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Contents

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Editorial

■ Jane Johnston ■ Sue Dale Tunnicliffe

So much more…

Emergent science is so much more than the very restrictive content of national curricula. It includes and builds on children's early, pre-school experiences of the world around them, so that children continue to develop scientific practical and thinking skills, knowledge and attitudes. Eliza Rybska and her colleagues, in their paper *What's inside a tree? The ideas of five year-old children,* illustrate how very young children learn from the world around them and develop understandings and positive attitudes. The idea that emergent science is achieved through challenging, scientific experiences was a key focus of the first editorial in *JES*. Four years later, we wonder if it is possible to restrict their learning and development by adhering rigidly to a proscribed curriculum.

Emergent science encourages young children to communicate and share their ideas with others. In the last four years, *JES* has identified research that has indicated that effective emergent science is creative, challenging and involves good language skills, *'sustained shared thinking'* (Siraj-Blatchford, 2009: 77). It does not limit children and neither does it advocate didactic teacher-led approaches; rather, it recognises that the best learning strategies often involve the practitioner 'standing back' and allowing children time and space for exploration (Cremin *et al*, 2006). In this way, children learn through realistic problem-solving and critical play with a purpose.

Experience using cognitive and kinaesthetic skills is essential for learning and understanding science in the observable everyday context. From their earliest years, children are hands-on intuitive scientists, observing, thinking and trying out things and observing the results, hence collecting and evaluating data (Gopnik, 2009). Such observations and investigations occur in everyday contexts, often unasked and verbalised through hidden questions presented as statements. They are often observed during play, which is divisible into experimental investigative play and narratives, when they are working through a past experience imaginatively or interpreting a story that they have heard.

Hands-on activities are essential for the learning of science in the early years. The science explanation does not need to be given, but the practical experience of the phenomenon is essential to further learning. At this age, the foundations for observational and planning skills are laid, as well as the process skills of manipulating items, collecting and evaluating such. Later in a child's formal science education, such fundamental experiences provide them with an experiential foundation on which to construct the curriculum science required for examinations. Teaching engages in a 'handover' process and their support of the teacher or facilitator is gradually withdrawn as the learners gain confidence and skill at interpreting their own observations and ideas (Driver, 1983; Fleer, 1992).

Olivia Humphries' research into *Tooth Decay and Coca Cola* illustrates how effective and meaningful understanding comes from child-led exploration and investigation, which does not limit the child. What would Olivia have learnt if the focus had been on teaching rather than learning?

Maria-Christina Kasimati's research, *Investigating early years children's understanding of species metamorphoses,* which was undertaken as part of an MRes, indicates how much more children are capable of in their scientific thinking, as well as how developed understanding comes from partial and incomplete thinking that challenges children. We need to encourage children to observe and explore. We need to challenge their thinking and consider alternative ideas. We need to see possibilities and not restrict learning just because the curriculum deems what knowledge is age-appropriate. We need so much more...

There is now more support for practitioners carrying out emergent science research, with opportunities to undertake research into practice as part of both undergraduate and postgraduate research, research supported by outside agencies and an integral part of CSciTeach (Chartered Science Teacher Status). There is increasing recognition of the part that good research plays in good teaching and learning, so that reflective practitioners move to become effective practitioner researchers. Frodsham and McGregor's research, *Young children's views of creativity in science: Exploring perspectives in an English primary classroom,* was supported by the Primary Science Teaching Trust (PSTT) and illustrates some of the fundamental principles of *JES*: the link between creativity and scientific development and the importance of identifying impact of research findings on practice and/or policy. After all, practitioner research is of little use if it does not impact on either personal practice or influence the practice of others. Again, we need so much more...

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Jane Johnston and Sue Dale Tunnicliffe,
Co-Editors of the *Journal of Emergent Science*

Contributing to the Journal of Emergent Science

Instructions for authors

The Journal of Emergent Science (JES) focuses on science (including health, technology and engineering) for young children from birth to 8 years of age. The key features of the journal are that it:

- is child-centred;
- focuses on scientific development of children from birth to 8 years of age, considering the transitions from one stage to the next;
- contains easily accessible yet rigorous support for the development of professional skills;
- focuses on effective early years science practice and leadership;
- considers the implications of research into emergent science practice and provision;
- contains exemplars of good learning and development firmly based in good practice;
- supports analysis and evaluation of professional practice.

The Editorial Board of the journal is composed of ASE members, including teachers and academics with national and international experience. Contributors should bear in mind that the readership is both national UK and international and also that they should consider the implications of their research on practice and provision in the early years.

The Editorial Board

Please send all submissions to:
janehanrott@ase.org.uk in electronic form.

Articles submitted to *JES* should not be under consideration by any other journal, or have been published elsewhere, although previously published research may be submitted having been rewritten to facilitate access by professionals in the early years and with clear implications of the research on policy, practice and provision.

Contributions can be of two main types: full length papers of up to 5,000 words and shorter reports of work in progress or completed research of up to 2,500 words. In addition, the journal will review book and resources on early years science.

Guidelines on written style

Contributions should be written in a clear, straightforward style, accessible to professionals and avoiding acronyms and technical jargon wherever possible and with no footnotes. The contributions should be presented as a Word document (not a pdf) in Times New Roman point 12 with double spacing and with 2cm margins.

- The first page should include the name(s) of author(s), postal and e-mail address for contact.
- Page 2 should comprise of a 150-word abstract and up to five keywords.
- Names and affiliations should not be included on any page other than page 1 to facilitate anonymous refereeing.
- Tables, figures and artwork should be included in the text but should be clearly captioned/ labelled/ numbered.
- Illustrations should be clear, high definition jpeg in format.
- UK and not USA spelling is used i.e. colour not color; behaviour not behavior; programme not program; centre not center; analyse not analyze, etc.
- Single 'quotes' are used for quotations.
- Abbreviations and acronyms should be avoided. Where acronyms are used they should be spelled out the first time they are introduced in text or references. Thereafter the acronym can be used if appropriate.
- Children's ages should be used and not only grades or years of schooling to promote international understanding.
- References should be cited in the text first alphabetically, then by date, thus: (Vygotsky, 1962) and listed in alphabetical order in the reference section at the end of the paper. Authors should follow APA style (Author-date). If there are three, four or five authors, the first name and *et al* can be used. In the reference list all references should be set out in alphabetical order

Guidance on referencing Book

Piaget, J. (1929) *The Child's Conception of the World.* New York: Harcourt

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Chapter in book

Piaget, J. (1976) 'Mastery Play'. In Bruner, J., Jolly, A. & Sylva, K. (Eds) *Play – Its role in Development and Evolution*. Middlesex: Penguin. pp 166-171

Journal article

Reiss, M. & Tunnicliffe, S.D. (2002) 'An International Study of Young People's Drawings of What is Inside Themselves', *Journal of Biological Education*, **36**, (2), 58–64

Reviewing process

Manuscripts are sent for blind peer-review to two members of the Editorial Board and/or guest reviewers. The review process generally requires three months. The receipt of submitted manuscripts will be acknowledged. Papers will then be passed onto one of the Editors, from whom a decision and reviewers' comments will be received when the peer-review has been completed.

Books for review

These should be addressed and sent to Jane Hanrott (JES), ASE, College Lane, Hatfield, Herts., AL10 9AA.

What's inside a tree? The ideas of five year-old children

■ Eliza Rybska ■ Sue Dale Tunnicliffe ■ Zofia Anna Sajkowska

Abstract

Children discover the world surrounding them from very early childhood, as they observe, listen and experience what is in their everyday environment. Plants, and trees in particular, are usually accessible and likely to be noticed because they are very common in our landscape. Whilst observing living things, these children construct a mental model, which stays in their minds and may influence their development. Fifty-seven children, aged 5, from a kindergarten in Poznan (Poland) were asked to draw what they thought was inside a tree. Children drew both internal and external structures on a drawing of a tree. Our research showed that the conceptions of these children about trees varied. Moreover, they did not always consider trees as living organisms. Since 5 year-olds are pre-school children, early years teachers should focus on such ideas in order to help the children develop positive attitudes towards nature and an understanding of prominent plants in the environment.

Keywords:

children, conceptions, plants, emergent biology

Introduction

Young children have a basic knowledge about objects (including plants) that they observe in their surroundings (Carey, 1985; Osborne & Wittrock, 1983; Patrick & Tunnicliffe, 2011). The sources of their knowledge are largely similar across European countries. Young children acquire information from their parents (Gatt *et al*, 2007; Tunnicliffe & Reiss, 2000), books, media, cartoons, story tales (Pergams & Zaradic, 2006, 2008) and informal education experiences, such as keeping pets (Prokop *et al*, 2007) or having a garden or park within reach of where they live in which they make their own observations.

Children's ideas about plants have been examined in a few studies, which show that plants are not considered to be very interesting objects to pupils. In contrast, animals, especially mammals, are considered as 'lovable' and any organisms that move catch their attention. Plants, however, are not very popular across all ages (Lindemann-Matthies, 2005; Patrick & Tunnicliffe, 2011; Tomkins & Tunnicliffe, 2007). Children are not informed as often about plants as they are about animals (Lindemann-Matthies, 2005). This might explain their lesser knowledge about this group of organisms. Children do notice plants in their surroundings (Patrick & Tunnicliffe, 2011), but they are sometimes seen as lifeless (Lindemann-Matthies, 2005). Although plants play a key role in almost every ecosystem, Wandersee and Schussler (2001) describe a phenomenon of 'plant blindness' in children when describing their inability to recognise plants as important elements of the environment and human everyday life. In addition, Bell (1981) reported that New Zealand children do not consider trees as plants.

Some researchers are interested in children's ideas about the insides of organisms, both plants and animals, including humans (Berti *et al*, 2010; Tunnicliffe & Reiss, 2000; Tunnicliffe, 2001). Such representation of the surrounding world is referred to as a mental model (Buckley & Boulter, 2000). One effective way of gathering such information as the mental model, accessed as an expressed model, is to ask children to draw a certain object (Barraza, 1999; Reiss *et al*, 2007). Gardner (1980) describes the development of children's drawings, from scribbles made by two year-olds, through geometric forms including the enigmatic *mandala* (at the age of 3), to the next step at age 4 to 5 years when a child may create representations that are not totally realistic, including imaginary elements, but with some representation of actuality. Such drawings, which are representations of objects, might also show a person's knowledge, and this was the subject of studies showing analyses of ideas that come out of pictures. On the other hand, children do use knowledge about themselves to explain the internal organs of other organisms (Carey, 1985), so this means that they use the human form as a template to describe how other organisms are built and how they carry out their functions (Prokop *et al*, 2007; Reiss *et al*, 2002; Reiss & Tunnicliffe, 2001; Reiss *et al*, 2007; Tunnicliffe & Reiss, 1999). We were interested in mental representation of a biological object, 'a tree'; therefore, we selected a group of 5 year-old children with whom to explore this botanical subject. There are not many research studies that deal with drawings of plants. Recent studies about trees include those by Tunnicliffe (1999) and Bartoszeck and Tunnicliffe (2013).

In Poland, children have to attend kindergarten at the beginning of the calendar year in which they reach 5 years of age. The Polish National Curriculum has a section written for this age group. It provides some details about science education (referred to as environment education), which are:

- Student (at age 5-6) knows the names of common plants and animals appearing in some environments (fields, forest and meadow);
- Student knows what animals and plants need for their development; and
- Student can list changes that are taking place during the life cycle of animals and plants, together with seasonal changes.

There is no obligatory textbook for this period of education or details of what the teacher needs to tell pupils. Whether any science is done depends only upon the knowledge and willingness of the class teacher. Such a situation is similar to those described in Gatt (1998) and Gatt *et al* (2007), where all the science carried out in the classroom depends upon teacher willingness.

This research project examined children's mental models of the internal features of trees through the research question:
What are the mental models of 5 year-old children of what is inside a tree?

Methods

Children in this research study attended two public kindergartens located in Poznan, which is a city in north-west Poland. The permission of the Headteacher was obtained and appropriate ethical requirements met. Poznan is known for its green areas, parks and even reserves located within it. Irrigation is a feature of the flat area in which the kindergartens are situated. The area has recently experienced a water shortage and the problem this causes for agriculture is frequently mentioned in the media. Both institutions (and almost every kindergarten in Poznan) have very easy access to parks and children are provided with opportunities to observe trees.

A group of children of age 5 (57 children: 26 boys and 31 girls) was asked to draw on an A4 sheet of paper what they thought was inside a tree. They were allowed to draw for 20 minutes. Each child was asked by the researcher what each unlabelled part of the drawing was and the researcher then wrote the label. In addition, children were asked to explain why they drew some elements. Their explanations were noted. Most of the children could not yet write so, in each case, the researcher paid special attention to writing the names of what children thought they had drawn, and labelled the drawings accurately. Subsequently, analysis was carried out of the drawings, together with children's comments. Children were provided with a shared opportunity to observe trees immediately prior to making their drawings, and they could also observe them through the classroom window whilst drawing.

The drawings were analysed using a rubric scale of levels that was completed based on those constructed in other biological organisms (e.g. Bartoszeck *et al*, 2011; Reiss & Tunnicliffe, 2001), and on trees (Bartoszeck & Tunnicliffe, 2013, modified), on conceptual levels of anatomical features shown in the drawings. Features of external structure, as well as of ecological surroundings, were also recorded. Each category was further divided into subcategories. The rubric scale used to allocate a grade to the drawings is shown at Table 1.

Table 1. The rubric scale used to allocate a grade to the drawings.

