The Journal of Emergent Science

Issue 15 Summer 2018

The Association for Science Education
Promoting Excellence in Science Teaching and Learning

why & how? PRIMARY SCIENCE TEACHING TRUST

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The Association for Science Education
Promoting Excellence in Science Teaching and Learning

why & how?
PRIMARY SCIENCE TEACHING TRUST

Editorial

● Amanda McCrory ● Suzanne Gatt

For this Special Issue of JES, we are very fortunate to have Dr. Coral Campbell from Deakin University in Geelong, Australia as a guest editor, who explains – further on in her own Editorial – the importance of the focus of this issue – the 2017 ESERA Conference. Coral has been involved in industry, school and tertiary education for many years, and her research interests lie in practitioner learning and students' understanding in science and STEM, in all areas of the schooling sector. Her more recent research has focused on early childhood STEM.

We would like to thank ESERA for their kind permission to publish the extended abstracts of some of the 2017 Conference contributions in this edition. In particular, we are very grateful to Professor Costas Constantinou, President of ESERA, for his support. We will publish a second collection in issue 16.

In addition, this issue includes two articles from the Primary Science Teaching Trust (PSTT), both of which give interesting insights into science in the primary classroom. The first, written by Clarysly Deller, reflects on how drama techniques and dialogic practices can be used to effectively teach aspects of primary science. The second, by Isabel Hopwood-Stephens, grapples with the tensions that classroom practitioners face when attempting to improve assessment practice in primary science. Both articles make for thought-provoking reading!

We very much hope that you enjoy the varied and engaging articles presented in this issue of JES.

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Guest Editorial

● Coral Campbell

Welcome to this edition of the Journal of Emergent Science (JES), which highlights some very interesting research through some short papers presented at the 2017 European Science Education Research Association (ESERA) Conference in Dublin, Ireland.

Firstly, let me explain that the two *JES* Editors have asked me to write this *Editorial*, as I was the person who approached them about this special edition. This was as a consequence of my role as ESERA Early Childhood (EC) Science Special Interest Group (SIG) Co-ordinator, a role shared with Estelle Blanquet. At the ESERA Conference in 2017, the SIG discussed ways to improve the visibility and impact of early childhood science. Jane Johnston and Lady Sue Dale Tunnicliffe were the original Editors of *JES* as well as the first ESERA EC Science SIG co-ordinators, so it seemed fitting that ESERA and *JES* were associated again through this edition.

At the recent Conference in Ireland, there was a significant increase in the number and type of papers submitted around topics of research into early years science education. For example, when the SIG started (2009), there were approximately 15 people who submitted papers in two sessions. In 2011, in Lyon, there were three sessions and 19 papers presented, as well as quite a few poster presentations, each with a standard synopsis paper of the research. In 2017, the number of papers presented through six paper presentation sessions, two symposium sessions and one poster session, had increased to 35.

The indications, from the increasing number of submissions to the conferences, imply that early childhood science education is receiving more notice in the science education research community and is attracting more researchers looking at the depth and breadth of science education provision in early childhood.

In this edition of *JES*, we have included the extended abstracts from some of the presentations delivered in Dublin. Obviously, we could not publish everything, but feel that these offer a 'taster' of the international research happening across the globe. It is intended to include some more of these abstracts in issue 16 of *JES*, later in the year. Also, if you would like further examples, please refer to the ESERA website (https://keynote.conference-services.net/programme.asp?conferenceID=5233).

Contributors to this edition include:

- *Reflections on guidance to orientate untrained practitioners towards authentic science for children in the early years* – Linda Mcguigan and Terry Russell.
- *Potential for multi-dimensional teaching for 'emergent scientific literacy' in pre-school practice* – Sofie Areljung and Bodil Sundberg.
- *Pre-school children's collaborative science learning scaffolded by tablets – a teacher's view* – Marie Fridberg, Susanne Thulin and Andreas Redfors.
- *Teaching science in Australian bush kindergartens – understanding what teachers need* – Coral Campbell and Christopher Speldewinde.
- *Systemising and empathising in early years science – a video-based study with pre-school children* – Nina Skorsetz and Manuela Welzel-Breuer.

I attended as many sessions as I could, and enjoyed the variety of research being undertaken and the robust discussions afterwards. Interestingly, I attended the European Early Childhood Education Research Conference a short time after ESERA and found yet more early childhood science papers presented there. There were significantly fewer of them, but still of excellent quality and, of course, discussion was engaging.

I invite you to sit back, read and enjoy the content of this edition of *JES*. If a particular article intrigues you, please follow it up with the author – it is likely that further research has been published in the last few months.

Coral Campbell

Dr. Coral Campbell is an Associate Professor in science education at Deakin University in Victoria, Australia. Her research interests include early childhood and primary science/STEM education.

Systemising and empathising in early years science – a video-based study with pre-school children

● Nina Skorsetz ● Manuela Welzel-Breuer

This paper has also appeared in: Finlayson, O., McLoughlin, E., Erduran, S. & Childs, P. (Eds.) (2018) Electronic Proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education. Dublin, Ireland: Dublin City University.

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Abstract

Children are very different in their motivation to do science. An approach used to explain these differences in the motivation for science could be through the Empathizing-Systemizing (E-S)-Theory (Baron-Cohen, 2009). This theory states that every person's brain has two dimensions: the systemising and the empathising. Both dimensions can be measured with a questionnaire and represented in an EQ- and a SQ-value.

People with a high SQ-value are called 'systemisers' and tend to search for systems behind things; 'empathisers' orientate themselves to other people's feelings. Systemisers are generally more engaged in science and more motivated to do science than people with a high EQ-value, who are stronger in empathising (Zeyer et al, 2013).

The main goal of this study is to find out if pre-school children with various EQ- and SQ-values act differently in different scientific learning environments. Children were observed during two pedagogically differently arranged learning environments, to investigate potential different behaviour. In this study, the brain types with respect to the EQ- and SQ-values of 4 to 6 year-old pre-school children were determined with a 55-item EQ-SQ questionnaire (Auyeung et al, 2009), which was translated into German. In terms of a design-based research approach (Collective, 2003), the tested children were video-observed while participating in the two different scientific learning environments, in spring 2015 and 2016.

Results seem to show that children with a high SQ-value, as reported in literature, tend to be more motivated to do science than children with a high EQ-value. Children with a high SQ-value were motivated in both learning environments, which could lead to the interpretation that these children are motivated to do science independent from the pedagogical arrangement of the learning environment. For children with a high EQ-value, no such correlations for their motivation to do science were found. They seem to be less motivated in both learning environments than children with high SQ-value. More research is needed.

Keywords: Early years science, video-based research, design-based research

Introduction

Starting point: Diversity

Children in kindergarten are often very motivated to do science, but this motivation varies from child to child and fades away with age (Patrick & Mantzicopoulos, 2015). One usual explanation for the different motivation to do science is the gender difference between boys and girls. A slightly different approach for explaining differences in the motivation for science is the *Empathizing-Systemizing (E-S)-Theory* by Baron-Cohen (2002). The basis of his theory is that every human brain has two dimensions. On the one hand, there is the 'empathising' dimension, which is defined by the drive to *'identify another's mental states and to respond to these with an appropriate emotion, in order to predict and to respond to the behaviour of another person'* (Baron-Cohen *et al*, 2005). On the other hand, there is the 'systemising' dimension, which is defined as *'the drive to analyze or construct systems'* (Baron-Cohen, 2009, p.71). With questionnaires, the measure of the peculiarity of both dimensions – called EQ and SQ – can be determined (Billington *et al*, 2007).

People with a high SQ-value, called 'systemisers', are generally more engaged in science than people who are stronger in empathising (Zeyer *et al*, 2013, p.1047). In Baron-Cohen's studies, it seems that the two dimensions are independent from each other. Baron-Cohen and his colleagues calculated the difference between the EQ- and SQ-value and statistically identified five so-called brain types: *Extreme Empathisers; Empathisers; Balanced; Systemisers;* and *Extreme Systemisers.* Further studies showed that the two dimensions do not depend on each other and the concept of brain types was sometimes misleading, because a person can have a balanced brain type, with either two similarly high EQ- and SQ-values or two similar minor values (Svedholm-Häkkinen & Lindeman, 2015, p.366).

