (0.93)

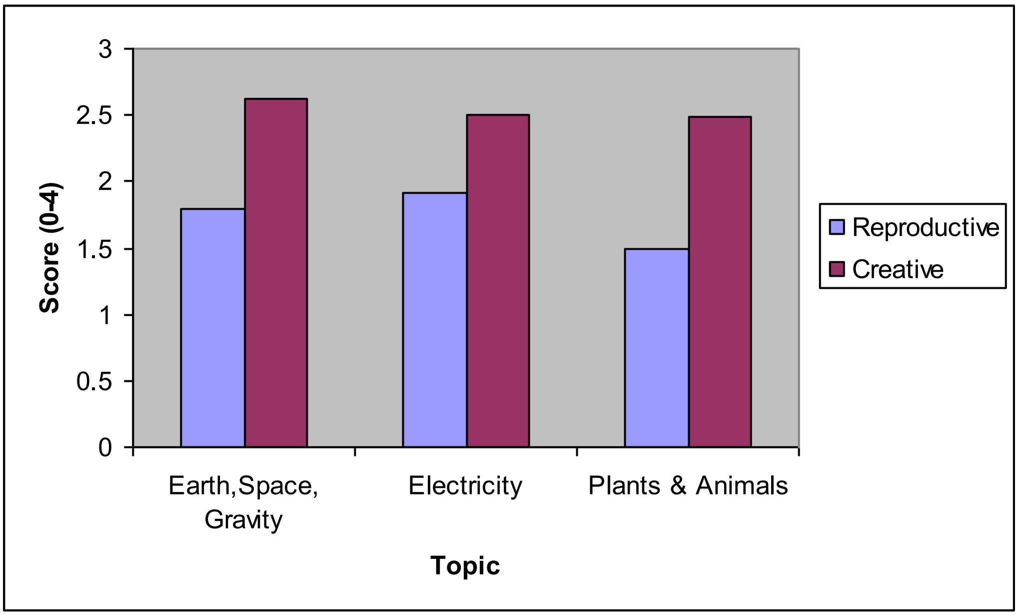
Table 5: Practical problem solving ANOVA summary table (main effects and relevant interactions are listed).

Source	df	SS	MS	F	p
Kind of Thought (KOT)	1	24.38	24.38	22.70	0.00
Topic	2	1.06	0.53	0.87	0.42
KOT*Topic	2	5.93	2.96	6.19	0.00
Error	44	21.07	0.48		
Total (overall)	137	164.32			

Table 6: Mean scores standard deviations (in brackets), and score range for incidents offering non-scientific opportunities for creative thought.

Item 30	When learning about plants, the children visit a garden centre and then paint pictures of bouquets of flowers they would like to give their mothers.	0.97 (1.12) 0-4
Item 12	The teacher has the children write a diary about a long journey on a spaceship giving attention to the tensions of living together.	1.39 (0.97) 0-3
Item 23	The children draw pictures of thunderstorms to make a Storm frieze for the classroom.	1.39 (1.05) 0-4
Item 24	The teacher introduces the phrase, ‘bright spark’, and has the children think up five sentences in which they use it.	1.57 (1.06) 0-4
Item 11	The children look at pictures of planets while listening to the *Planet Suite* then use a xylophone to make tunes which suit the Earth, Jupiter and Mercury.	1.78 (1.18) 0-4
Item 28	After the children learn about some endangered animals, they choose one and design a poster to draw people’s attention to its plight.	2.57 (1.17) 0-4

Figure 1: Mean scores for reproductive and creative incidents in each topic.



Captions (Tables)

Table 1: Some examples of reproductive and creative thought in elementary science lessons

Table 2: The mean scores awarded the incidents for Fields 1 and 2 (the higher the score, the greater the perceived opportunity for creativity).

Table 3: ANOVA summary table (the number of interactions is large so only main effects and statistically significant and near significant interactions ($p<=0.05$) are listed).

Table 4: The mean scores awarded to the practical problem solving incidents (Field 3). The higher the score, the greater the perceived opportunity for creativity.

Table 5: Practical problem solving ANOVA summary table (main effects and relevant interactions are listed).

Table 6: Mean scores standard deviations (in brackets), and score range for incidents offering non-scientific opportunities for creative thought.

Captions (Figure)

Figure 1: Mean scores for reproductive and creative incidents in each topic.