Level	Source of knowledge
0	Scribble/no picture at all
1	First-hand observation remembered (resemblance of a tree)
2	Internal parts of a tree
	P –tubes/pipes/roots
	H – human template – heart, lungs
	J – juices/resin/water/oxygen
	A – age/timber
	D – hollow
3	External parts
	L – leaves
	F – fruit
	B – bark
	G – branches
	S – seeds
4	Ecological and habitat views associated
	B – birds
	O – ants (insects)
	P – spiders
	Ps – spider web
	M – mammals (such as squirrel)
	I – other animals
5	Additional elements that arose through religion or culture and go together with biological features, and the biological explanation of a tree, e.g. soul, elevator, furniture

We do not include flowers here, due to the fact that flowers were not drawn on any of the pictures analysed. The fifth category in the rubric was constructed to gather all those elements unconnected to some biological understanding of what can be found inside a tree, such as elements that arise for cultural or religious reasons (e.g. elevator, furniture, soul).

Scoring of the data was through a reiterative process, conducted independently, by three researchers and data obtained were compared and the scores agreed.

Analyses of drawings

After collecting the drawings, all were numbered for reference and coded according to age and gender. This coding ascertained anonymity. Afterwards, three people scored each drawing. These three people at first scored them separately and then met and discussed those drawings that they had scored differently, until they agreed on the same score. The 'artistic' value of the drawings was insignificant in this research study.

For example, on page 10 is a scored drawing done by a 5 year-old (see Figure 1), which was coded as 1, 2JD, 3LFGS (see Table 1 opposite).

The rubric scale is not hierarchical. We endeavoured to score everything that children drew on their picture using this rubric scale. Using the rubric scale did not allow for recording the relative positions or sizes of the different features included in children's representations.

Results

For children of this age, it was quite a difficult task to draw what they thought was inside a tree. Initially, many of them were very confused about this question. The researcher had to repeat the question several times. A few children (8) did not draw anything on the paper, not even a resemblance of a tree. One explained that he could not come up with any ideas because he could not draw 'nothing'. One of the children (see Figure 2) did not draw a tree, but drew everything that she thought was inside in a key form, indicating 'bug', 'grass', 'roots', 'hollow', 'bird' and 'the sun'.

Figure 1.

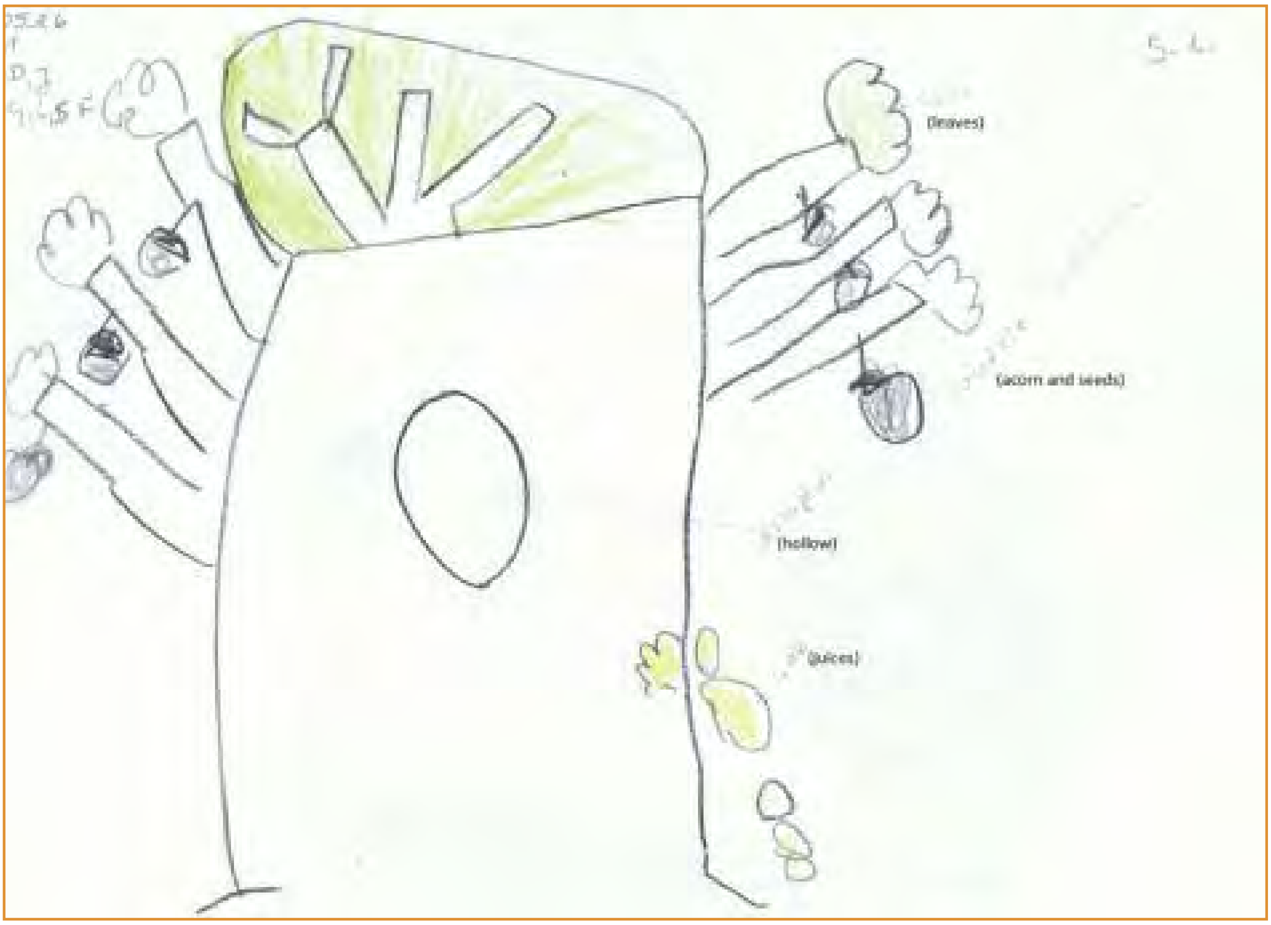
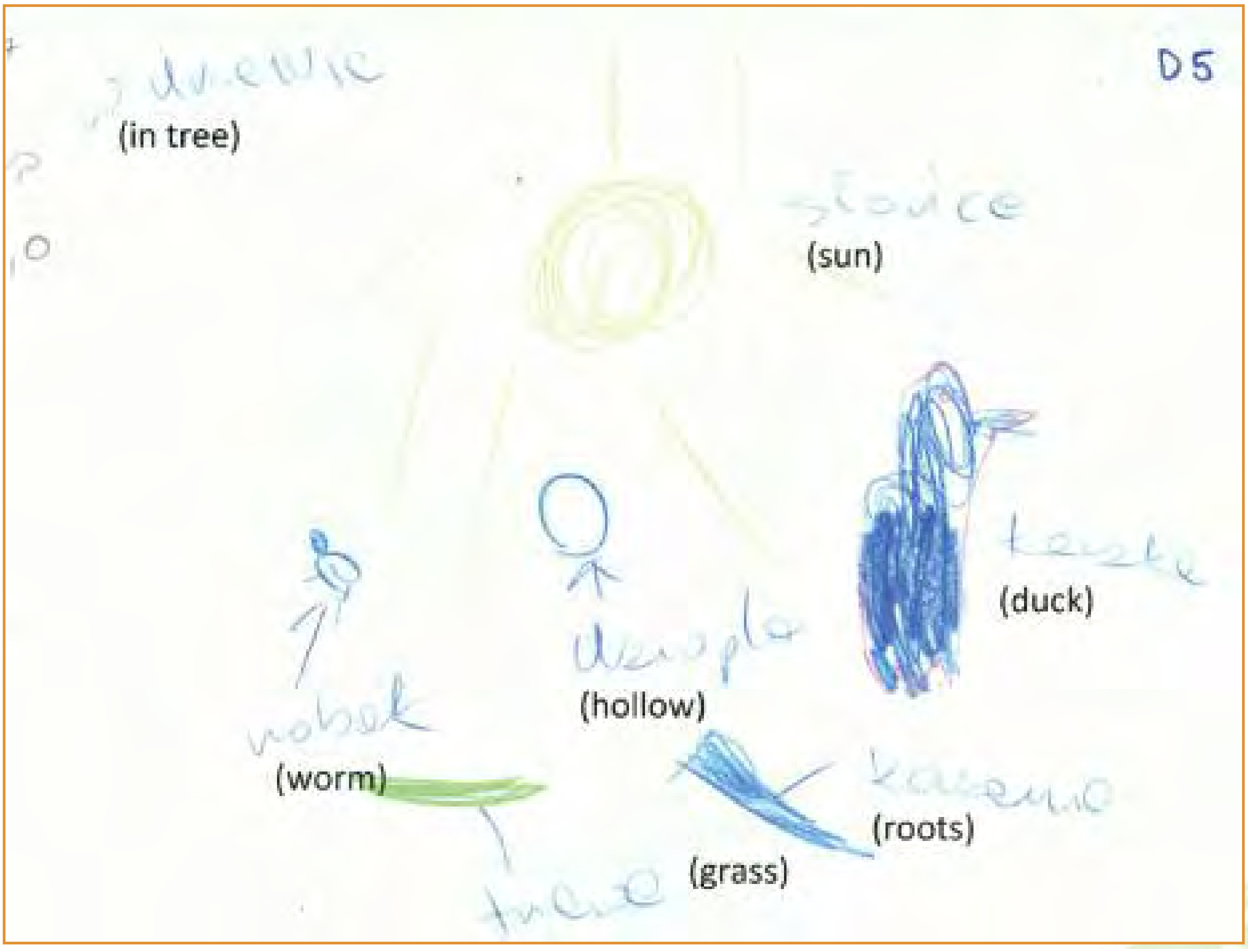


Figure 2.



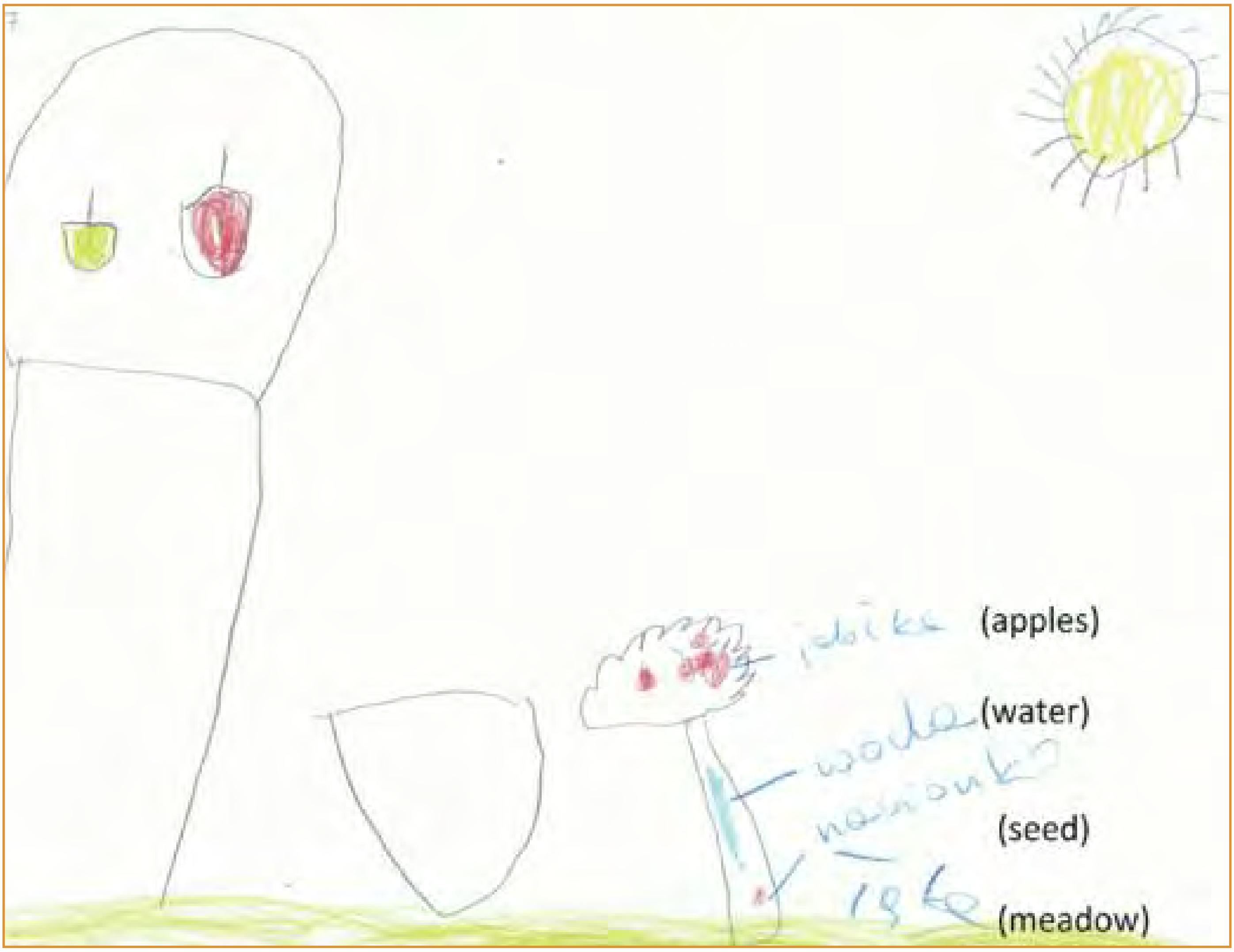


Figure 3.

The data were tested by *Fisher's Exact Test for Count Data in R program* (R version 3.0.2). This test was used because of its accuracy and adjustment to this amount of data (Sokal & Rohlf, 1995; Zar, 1999).

The results were on the border of being statistically meaningful for gender. The established p-value was 0,05.

The most frequent interior feature on the drawings was a hollow. One child explained that inside a tree is a hollow – and that he saw it many times in the park near his home. The next most frequent category was reference to many different kinds of internal fluids – from water to maple syrup. Some children literally drew water inside a tree (Figure 3). When asked, children explained that water is crucial for the tree in order to survive, and that it comes all the way from the ground to the leaves.

There were some pupils (13) who drew human organs inside a tree. The most common organ drawn was a heart. It appeared in 12 pictures (see Figure 4). Surprisingly, four children put 'soul' as an internal or even external feature of the tree (see Figure 5).