Zeyer *et al* (2013) showed that only the SQ-value has an impact on the motivation to do science. So far, the relation between the SQ-value and motivation for science has not been tested with young children, only with high school students. However, the EQ- and SQ-values can be measured for 4-11 year-old children using a combined 55-item EQ-SQ Child Questionnaire, which was validated in a large study with over 1500 participants (Auyeung *et al*, 2009). In this case, the parents filled out the questionnaire for their children.

In this current study, the goal is to find out whether there are differences in motivation between systemisers and empathisers when attending scientific learning environments at kindergarten (Skorsetz & Welzel, 2015). Maybe children with different brain types need different forms of access to science (Zeyer *et al*, 2013, p.1047)?

What is motivation?

Before we can find out how motivated pre-school children are when participating in scientific learning environments, we have to first define the term 'motivation'. A useful definition is: *'Motivation is an internal condition that elicits, leads and maintains the children's behaviour'* (Glynn & Koballa, 2006). 'Motivation' is here being considered to be motivation to learn something, or the desire to gather knowledge (Artelt, 2005). Motivation can be seen as 'time on task' (Artelt, 2005, p.233) spent focusing on the subject. If somebody is motivated to learn something, s/he will probably spend more time on it.

There are several constructs concerning motivation. Following Glynn & Koballa (2006), these are, for instance, intrinsic/extrinsic motivation, goal orientation, self-confidence, self-determination and anxiety (Glynn & Koballa, 2006). Thus, the challenge is to observe different aspects of motivation, knowing that *'motivation cannot be observed directly'* (Barth, 2010). Different types of instruments measure the amount of motivation, such as the Leuven's scale of involvement/engagement (Laevers, 2007). Within this measure, Laevers specified different signs of motivation: bodily posture, attentiveness, endurance, accuracy, responsiveness and contentment. If we assume that someone is motivated when s/he follows attentively in a situation, we can observe the different focus of attention that the children choose in the scientific learning situations, and their duration.

Early years science in German kindergartens

In German kindergartens it is common practice to use two different approaches to do science. The main difference between these two approaches is in the degree of structuring of the didactical and methodic arrangements used. An aspect that both ways have in common is that the learning environment often starts with the exploration of a natural phenomenon.

The first applied approach is 'rather structured', because the idea is that the child co-constructs new knowledge with others: for example, in a structured experiment an instruction is followed by an interpretation and guided by questions and interventions of the teacher (Lück, 2009). In this way, the learning environment is led and structured by the pre-school teacher. The pre-school teacher and the children are often sitting around a table. The materials to be used are displayed by the teacher on a dark pad and labelled by both teacher and children. A manual is used, which is followed using a step-by-step procedure.

The experimentation phase is followed by an interpretation phase, where the children try to find an explanation for the phenomenon.

For the other approach, the idea is that the child makes holistic (nature) experiences together with others, in a playful way and in a communicative setting. Hence, s/he has the possibility to identify him/herself with somebody else, or with a situation in a social setting, for example through a fictional framing story (Schäfer, 2008, 2015). The children and the teacher are often sitting on the floor in a circle and the materials are displayed. A framing story is 'told' by a puppet, for example, and the story ends with a problem encountered by the puppet, which has to be solved by the children. After the story, the children have time to explore the materials or the phenomenon and solve the problem in their own way, in order to 'help' the puppet.

Research questions

The main goal of this study is to find out how pre-school children with different EQ-/SQ-values act and react in different didactical and methodical learning environments, on the same scientific topic. In other words, we are observing children in the two different learning environments in order to investigate potential different behaviour.

Our hypotheses in this context are:

- H1: Systemisers could be more motivated to do science in more structured learning environments because of their higher SQ-value, which leads them to search for systems.
- H2: According to Zeyer *et al* (2013), we assume that fictional stories and the possible identification with protagonists should especially motivate empathisers to do science. An additional idea is that learning environments that include time to explore the materials could be motivating for empathisers.

Based on these hypotheses, we developed the following research questions in order to find differences between the children in two contrasting learning environments. First, we have to find out whether different EQ- and SQ-values can be found among pre-school children:

- RQ1: *To what extent do pre-school children show empathising or systemising characteristics?*

At first, all tested children in the first year of the project and of both brain types participated in a more structured setting. In the following year, other tested children (the 'next generation'), again of both brain types, participated in the more exploratory learning environment. So, our research question is specified for the two settings:

- RQ2: *To what extent is the influence of brain type or of the EQ- and SQ-value reflected in differences in children's actions in a 'rather structured' (RQ 2.1), or a 'rather open' (RQ 2.2), learning environment based on the behaviour chosen for measurement and its duration?*

Method

In order to answer the research questions, our study was organised in three steps:

- (1): implementation of the EQ-SQ Child Questionnaire (developed by Auyeung *et al*, 2009);
- (2): implementation of the more structured learning setting, and of the rather exploratory type of learning environment; and
- (3): analysis of correlations between the brain type of the children and their actions in the different learning settings.

(1): At first we had to translate and validate the EQ-SQ Child Questionnaire (Auyeung *et al*, 2009) in order to determine the EQ- and SQ-values of every child in a communicative validation process (Lamnek *et al*, 2010). The questionnaire was given to the children's parents because of the young age of the children participating in the study. The tested children were 5-6 years old and were in the last year of kindergarten before entering primary school.

(2): In order to measure different actions concerning the children's motivation and to investigate if these were independent of the didactical and methodological arrangement of the learning environment, a two-step procedure was followed, where children participated in one of the two contrasting scientific learning environments. Both learning environments were based on the same scientific phenomenon: 'absorbency properties of different materials' (Krahn, 2005). The learning environments were theory-based and evaluated using the Design Based Research approach (DBR Collective, 2007).

One of the mixed groups of tested children participated in the 'rather structured' approach; the other group participated in the 'rather open' approach. The children's behaviour (n=50) was observed (video-recorded) carefully. The same procedure was performed with the 'rather open' approach in the following year. The videotapes formed the basis for the empirical analysis, using inductively developed observational categories focusing on what the children were looking at (Mayring, 2008).

(3): The third and last step was to calculate statistically the correlation between the compiled EQ- response and SQ-values with the data from the video analysis, in order to find the expected significant differences between the two groups of children (Bortz & Döring, 2006).

Results

The EQ-SQ Questionnaire

The analysis of the questionnaire was carried out with the participation of different researchers from different faculties in order to achieve communicative validation (Lamnek *et al*, 2010). About 17 scientists, who usually meet regularly during a seminar, participated in this two-step procedure. For the pre-test, the first version of the questionnaire in German was trialled with a mother and her child in that age group. From this, we obtained answers to the questions, as well as comments about the clarity of the questions. After another communicative validation process with the above research group, based on the mother's comments, the second and improved version of the questionnaire was finalised. The pilot study followed, with the questionnaire administered to 25 parents of pre-school children. The internal consistency of the results was tested statistically. Cronbach's alpha coefficients were calculated and showed acceptable coefficients for empathy items (α=0.81), as well as for systemising items (α=0.61). This result is in accordance with the literature (Auyeung *et al*, 2009). Thus, we can conclude that the translated questionnaire was valid and reliable. Overall, 112 children were tested by the questionnaire during data collection in the spring of 2015 and spring 2016.

Development, implementation and analysis of the learning environment

Both learning environments were based on the scientific phenomenon of absorbency. We expected the children to recognise this phenomenon from situations experienced at home and in kindergarten and involving the spilling of fluids.

For the study, children with brain type/EQ- and SQ-value participated in the learning environment in groups of four. All activities were video-recorded using two video cameras filming the sequences from different angles. During the summers of 2015 and 2016, 99 pre-school children, aged 5-6, from seven different kindergartens in the area of Heidelberg, Germany, were filmed.

The data collection of the 'rather structured' learning environment took place in spring/summer 2015 in 15 settings with 52 children. The data collection of the 'rather exploratory' learning environment comprised of 14 settings with 47 children, which was implemented in spring/summer 2016. Hence, the total number of video material added up to about 10 hours.

The two videotapes of each setting were inputted in the evaluation software programme *Videograph* (Rimmele, 2012) and synchronised. Inductively, we developed eight observation categories with the focus on the children's viewing directions. These included children looking:

- Towards the pre-school teacher
- Towards other children
- At the experimentation material
- Towards the observer/into the camera
- Around
- At material not relevant to the immediate situation
- Indistinguishable
- At anything else

Variable	2	3	4	5	6	7	8	9	10
1 Difference	–.69**	–.38**	–.03	–.16	.16	–.01	–.10	–.18	–.14
2 EQ		–.32**	.12	–.22	–.11	–.09	–.06	–.09	–.08
3 SQ			–.21	.04	.00	–.07	–.02	–.31*	–.28*

Notes: Difference = Difference EQ/SQ = Brain Type, EQ = relative EQ-value (2); SQ = relative SQ-value (3), Teacher = View towards Preschool Teacher (4), Children = View towards other Children (5), Exp.mat. = View towards the Experimentation Material (6), Cam. = View toward the Observer/into the Camera (7), Around = View around (8), Mat. n. r. = View t. Material that is not relevant right now (9), Distraction (10)
* $p < .05$, ** $p < .01$. (one-tailed)

Table 1: Correlations ('rather structured' learning environment).

Next, we converged categories 4, 5 and 6 into a new category, 'Distraction/ Attentiveness'. The 6th category involved material that the children stored in their pockets, or experimentation material that had been used before but was no longer relevant. The 8th category was not used. A manual was produced.

The videotapes of both learning environments were then analysed in detail according to the manual. All videos were analysed by two coders. In the 'rather structured' learning environment, the children's viewing directions were gathered for the whole setting. With the software programme *Videograph*, the duration was measured as a percentage independent from the duration of the setting. Different codes were identified and discussed in the communicative validation process (Lamnek *et al*, 2010). The same procedure was followed with the 'rather exploratory' learning environment. In contrast to the first setting, the coding of the viewing directions of the children started just after the end of the presentation of the framing story.

Correlations

In order to answer the second research question, the EQ- and SQ-values of each child were correlated using the video-analysed data. Table 1 shows the results of the correlations of the data from the 'rather structured' learning environment and the children's EQ- and SQ-value. Two significant values were identified in this one-tailed Spearman correlation: r=–.31* (negative correlation between SQ and 'View to material that is not relevant right now', row 3, column 9) and r=–.28* (negative correlation between SQ and

Variable	2	3	4	5	6	7	8	9	10	11
1 Difference	–.68**	.56**	–.02	.04	.02	–.03	.01	**.34****	–.14	–.02
2 EQ		.20	–.05	.17	.11	–.02	–.14	**.28***	–.08	–.14
3 SQ			.04	.20	.11	–.01	–.12	–.23	.13	–.16

Notes: Difference = Difference EQ/SQ = Brain Type, EQ = relative EQ-value (2); SQ = relative SQ-value (3), Teacher = View towards Preschool Teacher (4), Children = View towards other Children (5), Exp.mat. = View towards the Experimentation Material (6), Cam. = View toward the Observer/into the Camera (7), Around = View around (8), Mat. n. r. = View t. Material that is not relevant right now (9), Puppet = View towards Hand-puppet (10), Distraction (11)

Table 2: Correlations ('rather open' learning environment).

'Distraction', row 3, column 10). This means that children with a higher SQ-value tend to be more focused on the scientific related aspects.

In Table 2, the results of the correlation in the 'rather exploratory' learning environment with the children's EQ- and SQ-values are displayed. Our study has relevant correlation with a significant value (r=.28*, row 2, column 9) between the EQ-value and the 'view towards material that is not relevant right now'.

This means that children with a higher EQ-value tend to focus on non-relevant aspects, so they seem to be more distracted than children with a higher SQ-value. Another significant value is r=–.34** (variable difference, row 1, column 9) between the children's brain type and the 'view towards material that is not relevant right now'. This result could be interpreted as children with a higher SQ-value (in the difference accumulated) focusing less on distracting material. This could also be interpreted as meaning that, again, children with a high SQ-value are more motivated to do science.

Limitations

Looking critically at the data, we have to take into account specific limitations. Firstly, the parents filled in the EQ/SQ Child Questionnaire and evaluated their own children. Some of their answers could be socially desirable.

Secondly, characteristics (perhaps relevant) other than the EQ- and SQ-values were not collected through the questionnaire (e.g. socio-economical background, intelligence, previous knowledge), and no longitudinal data of the children were available. Thirdly, the influence of the use of small groups when the children participated in the learning environments could not be investigated.

Additionally, only some selected aspects, such as the focus of the children's views, which were considered as measures for motivation based on their duration, were observed in this study.

Finally, the comparability of the groups in the sample of 2015 and 2016 might not be entirely accurate given the random composition of pre-school children.

Discussion and conclusions

The first conclusion that we drew from the results was that children with a high SQ-value seem to be motivated in both learning environments.
So, children with a high SQ-value seem to be motivated to do science independent of the learning environment and the pedagogical approach used. This result matches our first hypothesis with respect to children with a high SQ-value being motivated to do science in structured learning environments. The results go beyond this hypothesis, because the children always seem to be motivated to do science whatever the learning environment.
However, the second hypothesis can neither be confirmed nor refuted, because we found no hint that children with a high EQ-value seem to be motivated to do science in the different learning environments. Maybe these children prefer to focus on the non-relevant material to contribute to the learning environment.

Therefore, the significant correlations lead to the following hypotheses, which need to be investigated further:

- Children with high SQ-values tend to be motivated to do science independent from the learning environment; and
- The 'rather open' learning environment motivates children with high EQ-values due to the possibility of choosing additional material for their activities.

Further analyses of the quantity and choice of objects touched and labelled could be an interesting additional focus.

Acknowledgement

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Pre-school children's collaborative science learning scaffolded by tablets – A teacher's view

● Marie Fridberg ● Susanne Thulin ● Andreas Redfors

This paper has also appeared in: Finlayson, O., McLoughlin, E., Erduran, S. & Childs, P. (Eds.) (2018) Electronic Proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education. Dublin, Ireland: Dublin City University.

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Abstract

The potential of tablets to support communication during collaborative inquiry-based science learning in pre-school has previously been reported (Fridberg, Thulin & Redfors, 2017). Children communicate in a more advanced manner about the phenomenon and they focus more readily on problem-solving when active in experimentation or Slowmation production. Here, we shift focus to the pre-school teacher's perspective on science and the work model with timelapse and Slowmation. The pre-school teacher's talk about the teaching was analysed from three perspectives: the relationships between teacher-science, teacher-children, and children-science. Possibilities and challenges expressed by the pre-school teacher in relation to the three perspectives were identified and, interestingly, the analysis shows most possibilities in the children-science relationship. In contrast, most challenges are found for the teacher-science relationship, in terms of lack of knowledge. We argue for the need to further discuss pre- and in-service pre-school teachers' experiences of science and science education.

Keywords: Pre-school, science, tablets

Introduction

One identified important factor for children's learning, whether in pre-school or in the education system as a whole, is teachers' content knowledge (Nihlfors, 2008; Gitomer & Zisk, 2015). Research also points to some key factors where teachers' knowledge of science is one central issue for the learning (Siraj-Blatchford *et al*, 2002; Yoshikawa, 2013). Furthermore, Fleer (2009) expresses the link between early childhood teachers' limited science knowledge and teachers' confidence and competence to teach science. However she, together with other researchers, also point to pre-school teachers' pedagogical content knowledge (PCK) and attitude towards science as having an impact on children's learning (Fleer, 2009; Thulin, 2011; Spector-Levy *et al*, 2013).

In this study, we make use of timelapse photography and *Slowmations.* Timelapse photography is a technique that shows a slowly changing event in accelerated speed, which is accomplished by photographing the event at certain intervals and, when played at normal speed, the event seems much faster. A *Slowmation* on the other hand is a stop-motion animation played in slow motion to explain a science concept (Hoban, 2007). The work model implemented with children aged 3 to 6 (Fridberg, Thulin & Redfors, 2017) constitutes four different learning contexts: i.e. hands-on experiments, timelapse photography, stimulated recall, followed by *Slowmation* creation, where the children represent explanatory models in different materials, and which is versatile and opens up possibilities for the children to generate, represent and discuss explanatory models.