Figure 4.

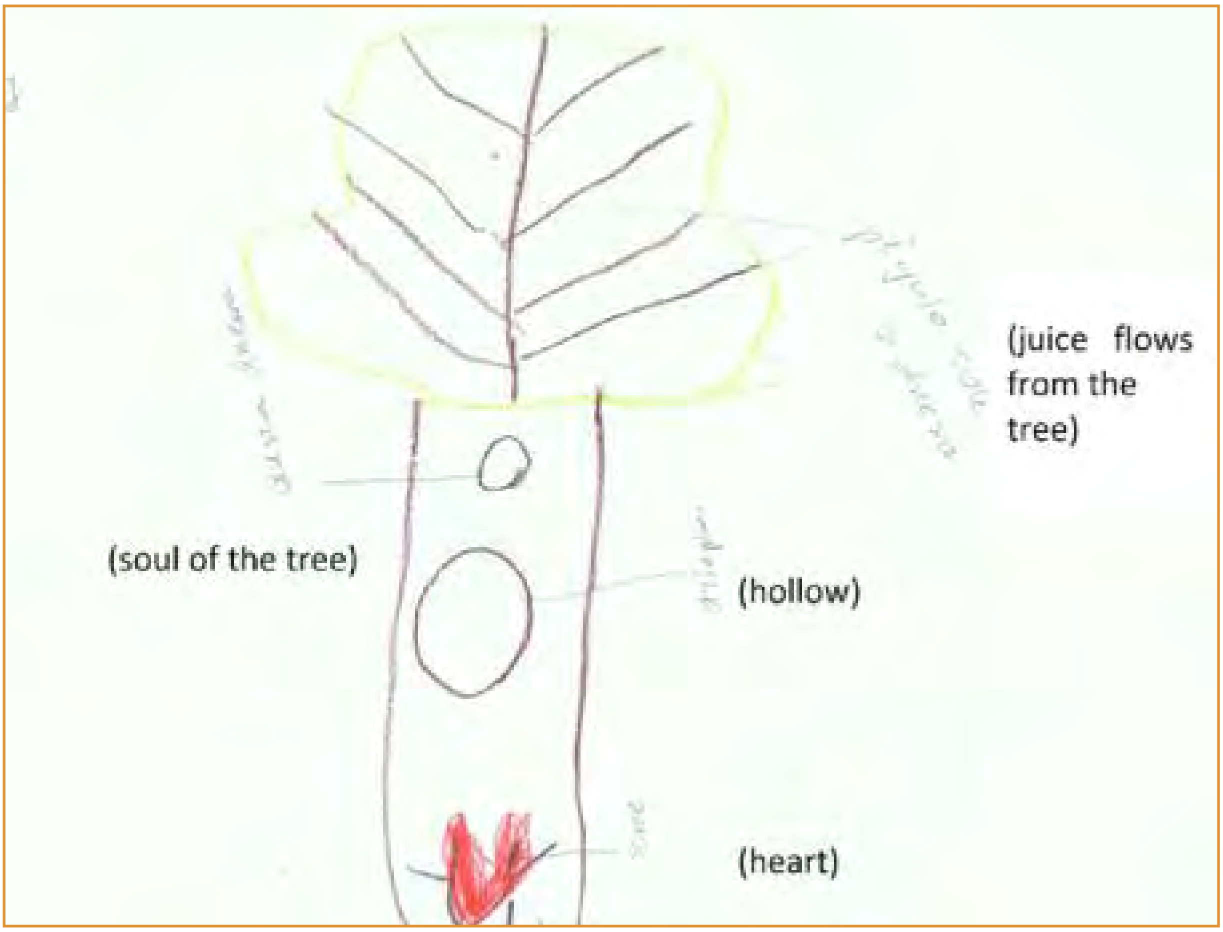
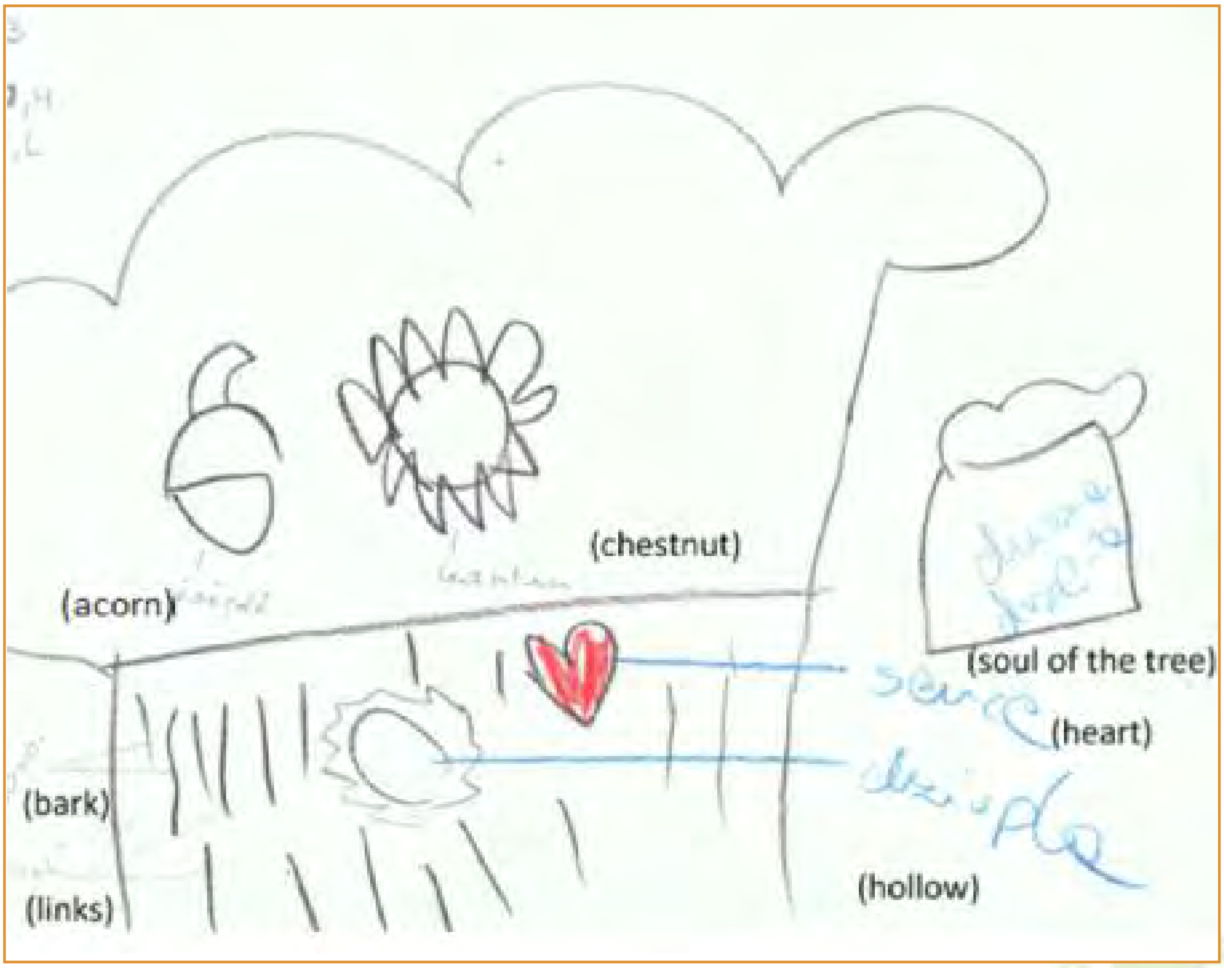


Figure 5.



For many children, trees serve as a 'home' for other organisms. Twenty-eight children drew a hollow as an internal part of a tree, explaining that it is inside, and serves 'as a home' for animals. A 5 year-old boy explained that a tree itself is just timber, but is used by other organisms such as spiders and ants as their home (see Figure 6). The most popular animals named by children of this age as living inside a tree were insects (17) and mammals (10).

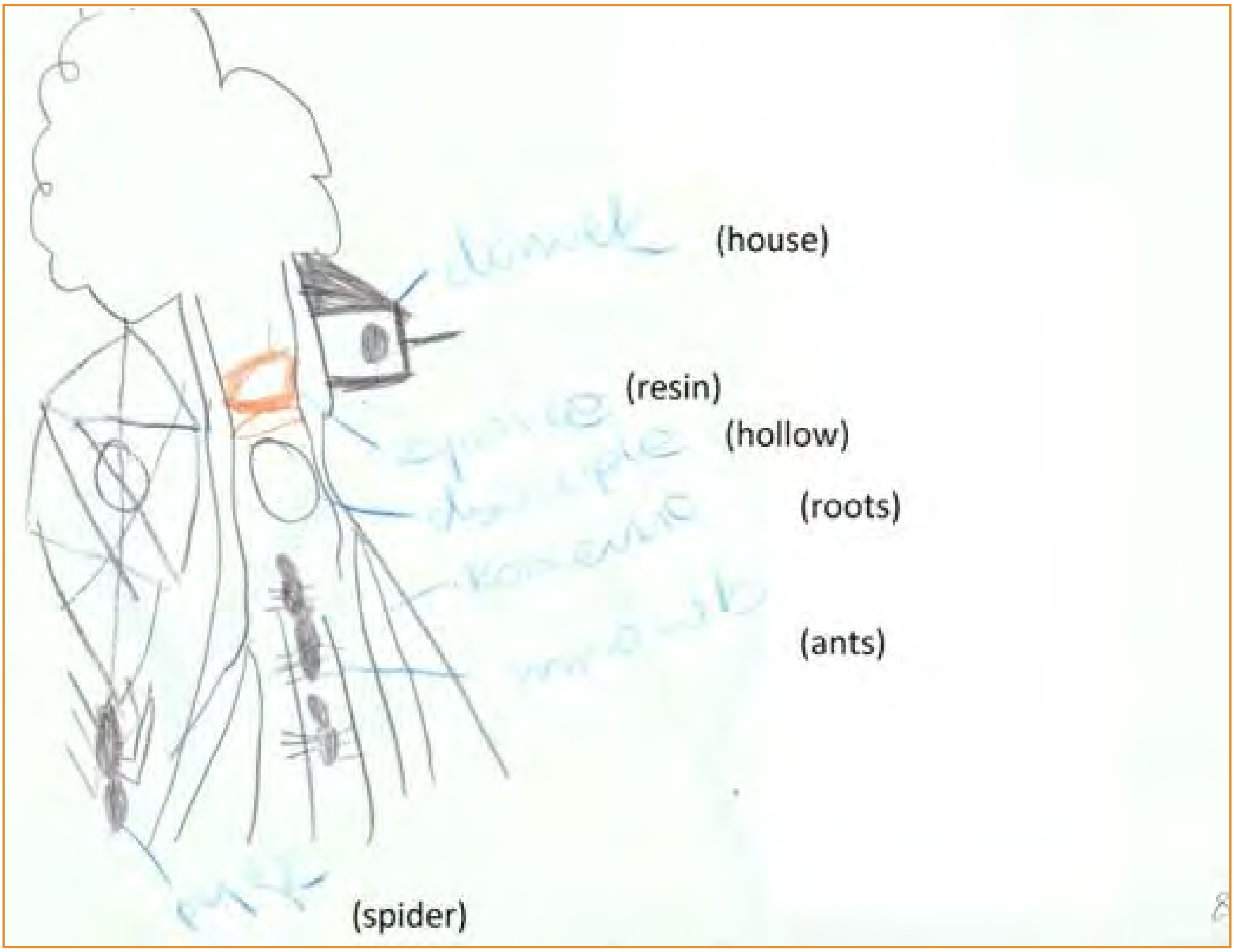


Figure 6.

Discussion

Drawings are an important tool in learning science. They are one form of visual representation; another is a photograph. Ainsworth and colleagues (2011) indicate that *'drawing should be explicitly recognised as a key element of science education'.* In other research, Krauss *et al* (2010) showed that photographs also help students to absorb and structure new information. Those results were supported by Katz (2011), who showed that photo-diaries might be not only a trigger for memories, but also and above all have significant influence on science learner identity.

Transfer of knowledge about what is inside 'myself' into what is inside a tree, using the human body as a template, has been reported in literature (Bartoszeck & Tunnicliffe, 2013; Carey, 1985; Tunnicliffe, 1999). The only one exception in this study was of a girl who drew blood, urine and faeces inside a tree. In all other cases reported, only a heart was indicated as part of the internal structure of a tree (see Figures 4 and 5).

The results presented here confirm that children develop a theory about nature and biological phenomena before they enter the school (Driver *et al*, 1994; Patrick & Tunnicliffe, 2011; Tunnicliffe & Reiss, 2000) and that they have their own experiences, observations and other people as sources of knowledge. Although their knowledge is not always in agreement with established scientific knowledge, it is their understanding and can be developed towards accepted concepts, if educators are aware of the children's understanding as a baseline for developing teaching and learning strategies. Children's ideas of what is inside a tree, as revealed by these drawings, indicate an understanding of some important biological phenomena, such as the importance of water to life or trees serving as a shelter for animals. In the drawings, the external part labelled most frequently was the trunk, followed by leaves and bark. The most common animals indicated in the drawings were insects and mammals, which suggests observation as one possible source of knowledge at this point. Similar results were obtained while examining the drawings of children from Brazil (Bartoszeck & Tunnicliffe, 2013).

In four cases, we observed that the sun was drawn inside a tree as well as outside. However, from our observations while working with young children, we believe that they usually draw the sun in pictures as standard. Some children put a 'soul' as an internal or even external feature of the tree and we do find such ways of thinking about organisms amongst children from Asia (Reiss *et al*, 2002). However, it was quite surprising to find such ways of thinking in Polish children.

Children at age 5 have little understanding of what is inside a tree, although they do perceive trees from an ecological perspective; for example, as a habitat for other living organisms. This is supported by results described by Bartoszeck and Tunnicliffe (2013).