From a theoretical framework primarily based on phenomenography and variation theory (Marton & Booth, 1997), focusing on developmental pedagogy (Pramling Samuelsson & Asplund Carlsson, 2008), this work aims to analyse variations of, in retrospect, expressed experiences by the teacher, for the four different contexts of science learning during a semi-structured interview.

The research question guiding the study is:

- What differences in referential meaning can be ascribed to the teacher's statements about the science teaching work model, especially concerning possibilities and challenges?

Method

A semi-structured interview with open-ended questions was performed with the teacher one year after the finalisation of the project. The teacher answered spontaneously, with follow-up questions from the researcher. In addition, we used stimulated recall where the teacher watched selected parts of the video-recorded activities with the children, and was asked to reflect on his role. The activities were chosen to represent four enacted learning contexts analysed previously (Fridberg *et al*, 2017). The teacher's statements were analysed and categorised with specific focuses, depicted in Figure 1.

Through a phenomenographic analysis, we could identify variations of experienced possibilities and challenges with parts of the science teaching work model, as described by the teacher.

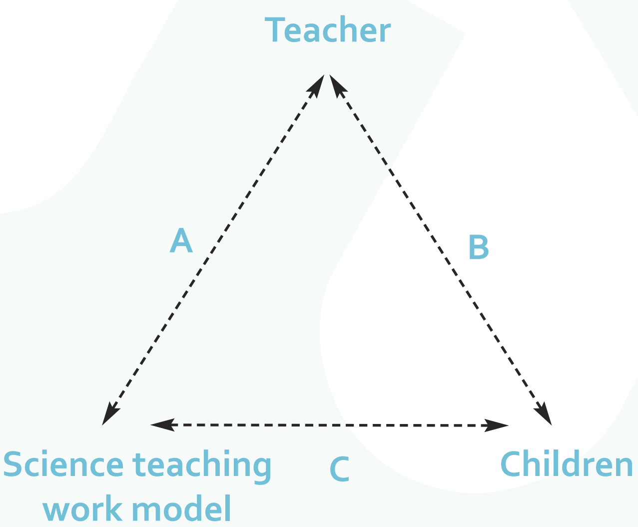

Figure 1: The triangle of analysis depicts the three relations A, B, C focused in the analysis of the teacher's statements, related to A) the object of learning in terms of the science teaching work model, B) the children, and C) the children's relation to science or the work model.

Results

The challenges and possibilities identified in the analysis of the teacher's statements involving science and the work model will below be summarised as belonging to the themes: *knowledge*, *number of children*, *children's previous experiences*, *time constraints*, and *interactions*.

Challenges described by the teacher include his experienced lack of knowledge in science, even though he also stated that the project increased his knowledge. Another challenge expressed is connected to numbers, when too many children take part in the activities. This was manifested in the teacher expressing the need to take a more controlling role in the situation, compared to when there are fewer children involved. Fewer children allow for him to stand back and the discussions among the children were more fruitful and less stressful. However, in addition, the teacher stressed that the number of children is only one factor influencing the outcome. The results achieved during the production of *Slowmations*, etc. also depend on the individual children involved and their previous experiences and ability to co-operate. Yet another experienced limiting factor is time and the pressure the teacher felt to reach conclusions and 'get somewhere' during the timeframe of the activity. This resulted in the teacher sometimes seeing himself as someone who provided the answers too quickly, or feeling that he did not give the children space to think through the activity. He described how the lived/felt time pressure sometimes negatively influenced the discussions between him and the children.
The teacher reported that, during the project, he came to expand his view of natural science from one restricted to biology to then include also chemistry and physics, something that can be thought of as opening up opportunities. This result also concurs with the results of Thulin and Redfors (2017), who found a large portion of students having changed their views accordingly from pre- to post-test related to a science course in pre-school teacher education.

The possibilities described lie in the work model itself. It takes into consideration the children's interest in tablets and captures many of the areas in the pre-school curriculum, such as natural science, mathematics and language, but also values and interaction. The work model, with discussions, hands-on experiments and timelapse/*Slowmation* production, where the children represent the phenomenon in different materials, is versatile and opens up the learning of the science phenomenon from several perspectives. This, according to the teacher, is consistent with the pre-school teacher's mission to include all children based on their individual needs and pre-conditions.

Most possibilities described by the teacher are found in the relationship between the children and the object of learning (side C in the triangle, Figure 1). He stated that the teachers and their attitudes to the work model or science are the limiting factor, not the children. These results can be compared to Thulin (2011), who stated that the children were interested in the content and asked content-related questions. The children have no difficulties working with experiments, movie production, etc. The results depend on the attitude of the teacher, who needs to be positive in order to have a fruitful outcome. Interestingly, and to the contrary, most challenges are described in the relationship between the teacher himself and the object of learning (side A in Figure 1), in terms of experienced lack of knowledge.

Discussion

An increasing number of studies (Ainsworth, 1999; Prain & Waldrip, 2006) suggest that students' learning is enhanced when they create digital artefacts, such as representations of science concepts. Through this creation of an explanatory model, skills such as creativity, problem-solving, communication and collaboration can be developed (Nielsen & Hoban, 2015). We have previously studied and proposed a work model for children's collaborative science learning through the use of computer tablets. This teaching model includes discussions, experiments documented by timelapse photography, stimulated recall for the teacher and children through watching timelapse movies, and a subsequent production of a *Slowmation* movie, where the children represented their explanatory model in, for instance, playdough or LEGO® (Fridberg *et al*, 2017). Prain and Tytler (2013) argue that there are particular learning gains for students when they construct their own representations of scientific processes and concepts. These gains include the development of students' cognitive and reasoning strategies, the promotion of contexts that engender meaningful communication of science understandings, and of activities that are highly engaging for students. Our results were in agreement and revealed the timelapse movies as beneficial for the children's model-based reasoning about the science content (evaporation), and the *Slowmation* movie production helped the children to think about explanations for, and representations of, the science content. Another interesting aspect of young children and their interaction with digital technology is described by Kjällander and Moinian (2014). They studied pre-school children's playful use of applications on tablets and described how their interactions resisted the pre-existing didactic design of the application. Instead, the children in their study transformed the application setting and objects into something that made sense and had meaning for them. The children designed their own process by making sense of affordances provided by the digital resource in relation to their own interest and previous experience. This finding reflects children's agency and opens up the way for thoughts on consumer and production processes in the digital arena (Kjällander & Moinian, 2014). We consider our proposed work model with timelapse and *Slowmation* production to fit well into an agentic view of childhood (Fridberg *et al*, 2017). In the present study, we expand our previous work, which focused on the children, to include the teacher's views and experience of science and the jointly developed work model.

In order to help children to learn about something, it is important that the teacher considers children's previous experiences, as well as the object of learning (Pramling Samuelsson & Asplund Carlsson, 2008; Thulin, 2011; Gustavsson, Jonsson, Ljung Djärf & Thulin, 2016). During the interview, the teacher highlighted the importance of the children's prior experiences when he stated that *'It's about what they have in their luggage too'* as he described the lived curriculum. It is not the age of the children, but their prior experiences, which set the limits according to the teacher and this concurs with the variation theory as described by Marton (2015). Important for a teacher to consider is what the learners have not yet learned to discern about a certain object of learning, since these 'lacking pieces' are critical aspects for further learning.

In a recent national report, Skolinspektionen (2016) describes how the science subject in Swedish pre-schools often is acted out in somewhat random experiment activities, without guidance towards a specific object of learning. The teacher in the present study pointed out the benefits of the work model, including several subjects and aspects of science such as, for instance, language, technology and mathematics.

During the work process, the teacher also saw other important parts of the curriculum being expressed, such as value systems and the children's ability to interact with each other. He suggested the work model to be used prior to a parent-teacher conference, since it would enable him as a teacher to learn things about the children and their capabilities that he didn't know about. The teacher talked about children whom he knew to be a bit shy and withdrawn surprising him by being active and expressing their thoughts during the timelapse and *Slowmation* production. He connected this to the pre-conceptions and taken-for-granted assumptions that adults and teachers often have about children's capabilities.