Conclusion

Children's attitudes towards nature depend greatly on their understanding of life, of complex systems, and functions that exist in ecosystems, etc. Children do not start school as a *tabula rasa*, thus it is important for teachers and curriculum developers to find out what pupils already know about the subject and to develop a strategy of designing the learning opportunities for these children based on their existing knowledge. It is crucial that educators find out the understanding of their pupils about phenomena, before they begin to teach them curricular requirements. Furthermore, we urge early years teachers to include botany as one element of a programme, in order to provide children with greater empathy and understanding of living organisms such as trees.

Teaching about trees should be conducted through direct observation of the trees; how they grow, what happens to them when they fall, and also observing the changes through time – differences between spring and autumn, for example. Such observations, when combined with, for example, photo-diaries or drawings-diaries of observed changes, may lead to positive personal attitudes towards nature and are also important for science learner identity.

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Investigating early years children's understanding of species metamorphoses

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Abstract

The aim of the current research is to explore 5 year-old children's initial ideas about two types of species metamorphoses (one incomplete: the dog; and one complete: the butterfly) and their life circles (cycles).

A case study approach was used and the data were collected by using semi-structured individual interviews as well as drawings made by 18 children. The interview protocol included questions based on coloured photographs of dogs and butterflies. The source of children's knowledge was also explored through questions.

The results showed that the 18 young children in this study are more familiar with the concept of incomplete species metamorphosis than that of complete species metamorphosis. They could argue in a more scientifically correct way about the maintenance of both personal and species identity of the dog than that of a butterfly. It was also shown that the previous experiences of children, which can be used as a basis to build new knowledge, vary a lot from child to child.

Keywords

Early years, species metamorphoses, biology, constructivism

Literature background

An understanding of metamorphoses plays an essential role in children's development of biological concepts and forms part of their logical thinking about the identity of things (Zogza, 2007). More specifically, as Gelman (1991) describes, there are 3 important conceptual insights that children must come to appreciate in this area. Firstly, real-life transformations are not random. They are predictable and obey certain laws of nature. For example, with development to adulthood, animals can become larger but not smaller. Secondly, the kinds of transformations that are possible are domain- and mechanism-specific (Keil, 1989; Schwartz, 1978). For example, growth applies consistently to animals and plants but not to artifacts (e.g. tables do not grow). Thirdly, even with dramatic changes in appearance, both personal identity and species identity are maintained across natural transformations of living kinds. For example, a plane tree continues to belong to the same species throughout its growth from sapling to towering maturity. Moreover, we consider it to be the same individual tree across the years (De Vries, 1969; Bruner, Goodnow & Austin, 1956: 2).

There are several types of animal metamorphoses, concerning only external features of living organisms, which are all depicted in Table 1 (Shepardson, 1997). This present study is concerned with two of these metamorphoses types. The first is the 'incomplete metamorphosis' type, which defines changes that occur to animals over time but where the basic physical form remains the same, with additional features developing with maturity, as in humans. The second type is the 'complete metamorphosis' type, which can be observed when the external form and internal organisation of the animal change in the pupal stage (e.g egg–larva–pupa-adult, which depicts the life cycle of a butterfly, for example).

Table 1: Scientific perspective of insect metamorphosis (Shepardson, 1997)

Type of insect metamorphosis	Stages of metamorphosis
Incomplete metamorphosis	Juvenile–adult: juvenile similar in form to adult, development consists of growing larger; emergence of secondary sexual characteristics.
Gradual metamorphosis	Egg–nymph–adult; nymphs resemble adults without wings or genitals; Same food habits.
Complete metamorphosis	Egg–larva–pupa-adult; comprises approximately 90% of known insects.

Note: *Metamorphosis separates physiological processes of growth (larva), differentiation (pupa), and reproduction (adult), and functions to reduce competition or hindrance among stages of development by broadening the ecological niche (different food sources) and habitat (different living environments).*

As will be discussed below, much research that falls within the field of 'Teaching and Learning of Biology' took place during the 80s and early 90s. Many of these studies were concerned with natural changes during the animals' growth, and researched how young children, from 3 to 9 years old, perceived these changes (Springer & Keil, 1989). Such research showed that children can be placed into two groups by the way they think about metamorphosis: those who believe that every metamorphosis is possible and those who believe that only a few metamorphoses can happen. More specifically, Keil (1989) has shown that, although 5 year-old children might accept changes within ontological categories (e.g. one living thing such as a dog can turn into another living thing such as a lion), they are less willing to accept changes that cross ontological boundaries (e.g. one inanimate thing such as a toy dog cannot turn into a living thing such as a real dog).

Carey (1985) examined children's understanding of natural changes, such as those that occur as part of the growth process. Physical growth is one well known type of naturally-occurring transformation that can radically alter the outward appearance of living things (Gelman, 1991). This research (Carey, 1985; Inagaki & Hatano, 1987) suggests that young children, aged 3-5, use perceptual appearance to make judgements about category membership and to infer characteristics to certain category members (Inagaki & Hatano, 1987). The work of Carey (1985) showed that young American children supported the idea that a change in an animal's appearance could mean that many other important properties of the animal also changed. Gelman (1981) considered that such an idea shows an extreme conservatism regarding the transformations that the members of animal categories may undergo. On the other hand, Gelman (1991) also considered that these very same findings could be interpreted as reflecting an extreme liberalism about the possible transformations. For example, children seem willing to accept the possibility of a dog being transformed into a lion. Thus, any change could be possible. In either case, these findings indicate that young children fail to appreciate the characteristic types of changes that animals naturally undergo. The view that children treat the appearance of an animal as crucial to its category identity is consistent with a general perspective of development that supports that young children are quite limited when it comes to reasoning about appearances and unable to look beyond the obvious (Wellman & Gelman, 1988).

Another study regarding children's understanding of natural transformations and how this understanding can be evolved over time and experience was conducted by Gelman (1991). This study included three experiments that, taken together, demonstrate that even 3 and 4 year-olds realise that animals (i.e. mammals and insects), but not inanimate objects, increase in size or change shape and form over time. Additionally, the data showed that, although 3 year-old children believe that animals' size and colour will not be changed during time, 5 year-old children realise that important changes may happen to animals as they grow older.

The studies cited above focused on the cognitive and psychological development of children. However, other areas of relevant research focus on 'the way we teach', and especially on the 'Teaching and Learning of Natural Sciences' (Zogza, 2007). Specifically, Shepardson (1997, 2002), researching in the USA school system, found that first graders' (aged 6 years) understanding about the life cycles of beetles and butterflies changed after a teaching intervention. Although children seemed to have a better understanding of the stages of the metamorphosis of beetles and butterflies, they continued to have difficulties in generalising the metamorphosis model to other animals. Nyberg *et al* (2004) reached a similar conclusion in a more recent study about USA elementary school pupils' understanding of life cycles.

Furthermore, Osborne *et al* (1992) indicated that young children in England at the age of 5 to 7 years are able to describe the developmental stages of a chicken and the life cycle of a butterfly. Moreover, they realise that species identity of animals is conserved from the stage of the egg to the adult. Finally, they seem to refer to food as the main cause of growth. However, the cited research was mainly focused on the psychological perspective of the aforementioned matters. For this reason, we believe that it is pertinent to review how children think, and consider the teacher's perspective by making suggestions for other ways of teaching the concept of metamorphosis through eliciting the initial ideas of some children.

Rationale

There has been scant research concerned with 5 year-old children's ideas and beliefs about the growth of vertebrate animals that have incomplete metamorphoses compared with the ideas of the same children regarding the life cycle of insects (invertebrate animals) that have complete metamorphoses.

This gap in existing literature, as well as the importance of having available information regarding children's initial ideas formed by their experiences, leads to the conclusion that there is a need for one study that points out the extent to which young children are familiar with the concepts of both incomplete and complete metamorphoses.

Most children begin to gain knowledge about animals and the rest of the natural world from outside the school system, mostly at home (Osborne & Freyberg, 1985; Patrick *et al*, 2013) and it is important, especially for teachers, to have available as much information as possible about these pre-existing and already-formed beliefs, in order to be able to build on them as children construct further knowledge at school (Roth, 1990). Thus, this study seeks to understand further the ideas of children regarding the growth of animals and, for this purpose, the metamorphoses of two species (the dog and the butterfly) will be explored with these early learners.

Research questions

Shaped by the constructivist educational theory (Piaget, 1952; Vygotsky, 1978) informing 'Learning and Teaching Biology' for pre-schoolers, and by the previous research undertaken in the field, the following research questions were developed. They all refer to children's understanding:

- Do young children understand that changes occur to the appearance of given living animal organisms over time? (Complete or incomplete metamorphoses)
- Do they realise that real-life metamorphosis is not accidental? (e.g. normal growth means an increase in size, not a decrease.)
- Do they understand that personal identity as well as species identity is conserved, even after major changes regarding the appearance? (e.g. a butterfly belongs to the same species, throughout its life, from the first egg stage to adulthood, although it does not have the same physical form in these stages).

Methodology

Research design and process

This was an exploratory qualitative research, which was undertaken as part of an MRes thesis. The research was based on the constructivist educational theory, aiming to offer an in-depth understanding (Robson, 2011) of how young children think about some specific biological concepts, such as species metamorphosis. Specifically, a case study (Yin, 2011) was conducted in order to approach the answers to the research questions set. Specifically, the case study reported here was conducted in one private school in London. The units of analysis were the reception classes in this particular school. Hence, the data identify patterns in the way those children in this specific school were thinking.

Semi-structured individual interviews (Robson, 2011), as well as some drawings made by the children (Chang, 2012), were used in order to explore their initial ideas and obtain answers to our research questions. The interviews included questions based on coloured photographs of dogs and butterflies, as well as some questions posed about those animals. The drawing activities took place before the interview in order to ensure that children were not influenced by our conversations and that they truly depicted their initial ideas on the paper. These drawings were used as a second source of data, where children depicted their understanding about metamorphosis stages. All 18 interviews were audio-recorded and subsequently transcribed by the researchers. Each interview lasted between 10-17 minutes.

Data analysis

The analysis conducted was thematic (Braun & Clarke, 2006), according to the three research questions we aimed to answer. The qualitative analysis software *N-Vivo* was used for the analysis.

Codes (Robson, 2011) were allocated to every different answer we received by reading and re-reading the texts of the transcribed interviews in *N-Vivo*, and some broad categories of answers emerged as will be shown below. Each super-ordinate category was then divided into sub-categories (Boyatzis, 1998), which indicate the level of understanding and the ideas of children regarding the biological concepts that we are dealing with in each of the three research questions set. In that way, themes were formed by the children's answers, which made it easier for us to present some answers to the main research questions.

During the analytical process (Yin, 2011), in order to gain a clear understanding of how familiar the children were with the dog's growth as well as the life cycle of the butterfly and the changes occurring to these animals over time, the data collected from the interviews and drawings were triangulated. This process compared the children's answers to the interview questions with their drawings, in order to identify whether these two different sources of data conflict or not. For example, we tried to decide whether the children who supported the belief that the dog will get bigger as it grows older during the interview were actually drawing the young dog smaller than the old one.

Sample

The participants were the students in the reception classes of one private primary school in London. This school had two reception classes, comprising a total of 18 children. Parental consent was gained and permission was granted for every child to participate, so the whole class was involved in this research project.

The youngest child was 4 years and 5 months old, and the oldest 5 years and 5 months old, at the time the research was conducted. Thus, there was a range of 12 months' experience between the oldest and youngest children, which represents between 20% and 25% of their total life experiences. The younger children, in their spontaneous responses to the interview questions, thus showed a lack of maturity compared to the older ones. For example, older children were able to justify their answers, whereas the younger ones could not.

Ethical considerations

Since the participants in the research were 5 year-old children, appropriate ethical procedures were followed. The *Ethical Guidelines for Educational Research* published by the British Educational Research Association (BERA, 2011), were followed.

The rationale behind this work was fully explained to the school. Teachers, parents and children were all aware of the research aims. In addition, parental consent was obtained through letters explaining the project. Moreover, before the beginning of the programme. child consent was also sought. To achieve that, the researcher read them a statement regarding their participation in the research, and then asked them to draw either a smiley face (indication that they agree) or a sad face (indication that they do not agree). Finally, all participants were reassured that they could withdraw at any time without any consequences at all. The information provided by the children has been held by the researcher on an anonymous basis.

Data collection tool

The interview questions were divided into three parts, where each one included questions related to one of the research questions. For example, for the first research question: *Do young children understand that there are changes occurring to the appearance of living organisms during time? (Complete or incomplete metamorphoses)*, the children were asked some questions about the dog and the butterfly: *Firstly, I show them a photograph of a young dog and ask: What is that? Do you think that, one year ago, or when it was a baby, it looked completely the same? What were the differences? Why do you say that?*

In this way, a connection was made between the interview questions and the research questions I sought to answer.

During the second question of the interview, children were asked to put pictures of a dog in the correct order, from the youngest to the oldest, in order to present how this dog will look like during its life. The next question, connected to the third research question, concerned the conservation of personal and species identity. In order to investigate the ideas that children hold upon this matter, they were asked: *'If a mother dog has a baby, what animal will it be?'* and then: *'Can this baby dog, who was born like a dog, become a cat/lion/bear when it grows up? Why? Even when it gets bigger and bigger (when it changes), is it still a dog? Why? And is it still the same dog?'*

In the next interview question, effort was made to combine all three research questions regarding the complete metamorphosis. To achieve that, the children were first asked whether they knew where butterflies come from (link with the first research question). Then, they were given four different cards depicting the metamorphosis stages of the life cycle of the butterfly, and asked to put these cards into the correct order so that they present the life cycle of the butterfly (link with the second research question). Finally, they were asked whether they believed that the caterpillar and the butterfly are the same animal (link to the third research question).

Results

Table 1: Results: first research question regarding the incomplete metamorphosis of the dog

Themes	Codes	Children
Changes–reasoning	Yes – colour and size–food Yes–size–birthdays Yes–size–growth Yes–size–food Yes–colour and size–friend	3 2 2 3 1
Changes–No reasoning	Yes–colour Yes–colour and size Yes–size–don't know	1 2 4

All children asked understood that changes occur to the appearance of living organisms over time. This means that all participants realised that there would be changes that occur to animals because of their physical growth. Most of them (11 out of 18) were also able to support their idea that a dog will change in terms of its appearance as it grows up, by using several different kinds of reasoning. Some of them used biological arguments (i.e. the food that makes the young dog turn into a bigger dog, and growth that results in a different size and shape of the adult dog compared to the baby dog), while others used psychological and anthropomorphic criteria (i.e. the young dog grows because it has birthdays, or because it needs to make friends). Finally, there were 7 children who, although they could not give a specific reason why the dog's appearance would change over time, were certain that changes in size and colour would happen.

Although all children seemed to realise, during our conversation, that a dog will only grow bigger over time, there were 3 who produced contradictory drawings. Specifically, the second dog that these children drew was not bigger than the first one, even though it was supposed to be the same, but younger, dog.

Table 2: Results: second research question regarding the incomplete metamorphosis of the dog

Themes	Codes	Children
Correct order	Correct–size Correct–size–growth Correct–size–only bigger	2 1 8
Semi-correct order	Semi-correct–size Semi-correct–size–only bigger	2 3
Not correct order	Not correct–don't know Not correct–energy	1 1

Table 2 indicates that most of the children (16 out of 18) were able to realise that a dog can only grow bigger and never smaller, hence that real-life metamorphosis is not accidental and follows a very specific course. However, 5 of those children were confused with the dogs appearing on the cards used, and believed that the oldest dog was younger than the adult dog. This happened because the oldest dog seemed to be smaller than the biggest and strongest adult dog and children used only their size as a criterion for age. As a result, a separate group was created (semi-correct order) for those 5 children who did not put the cards in absolutely the correct order but, nevertheless, supported their opinion by saying that the oldest dog would be younger because it appears to be smaller than the other dog, which is the argument we looked for. Finally, there were two children who could not put the cards in the correct order and had great difficulty in realising what they were seeing in them.

Table 3: Results: third research question regarding the incomplete metamorphosis of the dog

Themes	Codes	Children
Same animal and species	Same Same-–cannot change Same–different Same–food Same–same as mother	1 6 3 2 5
Not the same animal and species	Not the same–do not know	1

By examining the above table regarding the conservation of identity of the dog throughout its life, we can easily see that all the children except one could understand and support the opinion that the animal born like a dog will still be a dog and, specifically, the same dog, until the end of its life, even though some elements of its appearance can change. There were several ways in which children argued about the position they held. The most common was the opinion held by 5 children out of 18, that the offspring is supposed to look like its mother, as well as the belief that '*the dog cannot change into another animal, and it will always be a dog because this is how things happen*'.

Table 4: Results: three research questions regarding the complete metamorphosis of the butterfly

Themes	Codes	Children
Correct order	Correct order–different Correct order–different–colour Correct order–different–wings Correct order–don' t know Correct order–same–turn into	6 2 2 1 1
Semi-correct order	Semi-correct order–different Semi-correct order–different–colour Semi-correct order–different–wings	2 1 1
No order	No order–different	2

Table 4 indicates that 16 children were familiar with the life cycle of the butterfly. Twelve of them were able to name every different stage and they successfully put the cards into the correct order. However, there were 4 children who were not familiar with 'the egg', which is the first stage of the cycle, although they could name all the remaining stages. These children were included in the 'semi-correct order' theme.

The interesting part of this question lies in the fact that, from all 16 children who seemed to be familiar with the life cycle of the butterfly, only one claimed that the caterpillar and the butterfly were the same animal. The reasoning that the child gave for this belief was that this is true because the first turns into the second. The rest of the 16 children who were able to name the stages and put the cards in the correct order believed that the caterpillar and the butterfly are different species. These 16 children gave many different reasons to support their opinions. For example, two of them claimed the cause of their opinions was the different colours of the caterpillar and the butterfly. Two others claimed that they are different because the first one has wings while the other has not. However, 6 children were certain that they were different species because they generally looked different. The same reasoning is observed among the children who were not familiar with the egg. Finally, there were two children who could not put the cards in the correct order and were not familiar at all with the life cycle of the butterfly.

Table 5: Results: previous experiences of children

Themes	Codes	Children
School	All–book–school Butterflies–book–school	1 2
Outside school	Alive–outside All–book–home All–TV Book–home Butterflies–book–home Butterflies–outside None–books–home None–home	2 1 1 2 2 3 1 1
School & home	All–book–both All–TV–book–school	1 1

An interesting fact that emerged from considering the drawings that children made of the butterfly was that, of the 16 children who described the life cycle of the butterfly during the interviews, only half made drawings that were not contradictory with their sayings. The rest, 8 of them, represented two butterflies in their drawings instead of a caterpillar first and a butterfly next although, afterwards during the interview, they were able to describe accurately all the different stages of the life cycle of the butterfly with obvious references to the caterpillar.

During the analysis of the answers to this question, many different categories emerged because of the different encounters that these children had experienced. However, all the different codes mentioned in Table 5 could be allocated into three major themes, which include previous experiences from home, from school, or both. A very important factor in these children' s previous knowledge seems to be the children's book *The Very Hungry Caterpillar* (Carle, 2000), as most of the children (11 of the 18) referred to that as a source of their knowledge, either from home or school.

Discussion

Regarding the first research question, the results indicate that children accept physical growth to be one type of naturally occurring transformation that can radically alter the outward appearance of living things (Gelman, 1991). Specifically, these findings indicate that these children are willing to accept that the dog is going to grow bigger over time, while the caterpillar will change forms until it becomes a butterfly. Children also seem to justify their opinion in different kinds of ways. Although their reasoning is not always scientifically correct, the existence of a justification alone can make the 5 year-old children's thinking advanced and strong (Wellman, 1997).

For the second research question, the results indicate that these 5 year-old children have a well-formed understanding of the biological mechanisms of growth from young to adult. Almost all children (16 of 18) said that the dog will grow bigger over time and they could not accept any other possible way of development. However, the children were less sure about the complete metamorphosis of the butterfly. Fewer children (12 of 18) were absolutely sure about all four stages of the life cycle of the butterfly. Some of them (4 of 18) knew the three last stages, but not the first stage, of the egg. Probably these young children lack experience regarding the complete metamorphosis and, as a result, formal teaching needs to better explain all four stages.

Additionally, it was clear by the children's responses that they were deeply influenced by the children's book *The Very Hungry Caterpillar* (Carle, 2000) with which almost every child (11 of 18) was familiar. This was indicated as the children who could list the stages of metamorphosis other than the egg stage repeated the exact wording from the book, including the day of the week on which the transition to the next stage occurred, in a rote-learning way. Although this book offers a great first idea for young children regarding complete metamorphosis, teachers should ensure that their pupils realise the complete life cycle of a butterfly as well as the number of transformations taking place during its life, so that children are not just mechanically repeating what they heard in the story.

Finally, the results of the third research question indicated that there is a conflict in the thinking of these 18 children. On the one hand, these 5 year-olds strongly supported the belief that the dog will conserve its species as well as its personal identity. On the other hand, they could not accept the same conservation of identity for the butterfly. This shows that children are more willing to accept changes that occur to animals because of natural growth than the radical changes occurring through complete metamorphosis. This conclusion can be linked to the use of personification by young children, where they extend human attributes to any non-human (Inagaki & Hatano, 1987). In this way, children can apply personification to objects similar to humans and, in this case, dogs who, although they grow, always conserve their identity, as humans do. On the other hand, they cannot make the same connection with the metamorphosis of the butterfly, as this is not part of human metamorphosis. However, most of the children were able to describe the whole life cycle of the butterfly (12 of 18).

Additionally, the triangulation made between the drawings of children and their answers supported the idea of the existence of the above-mentioned conflict in the thinking of those children. This is important because it reveals that the children in this study might have some correct ideas formed as a mental model but need some form of prompt from the teacher/ facilitator in order to express this. More specifically, teachers should help those children who appear insecure about their ideas to express them so that they can construct further understanding.

The discrepancies between the answers of the children, such as those of the older children compared with those of the younger, could be explained by the different experiences every child has, or their age difference. Such an observation is also noted in the different categories that emerged from the interview question, which referred to the children's source of knowledge. Most of these sources mentioned were either the school or the home. Additionally, 2 children cited the media as a source of knowledge (Conway, 1981). However, regardless of the source of knowledge, children seem to develop mechanisms that help them towards the acquisition of the necessary knowledge transformations, which in turn lead them to meaningful learning processes when it concerns learning concepts that lie within the *'zone of the child's own mental abilities'* (Vygotsky, 1978). Consequently, the learning abilities of the child may develop better within a collaborative framework provided by peers or facilitators.

Based on the findings of this study, follow-up research could further explore the optimum possible ways of teaching and learning the biological concept of species metamorphoses. This could be affected by designing and implementing specific activities that will concern only this particular concept and will aim to fill the gaps in children's primary experiential knowledge evident in this project. Subsequently, these activities could be tested by post-interviews after obtaining initial baseline data, in order to ascertain whether the children's answers to the same questions as the ones in this project improved after the teaching intervention. If there is a positive change, these new activities could find a place in the formal National Curriculum regarding teaching biology in reception class, because the data would indicate that they are able to help children develop a more accurate understanding of the concept of species metamorphoses.

If we attempt a brief evaluation of the research, the data from this study indicate that the learners hold a mechanical understanding of metamorphosis picked up from literature, in the case of butterflies. However, the work does not indicate whether they really understand the issue or whether they could apply this initial knowledge to new species. A concern is that the fiction gives a distorted image of complete metamorphosis and an inaccurate timescale. However, the data also show that children better understand the gradual metamorphosis of a familiar species, which also replicates step change in the human life cycle.

In conclusion, all the above outcomes of this work, if interpreted under the theoretical perspective of constructivism (Piaget, 1952; Vygotsky, 1978), can be used as a base for designing and implementing new teaching strategies for young children. These findings could help teachers identify needs and weaknesses in children's ways of thinking about species metamorphoses and help them improve their ideas about this concept. In this way, the aim of constructivist-influenced teaching can be fulfilled, with teachers being able to facilitate children towards well-defined knowledge that will help them construct new, more scientifically valid ideas about our world.

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Tooth decay and *Coca Cola* (Coke)

Olivia Humphries Lyn Haynes

Abstract

This article comprises an investigation report written by Olivia, aged 8 years, on work that she had initiated 18 months prior to committing it to paper. That initial report was followed up with ideas that she believed six months after completing the initial report writing. The idea was to explore *how* she viewed the consumption of *Coca Cola* (Coke) and the rationale behind why people *do* drink it, along with the concomitant impact on their lives. Part of the latter exploration was through discussions after viewing a range of *Coca Cola* commercials online. The framework-questions were posed to guide her thinking and writing about her home-based investigation and her motivation for undertaking it. The senior (in age) author believed that, through the use of the above nominated strategies, she would be enabled to ascertain what learning and long-term comprehension the investigation had brokered in Olivia.

Six months after completing the report shown in the boxes below, Olivia and I started the interview by revisiting the questions from her report. All work in speech marks is from Olivia.

Why did I put my tooth in *Coca Cola*?

Olivia had wanted to find out IF the tooth would dissolve in Coke, *'because I didn't know the answer at that time'*. When asked why she had opted for Coke, her response was that it has the most sugar in it and is what most people tend to drink if they drink fizzy drinks. When this idea was probed further, Olivia only really knew one person (B) who drinks Coke, *but* her teeth are *not* rotten. Yet, Olivia continues to hold the link between drinking lots of Coke and bad teeth.

Why did I put my tooth in *Coca Cola*?

By Olivia

When I was six I pulled out my loose tooth and wondered what would happen to it if I put it in Coke. This seemed like a more interesting thing to do than let the Tooth Fairy have my tooth as I love doing investigations.

What made me decide to put the tooth in Coke?

People told me my teeth would be damaged, and the enamel dissolved, if I drank too much Coke, plus, my grandmother asked me if I knew about this long held belief. I started by doing some internet research but I could not find any information that said that Coke (and other fizzy drinks) does dissolve teeth.

When she read her report again, she was concerned that the presentation of the results was not easy to read and that it was *'young writing, not my best'*. Conceptual analysis had not been evident from her responses up to this point in the verbal exploration of her original work. An interesting comment was that *'these messy results in the report don't have the smell'* (of when she was recording them).

In attempting to explore what she had learned through undertaking her month-long investigation, the main concept that she held on to was that *'the tooth did not dissolve but got rotten'*. While this outcome and belief were maybe more positive than her original premise, she reported that she would still not drink a lot of Coke.

As the one person that she knew who is a Coke drinker is a young adult, we explored how she would use her knowledge from this investigation when talking to B and other adults about her findings and the potential implication of drinking *Coca Cola* on their lives. *'I'd say: If you want your teeth to be rotten, drink it, if you don't, don't drink it!'*. Had she ever said this to B? *'No, I'd be scared of hurting her feelings'.*

We explored the idea further on the grounds that maybe Olivia had a duty to warn B; how could she share her knowledge politely? *'I'd try to persuade her not to drink (so much) Coke. Or, I could ask B what made her start to drink Coca Cola. I'd tell her what happens when one drinks Coke and what happened when I did the experiment. I'd make it worse so that she properly understands. But, I'd try not to exaggerate too much because that would be going too far!*

'No, maybe I'd say: "It's not my choice to drink Coke; you can carry on drinking it if you want to." This way I would feel that I had done the right thing by sharing the information with B.'