Structural factors challenging the work with the model and science included the number of children participating in the activity: the more children, the more stressful a situation for the teacher to handle. However, he also pointed to the influence of *which* children one, as a teacher, groups together in the activities, something that may be viewed as a relational factor that either limits or enables the learning. If the children co-operate easily with each other, the group can be larger. Another structural factor challenging his work included an experienced lack of time during the activities. This, according to the teacher, influenced his discussions with the children in a negative way, and prompted him to provide them with the correct answer to his questions, or to move on too fast without giving the children time to think as much as he would have liked them to. However, the main structural factor expressed by the teacher as limiting for his work is his experienced lack of knowledge in science.

Interestingly, and striking from the analysis, most challenges are expressed in the teacher-learning object relationship (A) and in terms of the experienced lack of knowledge, while most possibilities are described in the children-learning object relationship (C). Different children show interest in different parts of the versatile work model, and the teacher viewed them as capable. Instead, he pointed out that it is the knowledge and attitude of the pre-school teacher towards science and the work model that will determine possible opportunities and challenges. In this case study, the teacher was stimulated by the work model, but was less well prepared for the science content. Research on primary science teachers of young children shows that teachers have insufficient knowledge of the subject and pedagogical content knowledge (Appleton, 2008; Fleer, 2009; Thulin, 2011; Spector-Levy *et al*, 2013). Other studies also point to early childhood teachers' lack of science subject matter knowledge (Kallery & Psillos, 2001; Garbett, 2003) but, to date, only a few studies have focused on practising in-service pre-school teachers (Andersson & Gullberg, 2014). This relates to justification for science in pre-school and the 'being' and 'becoming' perspectives, where 'being' refers to viewing children as actors in their own lives and letting them meet the science primarily for their own sake, while the 'becoming' refers to future uses of an early grounded knowledge. Thulin & Redfors (2017) do not polarise the two perspectives, but show that student pre-school teachers revealed a slight pre-dominance for the society – 'becoming' – perspective. However, from the results presented here, we can say that both teacher and children benefited from and experienced a 'being' perspective concerning their model-based reasoning.

In this study, different dilemmas that the teacher encountered when working with science and the work model could be identified. In the teacher's own words, *'It's a balancing act all the time, it's really tricky'.* The teacher has to consider and handle several factors at the same time, such as time management and children's interactions, when teaching a subject manifested in the curriculum about which he is not really comfortable with his knowledge. He talked about the need for support, from both the children's and the teacher's perspective. The children are dependent on him and his attitude towards the subject, and he in turn needs support in the form of someone with whom to discuss ideas, thoughts and questions. Or, in other words, the need for someone who supports his work through discussions about the intended and enacted object of learning. In Thulin & Redfors (2017), the majority of student pre-school teachers were positive about science and this result is contrary to the general impression in western countries that young people share negative views of science. Like the student pre-school teachers in the Thulin & Redfors survey, the pre-school teacher in the present study expressed a positive attitude to science. Instead, it was a feeling of not knowing enough about different science matters that the teacher in this study saw as the challenge in his work. This is further reflected in what we, as teachers in the pre-school teacher programme, encounter in our work with students and the science subjects. Our experience is that the students struggle with model-based reasoning, while the attitude towards the subject is one of positivity and curiosity among most students.

This raises an important question. When different content in the Swedish pre-school curriculum is discussed, it is often from the children's perspectives, and about how the content can be presented to fit the children's interests and previous experiences. Eshach (2006) reasons that the teacher perspective is equally important to consider when working with science in early years:

'I thus argue that educators should seek after such science activities that not only fit the children's needs but also the teachers' abilities, motivations and needs. (...) But to succeed in using such an approach, a kindergarten teacher must receive sufficient scientific support. (...) Thus, I argue that K-2 science education should be teacher-centered as well as student-centered, as opposed to the traditional student-centered approach' (Eshach, 2006).

Here, and in earlier work, we have seen the importance and benefits of intertwining science content and science education research results in working with in-service pre-school teachers – a view supported by Andersson and Gullberg (2014), who suggest four skills of which pre-school teachers can make use when teaching science: children's previous experiences; capturing unexpected things that happen in the moment; asking challenging questions to further investigations; and 'situated presence', that is, remaining in the situation and listening to the children. By making use of these skills, pre-school teachers may shift focus from their experienced insufficient subject matter knowledge to instead reinforce their pedagogical content knowledge (Andersson & Gullberg, 2014).

At the same time, we argue that a polarisation between science and science education is not beneficial. In intertwining support of science content with implementation of work models such as the one presented here, both knowledge of explanatory models in science and competence in handling activities with children can be seen to improve.

Conclusion and implications

The timelapse/*Slowmation* work model shows promise for future developmental work concerning both children and teachers. We agree with Eshach (2006) that support for teachers' work with science content in pre-school is needed, and the work model described by us could be viewed as one such support structure, through its framing and meaning-making of the science content. The work model with timelapse and *Slowmation* production concurs with teaching from a child perspective and an agentic role of active children in collaboration (Fridberg *et al*, 2017). In the present study, where previous work has been expanded to include the teacher's views and experience, we have found several distinct and important implications for pre- and in-service pre-school teacher education.

Results from this research on uses of our work model for science teaching have given a list of implications – four 'points-to-make' for teacher education and pre-school practice.
Firstly, teaching with and about the work model entails and highlights the importance and fruitfulness of having planned teaching activities with formulated intended objects of learning, which open up several overarching learning goals in the curriculum, such as communication, co-operation and world views, and bring in aspects of other subjects, including language, technology and mathematics. Secondly, it combines digital technology and science learning objects. Thirdly,

the work model facilitates active scaffolding by a teacher, but also brings into light the importance of

- support for pre- and in-service teachers on science content and science education principles;
- focusing on both 'being' and 'becoming' perspectives on teaching and children's learning;
- holding back and giving children time and opportunity to work things out; and
- managing the balancing act of holding back, giving answers, keeping order and letting children explore.

Fourthly, it highlights the children's capacity for problem-based collaborative inquiry to solve formulated questions, thus helping the teacher to keep focus on the learning object, to structure collaborative group work and plan group sizes based on communication skills and allotted time – all important aspects of collaborative inquiry in early years.

Using the work model helps the teacher to keep focus on the science learning objects through the activities, especially the *Slowmation* production. The process of planning and evaluation of intended – enacted – lived learning objects is an interesting and, in many countries, novel challenge for pre-school teachers. Project-based education for pre- and in-service pre-school teachers focusing on teaching with the work model will most likely bring all the points above into fruitful and generative discussions, especially because an interesting support structure for single teachers would be teams of teachers starting science projects together by formulating the intended and the enacted object of learning. In future studies, possibilities and challenges for these team-based formulations, during work with the work model, will be further investigated.

To conclude, our study points to great potential in the versatile science teaching work model as a teacher's tool for scientific explorations and discussions in pre-school. Furthermore, it casts a light over the pre-school teacher role in science teaching and contributes to important discussions about that role.

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Potential for multi-dimensional teaching for 'emergent scientific literacy' in pre-school practice

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Abstract

How can pre-school teachers form science teaching in a landscape of increasing focus on academically oriented learning outcomes, without losing the unique character of pre-school pedagogies? Seeking to contribute to the discussion of what pre-school science can be, we have analysed data from activities in fourteen Swedish pre-schools (for children aged 1-5 years), to examine if and how multi-dimensional teaching may be combined with teaching for scientific literacy. The overall picture is that elements of 'emergent scientific literacy' can be combined with a wide range of teaching dimensions, such as empathy, fantasy and storytelling. These results contribute important perspectives to what pre-school science can be and how it can be researched in a way that is suitable for the pre-school's conditions. We suggest our analytical questions, and the dimensions displayed in our results, as a tool for teachers who plan or evaluate science teaching in the early years.

Keywords: Early childhood education, science education, schoolification, aesthetics, emergent scientific literacy.

Introduction

- A group of children and a teacher gather around a drain on the side of the street, listening to the echoing sound of drops hitting the water surface deep down.
- Teachers encourage children to touch and taste snow and to listen to the creaking sound of their peers treading on snow-covered ground.
- A teacher helps children to build a nest for a plastic magpie, asking them to think of what the magpie might need to feel comfortable in its nest.