When Olivia was asked why she thought B had started to drink Coke, she suggested *parental influence*, explaining that parents are meant to set an example. If the parents did not stop children from drinking Coke, they would become addicted to the sugar and unable to stop. Another trigger was thought to be *friends*: if friends drink Coke, the person might think *'they know nearly everything so it must be the right thing to do'.* TV and radio advertisements might encourage children to think that *'it's amazing'* and so they would start (drinking Coke). Had Olivia seen a Coke advert (like the Haribos advertisement she sees on children's TV)? Her response was intriguing: *'No, but you never know!'*. When asked whether there are any roadside billboards that advertise Coke, Olivia responded: *'I don't really think billboards or Mum's magazines would advertise Coke'.* This response begs the question: what do young people think adults, drivers and mums should see as adverts? So, did Olivia think *Coca Cola* should advertise their product? *'No, because it's unhealthy and if you drink too much you will spoil your teeth'.* We would return to commercial advertising later, as I wanted to see how many of her strongly-worded and strongly-held beliefs she adhered to.

What I did?

I decided to try to see if this widely held, but not proven, belief was true. I put my tooth that had just fallen out in a pot and poured in Coke. For three weeks I checked the tooth, recorded my findings in My Notes. I decided to pour in fresh Coke every day. I did this because it would be more like drinking Coke every day, and so prove if Coke does dissolve a person's teeth.

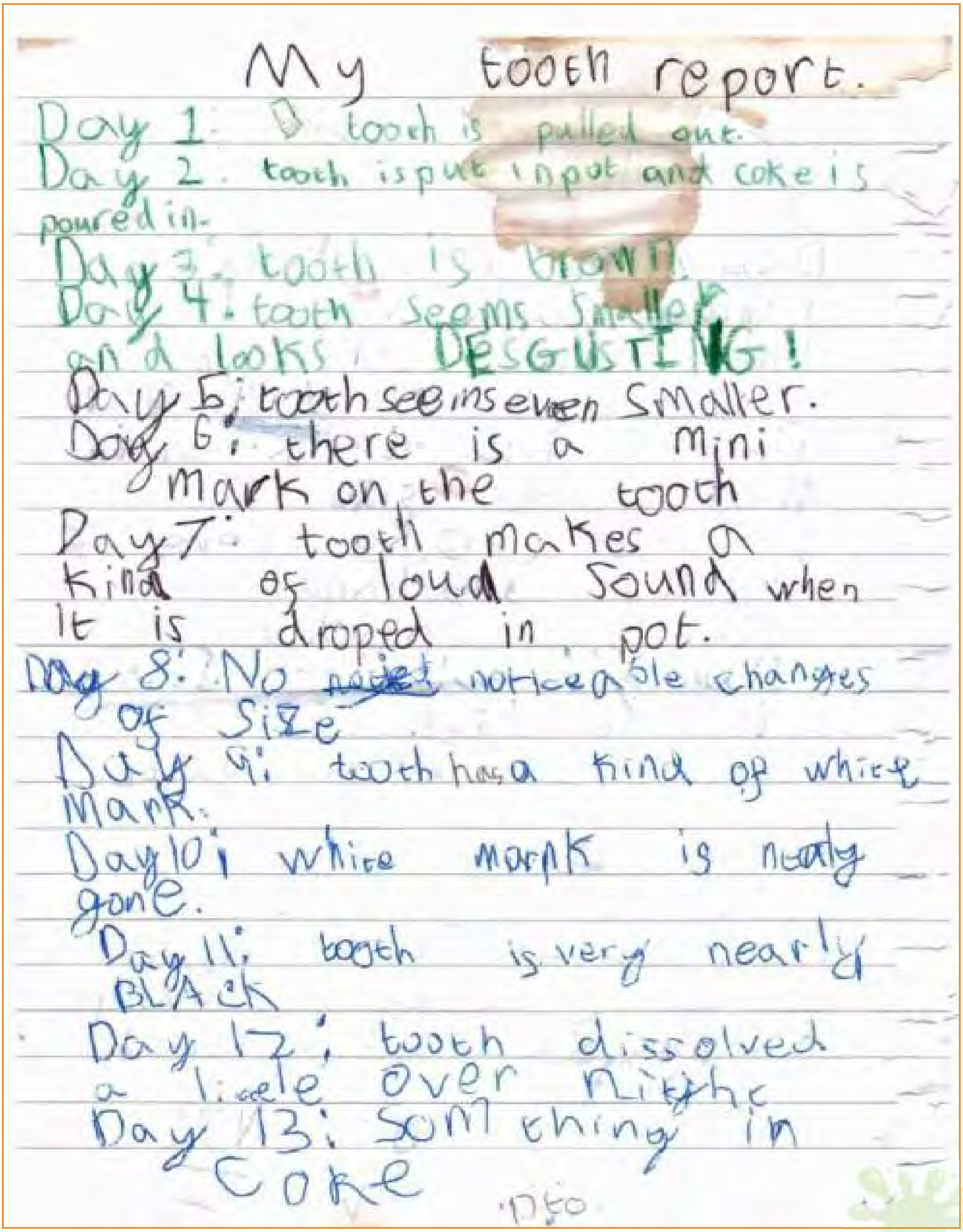
Notes

A copy of my notes made every time I checked the experiment is on the next page. I am writing this report almost two years later.

Olivia questioned the *What I did?* section of her report: *'What was that about?'*. Only after re-readng her notes and a 'think', did she realise that we were talking about the method that she had used for her investigation. Through deconstruction of her method she decided that maybe she had not changed the Coke every day (as she claimed) and that including the date in the results chart would have proven precisely how long the experiment had lasted. In addition, a major change proffered if she were to repeat the investigation would be to use fresh Coke every day, because it would be like drinking Coke: *'I like my fizzy drinks fresh and not flat'*, but *'this approach would make the experiment expensive'*. We discussed the idea of washing the tooth every day so that it would be like brushing teeth. Olivia even suggested removing the tooth, rinsing it and then brushing it twice a day: *'This would then actually seem like someone's real tooth, not just one in Coke'.* As it was her own tooth, she thought that she would have been prepared to hold her tooth to brush it. She was concerned that, by rinsing the tooth under the tap, there was a risk of losing it down the plughole. This barrier was soon overcome when she suggested *'stopping up the plughole!'*. The next barrier was the 'difficulty' of holding and brushing the tooth simultaneously. Maybe these ideas will remain as thought experiments, bearing in mind that on Day 4 she records that the tooth looked *'DESGUSTING!'* (see My Tooth Report).

She informed me that she now has a filling; the dentist says that the enamel on her teeth is 'weak'.

She described a permanent tooth that has been filled as a *'milk tooth that's not going to fall out'.* This idea of weak enamel triggered a new line of experimental posssibility. Should the experiment be done with permanent and milk teeth, on teeth with 'strong enamel' and 'weak enamel'? Did Olivia think that the results would be the same with this range of teeth? *'If the enamel is weak, probably not'*. What we do not know is if the enamel on her deciduous teeth is as weak as on her permanent teeth.



My tooth report.

Day 1: tooth is pulled out.

Day 2. tooth is put in pot and coke is poured in.

Day 3. tooth is brown.

Day 4. tooth seems smaller and looks DESGUSTING!

Day 5; tooth seems even smaller.

Day 6; there is a mini mark on the tooth

Day 7: tooth makes a kind of loud sound when it is droped in pot.

Day 8: No noticeable changes of size

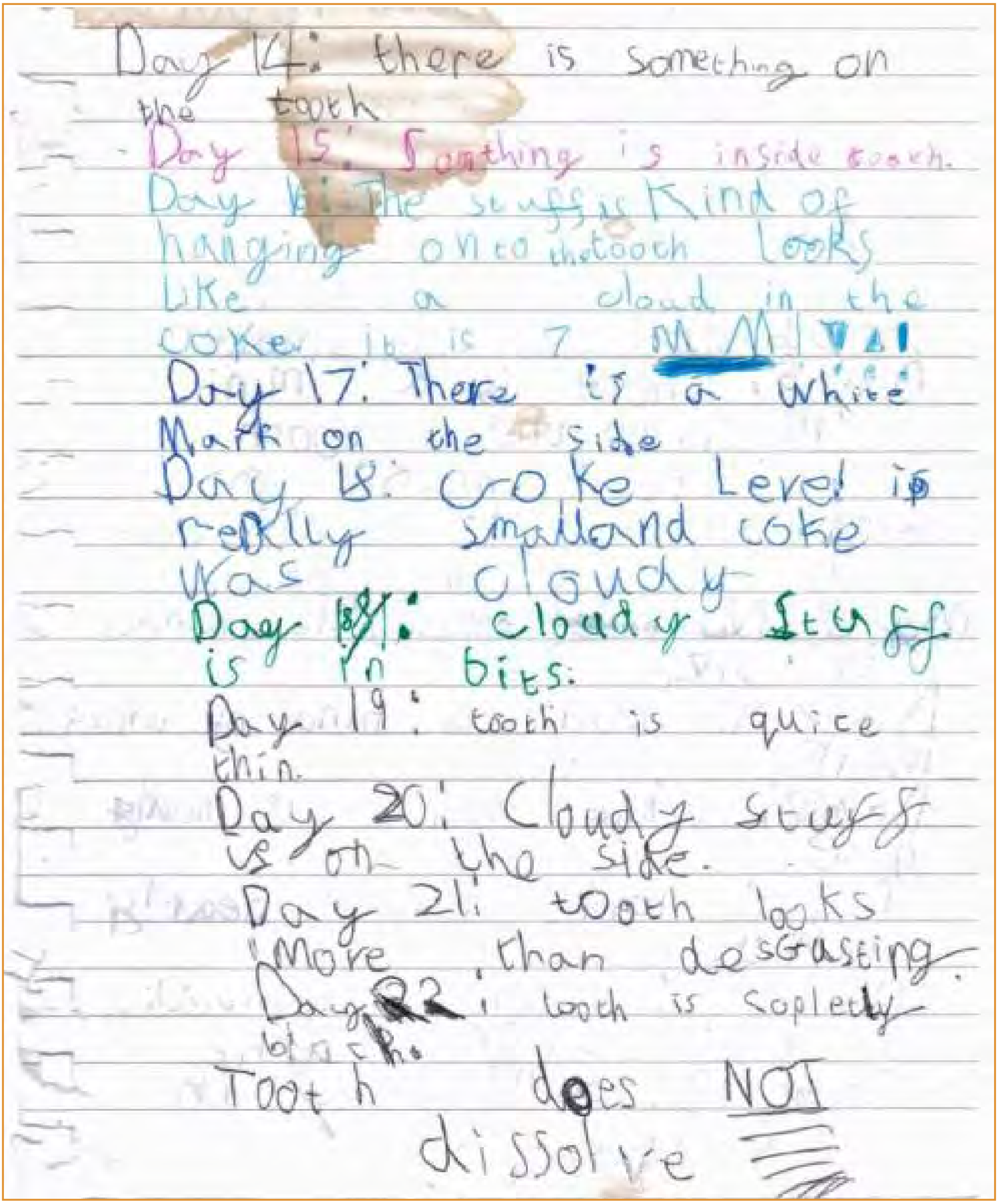
Day 9; tooth has a kind of white mark.

Day 10; white mark is nearly gone.

Day 11; tooth is very nearly BLACK

Day 12; tooth dissolved a little over nitht

Day 13; som thing in coke


Day 14: there is something on the tooth
Day 15: Samthing is inside tooth.
Day 16: The stuff is kind of hanging on to the tooth looks like a cloud in the coke it is 7 mm
Day 17: There is a white mark on the side
Day 18: coke level is really small and coke was cloudy
Day 18: cloudy stuff is in bits.
Day 19: tooth is quice thin.
Day 20: Cloudy stuff is on the side.
Day 21: tooth looks more than desgasting.
Day 22: tooth is sopletly black.
Tooth does NOT dissolve

Having discussed the method and ways in which it could have been done differently, Olivia did realise that only one thing should be changed at a time if we want to find the answer. At this juncture, it seemed pertinent to ask her what result she had initially expected: *'That it would dissolve a little and rotted. But as I have really, really weak enamel I think that it should have dissolved, not just rotted.'*

With the lab work completed, there is none quite like the converted. Olivia and I explored a range of *Coca Cola* commercials, from 1993 to 2014, online.

What did I find out?

I found that the tooth went rotten, but did not dissolve the whole tooth. The enamel of the tooth went very soft. I also found the tooth goes black in the Coke within three weeks, as you will find in the notes (My Tooth Report). I now believe that Coke is not good for teeth even though it does not completely destroy teeth.

She was invited to think about each commercial's intended message, and what she thought about this messaging. *'They're trying to convince people to drink it; look, the people are all happy. There's lots of energy in the video, lots of movement. Everyone is funky and cool to make you want to buy it.'*

We looked at the teeth of the actors: none appeared to have rotten teeth. In the 2014 advertisement, there was a sustainability message: the bottles can be used again for *many* things, including making music. Again, the theme of energy was prevalent; notably Olivia was not linking energy to sugar at this juncture as in the initial discussion. Other adjectives that frequently cropped up in her analyses were: happiness, fun, argghhhh, cute, *'you'll do anything for it – it's so great'!* Oh, the power of words?

What did those advertisements that we had watched together make her think the industry was saying to viewers? It did not take her long to say:' *'"This is really good. You are worthy of it." I say "worthy" because they want you to buy it.'*

We also viewed these commercials from a scientific perspective, accompanied by some 'science-talk': what do the bubbles in Coke feel like? *'Their softness makes the acid seem harmless'*. Olivia suggested that the CO_2 bubbles make you stop breathing for about half a minute, *'but you'd barely know that it was happening!'* She then linked CO_2 to acid and thus why the enamel can be damaged. The next link she made was the addiction to sugar, which would make the person keep on drinking Coke. (She did not make the links between excess sugar, energy, hyperactivity and obesity.)

So, if Coke seemed cool and safe to drink (no advert came with any health warning as do cigarette packets), then why would it remain a treat in her diet? *'If you have it too often they [fizzy drinks] start tasting a little dull.'*

How did Olivia think that she and other young people could tell the industry about their views on encouraging people to start drinking Coke? *'It's alright for a treat, but of course they are going to encourage us, then they get more money. Money is all they care about, or that's what I think that they care about.'* How then did Olivia think that the industry could help to make drinking Coke a treat? *'Simple, only sell it on special occasions!'* How would Olivia and other young people suggest that advertising could be changed? *'Make the adverts less interesting; raise the cost [of Coke] so that people don't buy it any more!'*

Conclusion

By 7 years of age, Olivia had learned and believed that drinking *Coca Cola* should be a treat, possibly on the premise that it was bad for her teeth as well as the sugar addiction. She and her siblings do not watch much commercial television (a maximum of 4 hours of children's programme a week), so her response to the Coke commercials, as an 8 ¾ year-old, was untainted. The idea about the power of the financial inducement for the industry was purely her thinking. At every step of the investigation, report writing and interview discussions, she proved to be solution-focused, whether from an investigation perspective or to use the voice of the child with a hope to influence the 'system'. She was able to pick up on intended messages in advertising commercials and still hold true to her original beliefs. Children do understand more than we give them credit for. Will the industry listen and thereby do their bit to help the future health of the nation(s)?

The investigation was undertaken when Olivia was 7¼. At the time of submitting this article for publication in July 2014, she was 8 ¾ years old. We must add that the tooth cost the scientific Tooth Fairy £2, in addition to the Coke!

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Young children's views of creativity in science:

Exploring perspectives in an English primary classroom

■ Sarah Frodsham ■ Deb McGregor ■ Helen Wilson

Abstract

The importance of creativity in the classroom has long been debated, as well as the ways in which it might be supported and evidenced in primary schools. This is despite the lack of a clear and universally agreed definition of creativity. Nurturing ingenuity and inventiveness in young children (and subsequently young adults) is essential, due to an unpredictable future (in life after school) with unknown challenges. Encouraging more creativity in the classroom requires the student to be an active thinker, recognise opportunities to be imaginative and utilise ways of being creative when appropriate. It is only by being attentive to the student's social, historical and cultural understandings (voice and actions) that teachers may begin to appreciate what children understand by creativity in the classroom. However, it has been suggested that the current education system may be constraining teachers' efforts to foster creativity but, despite this, some teachers have managed to embed creativity into their practice. The realisation of creativity in learning is of great interest, especially if the unforeseen challenges of the future are to be met. This study, based on a small sample of pupils in Key Stage 1 (ages 5-7), in an Oxfordshire school rated as 'outstanding' by Ofsted, explores children's views of creativity. It examines the opinions of these pupils and their perspectives of originality in and out of the science classroom. The findings suggest that young children can recognise and appreciate creative characteristics and how these might be utilised to further develop and augment individual creativeness, through generating original ideas, relating science to fresh contexts and thinking independently.

Keywords

Creativity, creative teaching, teaching creatively, teaching for creativity

Introduction

The ongoing debate between learning and creativity within the school environment was initiated by Guilford (1950) but, more recently, limitations within the educational system restricting creative practice have been highlighted. This includes *'its undefined terminology; conflicts in policy and practice; how the curriculum is organised and the centrally controlled standardisation of its practice'* (Craft, 2003:118–120). Whilst the debate about the characteristics and definition of creativity continues, the importance of its existence within the classroom has been acknowledged (National Advisory Committee on Creative and Cultural Education (NACCCE), 1999; Ofsted, 2010, 2013). This realisation is necessary, especially when life after school (or even whilst still at school) is unpredictable with unforeseen challenges or problems to solve. Nurturing creativity within the classroom may enable the child to live with complexity and uncertainty by becoming adaptive, resilient, resourceful and reflective (Cremin *et al*, 2008), all necessary traits for an unknown and probably challenging future because *'academic ability alone will no longer guarantee success or personal achievement'* (NACCCE, 1999:13).

If the above is to be taken seriously, then young learners will need to be supported to become active thinkers and agents of their own learning, and their perspectives will need to be heeded and integrated into learning opportunities to develop these skills. Ruddock, as described by Alexander (2010), endorses teacher consultation and active participation with the children to respond to this need, but some scholars take this a step further and emphasise the centralisation of the student in the classroom, making them *'active agents'* and *'citizens with rights'* (Glauert & Manches, 2013:14), thus enabling them to take full ownership of their own learning.

Creativity and the classroom

The word 'creativity' is frequently used in educational settings, but research indicates that there is no clear-cut agreement about how to define it. A review of literature by Mayer (1999) suggests that there are two key characteristics, *'originality'* and *'usefulness'*. Other researchers utilise the same or similar characteristics within their definitions (NACCCE, 1999; Kaufman & Baer, 2004; Boden, 2001; Kampylis *et al*, 2009), but Csikszentmihalyi (1997) believes that it is much more complex than just a handful of indicative characteristics and that it contains a range of many interwoven component parts. This could explain the elusive (Kampylis *et al*, 2009; Johnson, 2009) and often variable (Ofsted, 2010) definitions found within educational settings, despite its frequent usage.

Certain features of creative teaching have been seen or recognised to promote and enhance creativity (Jindal-Snape *et al*, 2013; Davies *et al*, 2014).

They are:

- Building positive relationships with pupils and setting high expectations for all, no matter their perceived ability, learning styles or needs, whilst supporting them to take risks appropriately depending on the individual's capabilities. This may involve the acceptance that the allotted time for the completion of set work may have to be extended, thus allowing children the time to complete their work at their own pace.
- Modelling and encouraging positive creative attitudes, by being flexible, willing to take risks, being adaptive, allowing collaboration and assessments to take place within social peer groupings and, by doing so, being open to alternative ideas/strategies and/or unpredictable outcomes.

Science, creativity and the classroom

'Creativity begins the scientific process' (Keogh & Naylor, 2011:104) and the process involves *'the highest levels of creativity and insight'* (NACCCE, 1999:35). It is also highly collaborative and occurs along with, and alongside, scientific peers (Glăveanu, 2013). This is in line with Glăveanu's (2011:127) explanation of the creative process, which requires *'interactions with the physical and social world'*. These interactions, if allowed to play out in the science classroom, would allow children to contemplate and engage in possibility thinking (Keogh & Naylor, 2011) and express their thinking by means of their natural dialogue and body language (Glauert & Manches, 2013).

Nickerson (2009) explains that the scientific process is driven by the generation of ideas that include the transformation of existing ways of thinking into new possibilities (Robinson, 2001). Creativity also involves moving between generative and analytical phases (suggesting or producing many ideas and then elaborating or interpreting possibilities) (Howard-Jones, 2008) and even recognising their shortcomings or limitations (McGregor, 2007). Thus creativity and the scientific process of a child can both be seen as a series of continuous speculations and re-evaluations of ideas or information whilst challenging and building on existing knowledge (NACCCE, 1999).

The *Creative Little Scientist Project* (CLSP) has developed a specific definition of creativity for primary school science; that is: *'[To] generate alternative ideas and strategies as an individual or community, and reason critically between these'* (Compton *et al*, 2014:5). They too recognise the importance of generating ideas and critically reflecting on them. This definition also focuses on and incorporates Craft's 'little c' creativity (Compton *et al*, 2014), which Craft (2001) describes as involving the active engagement and intentional taking of action on and within everyday challenges. The two key characteristics of creativity, 'originality' and 'usefulness' may not be initially evident, but incorporated within this definition is divergent thinking and problem solving. Cremin *et al* (2013) imply that problem solving and divergent thinking (McGregor, 2007) follow the cognitive model of creativity. The phases of this model can be observed within many of the present theories/models of creativity (Nickerson, 1999); for example, this is indicative of the Geneplore model of creativity, which consists of iterative cycles of generating ideas and subsequent 'explorative' stages, with the creation of pre-inventive structures between cycles until a final product/idea is produced (Finke *et al*, 1996). The CLSP definition can then be placed alongside and within the two key characteristics of the consensus definition when it is related to the individual and the everyday, as Runco (2003:318) succinctly states: *'The basic idea is that any thinking or problem solving that involves the construction of new meaning is creative. This may sound contrary to theories of creativity, which emphasise originality and usefulness, but there is no incompatibility if you keep in mind that a personal construction will likely be original and useful to that one individual'.*

Garnering the children's views

The aim of this study was to appreciate children's perspectives of creative teaching and learning within the confines of the science classroom. The study consisted of two focus groups from a primary school in Oxfordshire. The school had been classified as 'outstanding' by Ofsted and had 100% attainment at Level 4 in science (the nationally expected standard of achievement at eleven years of age) at the end of Key Stage 2 (i.e. in the final year of primary school). The two focus groups were from juxtaposed years (ages 5-6 and 6-7) and consisted of 8 children who were always fully engaged in classroom activities and were typical and representative of the year group as a whole. The discussions that took place provided rich, in-depth reflections about the learning experience from a child's perspective and enabled co-constructed reflections to emerge (Merriem, 2009), thus offering examples and insights into the ways the children perceived science and creative learning.

The questions asked were structured so that the interview could proceed sequentially from a generalisable question and subsequently move onto a more specific question relating to science (Green & Hogan, 2005). Both groups were asked the same four questions:

- What does someone being creative mean to you?
- What do creative teachers do in your lessons?
- Can you describe a time when you were the most creative in your class?
- Can you describe when you were creative in science?

The discussion was carried out outside the classroom and each child took it in turn to offer his/her personal view in response to each of the questions above.

Ethical approval was granted at university faculty level and consent from the school was sought and obtained from the Headteacher, teacher, parents and the young participants. Prior to the interviews, consent forms were signed by the parents, on behalf of the child, and individually tailored information sheets were given to both parents and children. The children invited to participate in the focus groups were considered by their teachers to be articulate and were able to clearly describe how they viewed their learning in science.

The focus group discussions were recorded and transcribed in full. The transcriptions were then analysed with a framework arising from the two NACCCE (1999) descriptors of creative teaching, which are: 'Teaching creatively' (relating to the utilisation of fun, engaging imaginative techniques) and 'Teaching for creativity', which requires the children being independent and actively involved with the creative learning process. This differentiation of creativity in the teaching and learning process is also supported by Davies (2011).

From the analysis process, four themes emerged from the data:

- Suggestions about being creative;
- Enactments of creativity;
- Teachers being creative; and
- Characteristics of creativity.

Each comment was categorised and aligned to the above themes. Table 1 provides an overview (and some exemplar illustrations) of the outcomes of this process.

Results

Discussion of the findings indicated in Table 1

Suggestions about being creative (33 comments) infer that children are able to easily recognise creative behaviour; however, the *enactments of creativity* (21 comments) appeared to be occurring through conditions that restricted the activity and focused on the creation of the final outcome without mention of conceptual understanding. The children were also able to readily recognise *teachers being creative* (14 comments), thus they could

Table 1: Children's perspectives of creativity: A summary of the findings

Themes	Numer of comments relating to themes	Example comments (ages 6-7)
Suggestions about being creative	33	Child 1: [...] I managed to makes lots of different transformers out of dough and I showed my mum and she was impressed [...].
		Child 6: [...] You can make something out of almost anything else [...].
Enactments of creativity	21	Child 3: I was creative in science when we had to estimate how long the chocolate takes to melt in the microwave.
		Child 6: I was creative when [...] we had to take a pencil for a walk and we had to let the pencil off when on another line and then we had to fill it in with colours and we had to do it on a computer.
Teachers being creative	14	Child 6: I think creative teachers can make fun homework and spellings for you to learn.
		Child 3: I think a creative teacher thinks of experiments and science and things to show, for their children to see to WOW them, so that they laugh and they like them.
Characteristics of creativity	7	Child 1: I think someone being creative is someone making something out of something else or making something [...] and not something, idea that someone else has given them.
		Child 2: I think creativity means that you have a really good imagination.

recognise creative teaching practices. The older children (ages 6-7) could articulate *characteristics of creativity* (7 comments) such as the generation of ideas via an iterative thought process, thus indicating their awareness of how the creative cognitive processes occur, but none was related back to their learning in the school environment.

The co-constructed discussions that took place were scrutinised further to enable full appreciation of how the children perceived being creative and creativity itself.

Analysis of co-constructed discussions

Analysis of the focus groups' discussions appeared to indicate that children recognised and appreciated characteristics of creativity, i.e. views that made reference to the iterative cycles of generative and analytical ideas (Finke *et al*, 1996), although they may have lacked the ability to articulate this process effectively (Runco, 2004); for example, Child 5: *'...people need houses to make their stuff. Like a place to. It's a bit like a workshop where you can make whatever you would like. So they make like sheds, to make things, so you need* *some things to make other things'*. Whilst this single characteristic is not indicative of creativity itself, this type of developing cognitive flexibility has been suggested, by Compton *et al* (2014), to be part of the learning process involved in science education; this can lead on to the generation of further and alternative creative ideas as suggested by the discussion that took place below:

Child 6: *Um. I think creativity means, um, when you can make things out of, make things out of literally everything that you can get.*
[*...After further discussion based around this comment, creative ideas were generated...*]
Child 4: *I make things out of people, shadows.*
Child 5: *And electricity.*
Child 4: *And buildings.*
Child 6: *You can make another building out of a building.*
Child 3: *Yeah, you could.*
Child 5: *You could knock it down and get the bricks again.*
[*...After further discussion, Child 6 declared...*]
Child 6: *We just like, gave you five ideas.*

This exploratory talk (Littleton & Mercer, 2008) illustrating original ideas proffered by the children, inspired through the back and forth communication like a see-saw conversation, is referred to as *'the collaboration of learning'* by Glauert and Manches (2013). The children articulated, explored, made connections between their suggestions and then subsequently envisaged potential relationships and outcomes via a reflective discussion, which, according to the Qualification and Curriculum Authority (QCA) (2004), is characteristic of children thinking and behaving creatively. As a result of the above co-constructed discussion, Child 6 also appeared to articulate metacognitive and evaluative processes, which have been associated with science education and the creative learning processes (Compton *et al*, 2014).