These three snapshots, from a pre-school for children aged 1-2 years, include several dimensions: children's sensory experiences (of water and snow), making (a bird's nest), and caring (for a fictive organism). They also include teacher-child interactions that relate to science content, such as sound, properties of snow and birds' living conditions. Yet, are they examples of science education?

We, the authors, are trained scientists/science educators and have been schooled in the science teaching traditions of compulsory school and higher education. However, in 2012 we began researching how science activities are shaped in Swedish pre-schools. Since then, we have been occupied with questions about what early years science education can be, because we soon realised that our school-oriented science standards were not adequate to describe the activities that we encountered in pre-schools, such as the snapshots above. Our questions adhere to a general 'schoolification' debate, dealing with the increasing focus on academically oriented learning outcomes in prior-to-school institutions and the tendency of compulsory school standards to put a downward pressure on prior-to-school education (Moss, 2008). Researchers have raised concerns that schoolification threatens the characteristics of pre-school pedagogies: for example, the role of care (Gananathan, 2011) and play (Gunnarsdottir, 2014) in pedagogy. When it comes to science education, Klaar and Öhman (2014) recognise the risk that a growing focus on conceptual knowledge may lead to subject-specific teaching at the expense of the subject-integrated, multi-dimensional teaching that often characterises pre-school pedagogies.

How can teachers form science teaching in a landscape where the focus on academically oriented learning outcomes is increasing, without losing the unique character of pre-school pedagogies? Is there room for the type of multi-dimensional teaching displayed in the above snapshots when science education is implemented in pre-school? The answer could be yes, if we consult recent studies of how Swedish pre-school teachers talk about their science teaching. For example, the teachers in Westman & Bergmark's (2014) study indicate that *'a child's whole being, mind and body, are used in the learning process'* (p.78), considering emotion and embodied experiences as prominent parts of scientific exploration. Further, Areljung, Ottander and Due (2016) show that teachers include imagination, individual taste, dramatising, as well as experiments, in their talk of science activities. While these studies mainly build on teachers' talk about their practice, the current article attempts to display examples of multi-dimensional science teaching that are based on observations of practice. Here, we use the term 'multi-dimensional teaching' to refer to a type of teaching that intertwines science content learning with multiple dimensions of children's lives, such as emotions, play, physical experiences and aesthetic modes of expressions. Seeking to contribute to the discussion of what early years science education can be, our aim is to examine if and how elements of scientific literacy are combined with multi-dimensional teaching in pre-school activities.

Scientific literacy and emergent scientific literacy

'Emergent science' relates to a general idea of 'emergent learning': that is, the idea that children discern qualities that are essential to learning something in particular (Pramling & Pramling Samuelsson, 2008). One example is 'emergent literacy', which is about discerning qualities such as the fact that words consist of letters, or in what direction we read, which is essential to eventually learning to read (*ibid.*). When it comes to science, the emergent learning can be about discerning meaningful qualities of the science phenomena that are under investigation. For example, experiences that help children discern how different items sink or float are meaningful to eventually learning the abstract science concepts 'density' and 'buoyancy' (Larsson, 2016).

What we are proposing is an 'emergent scientific literacy' that builds on the ideas of emergent learning (Pramling & Pramling Samuelsson, 2008). Scientific literacy has been used broadly in the latest decades, by various stakeholders in education, to address what science education should consist of in order to foster citizens equipped for the contemporary society (Roberts, 2007). Roberts has proposed that the concept 'scientific literacy' could be understood somewhere on a continuum between two 'visions'. Vision I points at being literate in relation to specific content knowledge and processes *within* the science community, while Vision II addresses the ability to handle science-related situations in a larger, societal context. In this article, we focus on scientific literacy closer to Vision I: being literate in relation to how the natural world works and in relation to the scientific methods of gaining knowledge about how the world works.

Our reason for adding 'emergent' to 'scientific literacy' is that we need a concept suitable to the pre-school's conditions in order to meet our aim to examine if and how elements of scientific literacy are combined with multi-dimensional teaching in pre-school activities. We propose that the characteristics of pre-school science practice might go unnoticed if we employ a school-oriented framework for distinguishing scientific literacy. In 'emergent scientific literacy', we include the emergent qualities of natural, chemical and physical phenomena that children experience prior to grasping the scientific concepts. For example, we consider children's experiences of pushing and pulling as emergent qualities prior to learning the abstract concept 'force' (Sikder & Fleer, 2015). Further, we include emergent qualities of scientific methods, such as observing, posing hypotheses, making inference based on empirical studies, and making models and other representations. Since our research builds on data from Swedish pre-schools, the national context is outlined below.

The Swedish context

Swedish pre-school practice builds on the idea that learning, fostering and care are intertwined and equally important. As in many other countries, the pre-school's responsibility for learning has been strengthened in the last decade. When it comes to science, the curriculum states that pre-school should strive to ensure that each child develop their interest and understanding of the different cycles in nature, how people, nature and society influence each other, and science and relationships in nature, as well as a general knowledge of plants, animals, chemical processes and physical phenomena (National Agency for Education, 2011). Also, the children should be encouraged to develop an ability to distinguish, explore, document, pose questions and talk about science (*ibid.*).

In Sweden, 83% of all children aged between 1-5 years are enrolled in pre-school and the common case is that teams of 3-4 educators work with a group of 15-20 children (National Agency for Education, 2016). The staff typically consist of several professional categories, of whom an average of 40% are pre-school teachers (*ibid.*). Though the pre-school teachers have a special responsibility for education in Sweden, all staff are responsible for both education and care.

Noteworthy is that Swedish pre-school is an example of institutionalised science education for children from the age of 1 year. This is rare from an international perspective, where science education most often targets children from 3 years and older (Sikder & Fleer, 2015).

Methodology and methods

Our data were collected in fourteen different pre-school units in Sweden. We selected the pre-schools because they had reported that science was a significant part of their practice. Three pre-schools volunteered to join after a lecture held by one of the authors. The remaining eleven were picked based on their responses to a large-scale questionnaire. We visited the pre-schools on four to ten occasions (97 in total) in order to observe and document both planned and spontaneous science activities. We also conducted stimulated recall group discussions (12 in total) and individual interviews (20 in total) with the teachers in these pre-schools.

We have previously used Activity Theory (Engeström, 1987) as a theoretical framework to analyse how cultural factors interacted with the shaping of the science activities in these fourteen pre-schools. This meant that we studied the videotaped activities, as well as group discussions and interviews with teachers, to discern the following seven elements: *subject*, *object*, *tools*, *rules*, *community*, *division of labour* and *outcome* (Sundberg *et al*, 2016). Our analyses resulted in one 'activity system' for each pre-school, including descriptions of the seven elements and how they interacted in the teacher's shaping of science activities. In this article, we revisit the activity systems to respond to the following analytical questions:

1. Were elements of emergent scientific literacy visible in the activities?
   a) Emergent qualities of scientific methods
   b) Emergent qualities of physical, chemical, or natural phenomena
2. If so, what teaching dimensions were visible in these activities?

In order to respond to the questions, we conducted a thematic content analysis of the material and communicative *tools*, the *object* (the purpose), and *the outcome* of the observed activities. For example, we followed a pre-school whose science activities were framed within a 'rolling and spinning' theme.

The teachers' *object* was that the children learned 'as much as possible' and gained many personal experiences of rolling and spinning motions. In terms of *material tools*, they supplied children with a large variety of everyday objects that could spin and roll as well as ramps and other material whose incline and surface the children were able to change.

In terms of *communicative tools*, the teachers used gestures and verbal communication to draw attention to children's achievements and discoveries, and to encourage children's further explorations. The pre-school's activities included rolling marbles through paint on a tray, treasure hunting for examples of rolling and spinning in the surroundings, rolling car tyres up and down a hill, and rolling oneself down a hill. The overall *outcome* was that children were afforded many different experiences of rolling and spinning motions.

In terms of elements of emergent scientific literacy (analytical question 1), we discerned the following themes through our content analysis of this pre-school's activities:

a) *Emergent qualities of scientific methods*: Observing similarities and differences; comparing and contrasting how items roll, depending on the incline.
b) *Emergent qualities of physical phenomena*: Concepts enfolded in rolling and spinning motion, such as friction, and the relation between the incline and the shape and speed of the rolling item or child.

In terms of teaching dimensions visible in these activities (analytical question 2), we discerned the following themes:

- *Fantasy and play:* Treasure hunt for things that spin and roll.
- *Aesthetic modes of expression:* Marble painting.
- *Embodiment:* Experiencing what it feels like to roll oneself down a hill and to roll a tyre up a hill.
- *Systematic inquiry:* Rolling marbles down ramps with different inclines.

Findings

By analysing activities from all fourteen pre-schools in our data set, we have found examples of the following teaching dimensions in activities that include elements of emergent scientific literacy: *fantasy and play*, *empathy*, *aesthetic modes of expression*, *storytelling*, *embodiment/sensory experience*, and *systematic inquiry*. In Table 1 (overleaf), we present the results through examples of common combinations of teaching dimensions and elements of emergent scientific literacy.

The examples are selected from: the 'rolling and spinning theme' that we discuss above; the snapshots presented in this article's introduction; and three pre-schools that we will describe in more detail below. In the table, we exemplify 'emergent qualities of scientific methods' with 'making models' and 'observing differences and similarities'.

Other examples, not included in the table, which we have identified in the pre-school's activities are: repeated trials, changing one factor at a time, posing hypotheses, drawing conclusions based on evidence, and making visual representations.

Frottage art to learn about the different tree barks

In one pre-school, for children aged 4 to 5, the teachers brought crayons and sheets of paper to the forest. The children were encouraged to do 'frottage art', putting the paper on the trunk of a tree and drawing gently with the crayon so that the structure of the bark resulted in a pattern on the paper. The children were also encouraged to touch the surface with their own hands and to compare what the bark on different trees felt like.

In this activity, we identified the following elements of emergent scientific literacy:

a) *Emergent qualities of scientific methods:* to observe similarities and differences (between the bark of different trees).
b) *Emergent qualities of natural phenomena* (the composition of a tree): the structure of a tree's bark.

Further, we identified that the main teaching dimensions were aesthetic modes of expression and sensory experiences.

Storytelling and examining figures sticking to a woollen blanket

In another pre-school, for children aged 1 to 2 years, the teachers arranged for a storytelling moment during a visit to the forest. The story was about a child going on a sleigh on an icy lake and, while reading, the teacher placed different toy figures on a woollen blanket: for example, a small sleigh and a plastic snowman. Since there was some snow on the ground that day, the teacher made a real snowman too, adding it to the scenario on the blanket.

At the end of the story, the teacher noticed that the snowman that was made of snow stuck to the blanket. Realising that this was something special, the teacher demonstrated several times how the snow-snowman stuck while the plastic snowman did not. She asked the children for suggestions of other things that they wanted to test to see if they would stick to the blanket. One child pointed at moss on the ground and the teacher asked each child if they thought the moss would stick or not before she tested (it did not stick).

Table 1: In the table, examples of pre-school activities are inserted in cells that represent the elements of emergent scientific literacy and the teaching dimension discerned in the activity. The table builds on the empirical examples provided in this article, not a comprehensive picture of possible combinations of elements of emergent scientific literacy and teaching dimensions. Hence, the fact that some of the cells in the table are blank should not be read as this being an impossible combination in pre-school.

	1. Emergent scientific literacy (examples)				
	a. Emergent qualities of scientific methods		b. Emergent qualities of science phenomena		
2. Teaching dimension	**Making models**	**Observing differences and similarities**	**Physical phenomena**	**Chemical phenomena**	**Natural phenomena**
Fantasy and play	Playing inside a model of the inside of a tree	Letter correspondence with a tree fungus about its eating habits, compared to how the children eat	Treasure hunt: finding things that roll and spin		Fantasy and play connected to the relationship between fungus and tree; how the fungi 'eat'
Empathy	Creating a nest for a magpie				Rejecting the notion that a tree fungus be cut down from a tree
Aesthetic modes of expression	Creating models of organisms in clay or papier-mâché		Rolling marbles through paint		Frottage art: drawing on a paper put on a tree trunk
Storytelling		Storytelling using figures of different material, which stick/do not stick to a woollen blanket			Teacher telling stories about how mushrooms eat
Embodiment/ Sensory experiences		Comparing what the bark of different trees feel like	The feeling of rolling oneself down a hill or rolling a car tyre up a hill	Properties of snow; tasting, touching and listening to snow	Sensing the structure of the bark of a tree
Systematic inquiry		Rolling and spinning different objects, in different settings, through controlled trials	Concepts tied to rolling and spinning motion, such as, friction, surface, incline and shape	'Sticking ability' of plastic, snow, moss and wool	

In this activity, we identified the following elements of emergent scientific literacy:

- *Emergent qualities of scientific methods:* repeated trials, changing one factor at a time, observing differences, and posing hypotheses (regarding how different material stick to wool).
- *Emergent qualities of chemical phenomena* (properties of various materials): 'sticking ability' of plastic, moss, snow and wool.

We identified that the main teaching dimensions were storytelling and systematic inquiry.

Building a fantasy world around a tree fungus and exploring how fungi eat

In a third pre-school, for children aged 1-5, a group of children had noticed that fungi grew on some of the trees in the forest. They 'adopted' one of the fungi, named it 'Musli' and, over a long period of time, they and their teachers developed an imaginary world around the life of Musli and his relatives. The children showed empathy for the fungus, discussing whether Musli may be cold and bringing warm clothes to dress the fungus.

On one occasion, the teachers placed a letter 'from Musli' on the particular tree for the children to find, to introduce the question of what and how the fungus eats, in comparison to the children. In later activities, the teachers told the children about how the fungus injected thin threads into the trunk of the birch tree, and that nutrients were transported from the birch to the fungus through these threads.

Following up on the 'food question', the teachers helped children to roll a big piece of paper into a cylinder, making room for as much as three children on the inside. The children then drew directly on the cylinder-shaped paper what they thought the inside of the tree might look like, hence creating a model of a tree trunk. Since it was big enough for children to fit inside it, the tree model became a site for playing.

On one occasion, the teachers brought a fungus (not 'Musli'!) to the pre-school for the children to touch and observe. Afterwards, the children made their own papier-mâché models of the fungus. Previously, the children had demonstrated that it was unthinkable to cut Musli or some of his relatives down from their trees, because it would be too cruel.

In this activity, we identified the following elements of emergent scientific literacy:

- *Emergent qualities of scientific methods:* making models (of the inside of a tree) and observing differences (between how fungi and children 'eat').
- *Emergent qualities of natural phenomena* (the relation between fungi and trees): how fungi 'eat'.

We identified many dimensions of science teaching: fantasy and play, empathy, aesthetic modes of expression, storytelling and sensory experience.

Discussion

The results contribute important perspectives to the discussion of what pre-school science can be, showing that elements of emergent scientific literacy can be combined with a wide range of teaching dimensions, such as empathy, fantasy and storytelling. In the studied pre-schools, there are no obvious signs of 'schoolification' in terms of compulsory school standards imposing a 'downward pressure' on pre-school education (Moss, 2008). Rather, the teachers seem to have found ways of shaping science activities that are in line with the multi-dimensional pedagogies characteristic of pre-school practice (Klaar & Öhman, 2014).

We put forward our analytical questions, and the teaching dimensions displayed in Table 1, as a possible tool for teachers to plan or evaluate their science teaching; what emergent scientific literacy are the children afforded, and what teaching dimensions are part of the science activities? Recognising that the concept 'emergent scientific literacy' captures elements in pre-school science teaching that would otherwise go unnoticed, we also suggest the concept as a methodological contribution to this field of research, supporting analysis and descriptions suited to the conditions of pre-school practice.