One child recognised 'independence' as an important personal characteristic involved in generating ideas; this is a trait recognised as belonging to the creative personality (Cremin *et al*, 2013). Whilst the comment below relates to an art lesson, the generation of ideas in art and science have a shared creative process (Howard-Jones, 2008; Nickerson, 2009), although the iterative process was not mentioned by Child 5:

Child 5: *Normally if it's a very good art lesson it makes you feel a little bit more independent.*
Interviewer: *[...] Is it important to be independent?*
Child 5: *Yes, because you get to do more things because normally if you're not independent you don't really get the best ideas out of you.*

Developing independence (learner agency) is highlighted by Lin (2011) as necessary if the teacher wants to encourage and provide opportunities to enable the child to achieve creativity. Feasey (2005) believes that this type of independence can be developed by allowing time for the children to engage in critical reflection, aiding the formation of their own ideas.

The formation of ideas in creative education was highlighted by Harlen (2004:2): *'Creativity in general involves creating or constructing something...[but] in education it is the creation of new ideas that is foremost, since all products....start from ideas'.* Most of the children seemed to have understood this, but the majority of their responses appeared to focus on the creation of a final product and/or idea, which, according to Runco (2004), should not be considered a prerequisite to subjective creativity. It is during the child's exposure to creative opportunities in the classroom that the production of the product was highlighted; for example, Child 1: *'I was creative in class one because, um, I would make robots out of just junk, like boxes and, um, tissue paper, rolls and lots of different things...'.* This comment also suggests how the child believes he was free to express himself creatively via the autonomous utilisation of varying resources, providing him with more opportunities to demonstrate his creativity (Davies, 2011).

However, the majority of the product-orientated discussions/comments that were articulated by the children appeared to revolve around activities designed by the teacher and had predetermined outcomes. These types of prescriptive teaching methods do not automatically accommodate subjective creativity (Oliver, 2006), as they place limits on self-expression and the potential for personal ownership of learning. However, they appear to be attempts by the teacher to communicate the subject matter in a creative and imaginative way, for example:

Child 3: *'I was creative at school when we made Tudor houses for our project for the Great Fire of London and we made the pictures of the Great Fire of London'.*

The comment on page 35 suggests that an imaginative creative activity is taking place, but these activities are focused on the teacher's carefully guided or supported creative enactment and the creation of a pre-specified product. This form of creative opportunity was also observed in other comments: Child 2: *'[I made] a Christmas stocking […] a bit before Christmas. […] Well, we didn't make one, there was already an outline and we decorated it'*. The activity itself, according to the NACCCE (1999) description of teaching creatively, is an attempt to make learning more interesting by the teacher, but it could also be argued that the constraints of the activity did not develop the child's autonomous cognitive thinking and learning processes. The creativity was limited to choosing combinations of colours to complete a picture, potentially limiting any spontaneous transitions towards substantial individual creativity (Jeffrey & Craft, 2004).

When both groups were asked to extend their ideas on creativity to suggest what creative teachers do in lessons, their responses related to fun activities, some teacher guidance and creating something that produces a final product. There was no mention, by any child, of the cognitive learning processes involved:

Child 5: *A creative teacher would make…. Would say to children what would you like to make? And well then they would maybe vote and she would tell you exactly, or he, actually how to make one and it's very good.*

The view expressed above indicates that the child recognises that a teacher inviting an individual to generate something unique to them is a creative opportunity. Interestingly, this does reinforce how often many children perceive creativity as strongly related to art, either where something is performed (such as playing a musical instrument or singing a song) or produced (such as a painting, drawing or an artistic object). The child also believes that the teacher is in charge of the creative opening and thus they maintain control of the activity by not allowing the child complete ownership of the task. However, active learning with the creative teacher presenting concepts in new and exciting ways was always expressed positively, indicating an exciting activity that is accessible and stimulating, piquing the children's curiosity; children regularly used words such as 'wow', 'laugh', 'enjoy' and 'fun' when discussing these viewpoints.

When discussing creative opportunities for learning in science, these were not always obvious to the children but, after further co-constructed dialogue within the group, the children produced creative activities that they thought may or may not have been related to science:

Child 2: *How do you be creative in science?*
[*…After further discussion…*]
Child 1: *We, we made a Chinese lantern.*
Child 2: *That was to do with literacy.*
[…]
Child 2: *Maybe it was literacy.*

This conversation may reflect the children's inability to understand the difference between producing a (final) unique outcome or product and the cognitive processes involved in the generation of distinctive ideas or innovative ways of thinking about things (i.e. creative learning).

When discussing creative activities in science, creative teaching approaches, such as the utilisation of metaphor, anecdote, visualisations, analogies and modelling were not identified. However, some children mentioned creative science experiments and imaginative ways of noting what they did:

Child 3: *I was creative in science when I made […] a little story map of what a kettle does to a mirror and how it brings the (stew) up and the gas turns, turns into. The liquid turns into gas and then the gas turns back into the liquid.*
Child 6: *Condensation.*
Child 3: *And evaporation.*
Interviewer: *Why is that creative?*
Child 5: *Because you get to see the mirror turn into something else and is quite creative because you can draw on the mirror, and you can go smiley face* [*…child laughs…*].
Child 6: *And you created the steam.*

Whilst the children enthusiastically discussed the creative science experiment, the designing of the story map or the formation of the smiley face on the mirror yet again exemplified the child's perception of the creative process relating to the creation of something tangible or visible, a product of some kind, and not to their own creative process of learning. The creative learning processes were also constrained by the nature of the predetermined structure of the activity, which did not appear to accommodate the children's creative thinking skills or behaviour, i.e. no 'mental play' was encouraged for exploration of alternative possibilities (Feasey, 2005), which is best developed and promoted in science *'through open-ended investigations requiring critical and analytical skills'* (Jindal-Snape *et al*, 2013). This can aid the children when looking *'for different interpretations of the evidence, not simply what they [the children or the teacher]...'* expect to observe (Keogh & Naylor, 2011:104).

Reflective discussion of the study

Spencer *et al* (2012) suggest that there are tensions between accessing children's creativity and how the school system is currently run; for example, it has been recognised that there is a great emphasis on achieving certain summative attainment levels, which do not recognise or assess an individual's unique, special characteristics (Barrowford Primary School, 2014) or, indeed, the way they go about tackling a problem to be solved. Craft (2003) takes this further by implying that it is the constraints of the curriculum, the pedagogical practices, leadership and financing that are the main limiting factors to nurturing creativity. Thus *'the challenge [for the teacher] is to manage the...national curricula in an inspiring and creative way'* (Feasey, 2005:1) and utilise more creative teaching strategies, which can stimulate interest and inspire awe, wonder and curiosity (Oliver, 2006).

Creative teaching pedagogy may be visualised on an implied continuum (NACCCE, 1999); at one end is teaching creatively: *'Using imaginative approaches to make learning more interesting, exciting and effective'* (*ibid:* 102) and, at the other, is teaching for creativity: *'Intended to develop young people's own creative thinking or behaviour'* (*ibid:* 103). Jeffrey and Craft (2004) suggested that teaching practices should aim for the latter half of this continuum; however, the comments made by the children in this study appear to be more focused on the former. Some literature appears to suggest that teachers' creative practices are failing to recognise the two component ends of the creative teaching spectra, implying that some believed it could be sourced off a shelf (Ofsted, 2003), but there is limited research on what each encompasses and how the two distinct, but potentially integral, approaches fit together. Perhaps this is because teaching provides the scaffold, guidance and direction for learning, which, if too tightly prescribed, will limit the opportunity for creativity in learning.

To offer opportunities for children to develop their creativity, teaching needs to take account of each individual and the varied ways in which they could contribute originality through unique thoughts and actions. Craft (2005) indicates that there is a need for a *'lens for understanding the middle ground between creative teaching and teaching for creativity'* (*ibid:* 27), because *'the neglect of spontaneous and creative learning and its characteristics...could result in difficulties in fostering children's creativity'* (Lin, 2011:152). It is hoped that this small study can contribute towards the debate about that.

Pupils in this study appear to have been taught creatively, but their personal creativity may have been a little stifled by teachers who could be overly scaffolding, tending to refer to their own or other preferred ideas, focusing on the production of a product, being more concerned about conceptual (National Curriculum-related) outcomes and not allowing the child flexibility to extend, elaborate or explore learning unfettered to develop his/her own knowledge base (Keogh & Naylor, 2011). Creativity could be enhanced by the teacher valuing (and offering) more open questions, encouraging speculation and considering alternative possibilities, and allowing the children a stronger sense of ownership and agency in their learning (Oliver, 2006). However, some teachers believe that they are unable to be spontaneous in the classroom due to restrictions constraining their practice (Galton *et al*, 2002). For teachers wishing to support more creativity, the nine characteristics outlined below could be considered and implemented into the science classroom (Davies, 2011). These are:

- Turning predictable outcomes into something better;
- Making the ordinary fascinating;
- Sharing a sense of wonder;
- Seeing differently;
- Maximising opportune moments;
- Humanising science;
- Valuing questions;
- Modelling explanations; and
- Encouraging autonomy.

Oliver (2006) emphasises these nine features, but also believes that allowing for flexible beginnings can aid creative learning too. Wilson (2008) acknowledges that teachers work hard and cannot be expected or asked to do any more, but teaching to develop pupil creativity can be designed to avoid additional burdens on their already precious but limited time.

Unfortunately there is an overwhelming abundance of literature that is easily disseminated and tends to refer to effective creative teaching strategies, without mention of teaching to nurture creativity; subsequent misinterpretation, quickly followed by a mechanised step-by-step approach, could be inevitable and may lead to an undemanding activity (Robinson, 2009).

Ofsted (2013) has highlighted the necessity of learning in science to focus on and develop students' current understandings to support their ongoing progress; this also needs to be applied to children's creativity. Appropriate formative assessment for learning (AfL) procedures (Oliver, 2006) are needed and should be embedded into the system for this to be successful (Davies *et al*, 2014); however, what constitutes best practice has yet to be established (Dunn & Mulvenon, 2009). Approaches to assessment of this kind could provide the children with the necessary tools to advance their own creativity (Coates & Wilson, 2003). Black and Harrison (2004) provide a list of 'essential ingredients' within the science classroom, which complement creative teaching and offer opportunities for AfL, They are:

- Challenging activities that promote thinking and discussion;
- Rich questions;
- Strategies to support all learners in revealing their ideas;
- Opportunity for peer discussion about ideas; and
- Group or whole-class discussions, which encourage open dialogue (*ibid:* 5).

Providing the whole class with increasingly challenging tasks and questions can result in opportunities for pupils to demonstrate their creative learning and understanding (Wilson, 2008) but, if the activity is constrained and/or teacher-orientated, then opportunities to understand the child's conceptual knowledge will be missed (Oliver, 2006). There is some evidence, in practical work, that more 'open' tasks are more likely to elicit a wider range of creative solutions (McGregor, 2007: 233). It becomes evident therefore that the extent of the development of creativity is strongly influenced by the teacher. Where the child appreciates and understands his/her creative potential and the teacher is able to scaffold and encourage collaboration, then both can work together to generate scientific creativity (Feasey, 2005).

It has, however, been recognised that children articulate their creative efforts in varying ways and have different creative abilities (Feasey, 2005). Some find it difficult to express themselves verbally (Hargreaves, 2004) in the classroom environment (Runco, 2004). Assessment procedures, therefore, could be integrated into varying approaches such as talking, writing, drawing and role play (MacBeath *et al*, 2003), to enhance the quality of teaching and learning taking place (Feasey, 2005). McGregor and Precious (2010) have provided examples of non-traditional approaches in science, which enable the teacher to observe the representation of conceptual understanding but, no matter the chosen assessment technique, best practice should always incorporate the student's voice (spoken or actional), in order to know how best to proceed and to make the most of the student's creative learning development. Accessing the ideas of children is important, as each child brings their own experiences and scientific understandings (Feasey,

2005) and *'what underpins all experiences, including those that are designed to develop creativity, is personal knowledge and skills'* (*ibid:* 17). Alexander (2010) puts it succinctly when he says that *'…it would be indefensible to ignore the voices [and/or ideas] of those whose lives, education and futures are what primary education is about, and who have to live with the consequences of decisions …'* made by others.

Conclusion

Creativity has been accepted as essential for education in preparing future generations to face unforeseen challenges. The research carried out in this study highlights the children's ability to appreciate and comprehend characteristics of creativity and to recognise their own and others' creative enactments. It appears, however, that they were unable to make clear connections between these elements and their own personal creative learning processes. It has been suggested, in this study, that a creative teaching pedagogy that more explicitly supports children realising and recognising creative learning processes would benefit from embedded formative (AfL) assessment techniques. However, it is imperative that the students' prior experiences and voice be taken into account to best develop their ongoing creative learning processes and allow them to take ownership of this development, so that they may become more independent learners.

Schools do appear to be increasingly integrating creativity into their curriculum. The creative practices taking place in the classroom, demonstrated by this study, are imaginative but product/outcome-orientated. The focus on an artistic product is not surprising, but it should not be the only indication of creativity, and this goal-orientated practice could be constraining learners into a predetermined course of action and may not be specifically nurturing individual or collective creativity in the classroom. It is the teachers' practices that are central to this process of successful recognition of creative process (such as raising thoughtful questions, seeing the extraordinary in the ordinary, realising something no-one else has thought about, etc). Limitations within the educational system cannot be ignored and have been implicated here. The delicate balancing act between a creative teacher's pedagogy and realising a student's creative potential is not helped by the overwhelming amount of literature directed at teachers to draw from when choosing between creative teaching strategies and techniques. The literature does not make a clear distinction between teaching creatively and teaching for creativity and thus may not be clearly articulating what is needed to support the development of originality, imagination and inventiveness in young children.

The above is an essential part of fulfilling the potential learning and creativity required for an unpredictable future but, until the educational system addresses the above concerns, creativity within the classroom could remain mechanistic and undemanding (and ill prepare the next generation for life challenges ahead).

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