The multi-dimensional science teaching that characterises the studied pre-schools implies that *'a child's whole being, mind and body, are used in the learning process'* (Westman & Bergmark, 2014, p.78), which in turn caters for solid engagement and learning in science. Still, our analysis does not capture *what* the children learn. Therefore, if teachers use our analytical approach to plan and evaluate their science teaching, it needs to be accompanied by a plan of how to capture and support children's learning. We stress this since researchers have pointed out that pre-school children are often left to discover the surrounding world on their own, lacking the instruction necessary to make scientific meaning of their discoveries (e.g. Fleer and Pramling, 2015). Further, research has shown that teachers' science learning goals are obscured as an effect of their prioritising other goals (Sundberg *et al*, 2016) or as an effect of teachers' will to address every child's comment or to address fantasy and play in their communication about science content (Gustavsson *et al*, 2016). This article points at the *potential* of multi-dimensional teaching for emergent scientific literacy in pre-school. However, in order for learning to take place, teachers need to hold on to their science learning goals and help children to make scientific meaning of the emergent qualities of science phenomena that they experience. Otherwise, the emergent scientific literacy risks suffering defeat in the multi-dimensional competition of everyday life in pre-school.

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Reflections on guidance to orientate untrained practitioners towards authentic science for children in the early years

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Abstract

There are currently a number of concerns facing early years education in England. A diverse range of pre-school settings for 0-5 year-olds exists. Those settings in the government-maintained sector are required to have at least one qualified teacher, whilst settings in the Private, Voluntary and Independent (PVI) sector are not required to employ a qualified teacher. Moreover, there is no requirement for a qualification to work in early childhood education and care settings.

While the proportion of unqualified practitioners varies according to setting, about a tenth of adults working in early years in England are unqualified. Moreover, although the majority of settings are graded 'good' or 'outstanding', there are doubts about the quality of provision, particularly in relation to science. Criticisms tend to centre on practitioners' knowledge and confidence in relation to science and the quality of science experiences on offer. We argue that views of what constitutes science education and approaches to young children's learning have developed and changed, with contemporary science adding epistemic and communicative dimensions to longstanding concerns with process and content.

Current social constructivist views of learning, together with neuroscientific evidence, point to the brain being primed for social interaction (Hinton & Fischer, 2010). These considerations offer grounds for optimism that changes in emphasis within science education bring the subject closer to developmental perspectives on the education of the whole child. We suggest that the epistemic and communicative elements that are increasingly recognised as authentic and essential to science education can be enhanced by early years practitioners drawing on their existing holistic cross-curricular skills. While acknowledging the benefits of specialist early years training, there are messages to be drawn for all practitioners, including, and perhaps especially, those whose access to training is limited or less than optimal. The fresh perspective that we suggest is to bring early years science into closer alignment with wider holistic practices. From this standpoint, we draw on some insights from our research to suggest strategies that combine theory with practical and applied approaches to early years science education. It is striking that the foundations for an epistemic approach can be identified in existing early years curricula and practice and are ripe for more focused attention. Specifically, we refer to the encouragement of multimodal expressive skills, critical listening, and expecting reasons for ideas (or 'claims') in dialogic exchanges that increasingly expect evidence in support of beliefs.

Keywords: Early years, epistemic, discourse

Introduction

A recent report by the Department for Education (2017b) claims that 94% of three year-olds and 99% of four year-olds in England access some government-funded early years education and care (Department for Education (DfE), 2017b). Early years provision is available through a variety of settings, including maintained settings (usually nursery school attached to a school or local authority nursery), or through the Private, Voluntary and Independent sector (PVI), which tends to include private and voluntary day nurseries, playgroups, pre-schools and childminders.

In England, a qualification to work with children in the early years phase is not required. Nutbrown (2012) recommended that, by 2022, all staff should be qualified. The data relating to the proportion of qualified staff in settings suggest continuing concerns about the proportion of early years staff having no qualifications. For example, according to Simon, Owen and Hollingworth (2016), a quarter of childcare workers held no suitable qualifications. A report in the same year by the National Day Nurseries Association (NDNA) (2016) claimed that the proportion of unqualified early years staff in nursery settings in the UK was more than one in ten. Our aim in this article is to consider the support needs of the entire spectrum of early years staff, including unqualified personnel, as well as those holding early years and teaching qualifications of some kind.

Notwithstanding the lack of formal qualifications amongst some staff, reports suggest that almost all (85%) eligible children receive their early childcare in settings graded as 'good' or 'outstanding' (DfE, 2017a). In contrast, a recent study of the impact of nursery attendance on children's learning (Blandon, Hansen & McNally, 2018) demanded greater attention to the quality of teaching and learning. Accumulated international research signals that deficits in the science achievements of young children that persist throughout schooling, across race, ethnicity, gender and socio-economic levels, may influence career choices (Trundle, 2015; Morgan, Farkas, Hillemeier & Maczuga, 2016; Sackes, Trundle, Bell & O'Connell, 2011). Criticisms of the nature of early years science education point increasingly to the lack of focus on children's learning (Sylva, Melhuish, Sammons, Siraj-Blatchford & Taggart, 2010). This lack is often attributed to low levels of confidence and science content knowledge amongst early years practitioners (Kallery & Psillos, 2001; Garbett, 2003), as well as to an inadequate understanding of the nature of science (NOS) (Bell & St Clair, 2015). Critics of early years science practices point to the absence of effective science instructional techniques (Tu, 2006) and the fewer opportunities available for children to engage with science activities compared with literacy and mathematics (Sackes *et al,* 2011). Early years activities are widely understood to offer an almost exclusive focus on children 'doing' through hands-on activities (Inan & Inan, 2015) and rarely explore NOS issues (Akerson, Buck, Donnelly, Nargund-Joshi & Weiland, 2011).

The tendency to prioritise low level hands-on activities contrasts sharply with growing evidence that early years children show remarkable capabilities to express and reason about their own ideas and those of others (Piekney & Maehler, 2013; Mercier, 2011; Kuhn, Amsel & O'Loughlin, 1988; Carey, 2004). Gopnik (2014) acknowledges young children's capabilities in distinguishing fact from fiction – an important precursor to weighing evidence. Increasing evidence of children's early capabilities led the US NRC (2007) report to the Committee on Science Learning K-8 to recommend an increase in the quality and challenge of science experiences offered to young children. They concluded that: *'All young children have the intellectual capability to learn science. Even when they enter school, young children have rich knowledge of the natural world, demonstrate causal reasoning, and are able to discriminate between reliable and unreliable sources of knowledge. In other words, children come to school with the cognitive capacity to engage in serious ways with the enterprise of science'* (National Research Council, 2007, p.vii) Despite this wider recognition of children's early capabilities, there is continued evidence of a mismatch between capabilities and the learning environment. In 2015, drawing on evidence of their review of practice and of some of the evidence of children's emerging scientific reasoning skills, Trundle and Sackes (2015) claimed that: *'Despite these capabilities, children's emerging skills usually are not the target of instructional practices in typical early childhood classrooms'* (Trundle & Sackes, *op. cit.*, p.242). In 2015, the OECD set out the alignment of early years curricula with the goals of primary education (OECD, 2015) in an initiative designed to help children realise their potential.

Historically, in England there has been a widespread acceptance of the notion of science for all and a recognition of the value of science learning for children's wider development. Science was introduced as part of the core curriculum for the primary years (5-11 years) in 1989 (HMSO, 1989) and forms part of the early years foundation stage (EYFS) (3-5 years) curriculum within an area of learning entitled 'Understanding of the world' (EYFS, 2012). The curriculum makes explicit that it is through this area that children's communication and language should be strengthened and applied, so wider curricular links are explicitly acknowledged.

Over the years, there has been debate about what constitutes science education, and the early debate centred on a tension between the teaching of science processes or content. In more recent years, educators' views of science have been extended to include an emphasis on social, communicative and epistemic processes as realised in science discourse practices (Duschl & Jimenez-Aleixandre, 2012; Duschl & Grandy, 2013). By making explicit the relationship between communication, language and emergent science, the early years curriculum provides key opportunities for the introduction of early discourse practices and ways of thinking scientifically within high quality social interactions between children, and between children and supporting adults. Developments in understanding learning more generally have shifted from behaviourist and information processing perspectives towards dominant views from cognitive psychology about the social construction of learning (De Corte, 2010). The focus on the social nature of learning is further supported by contemporary evidence from neuroscience, which describes the brain as being primed for social interaction (Hinton & Fisher, 2010).

In this article, we consider how the development of scientific literacy can be encouraged 'bottom-up', using approaches consistent with contemporary developments in science education research and a 'whole child' perspective on young children's learning. This perspective acknowledges the training needs of early years practitioners, but suggests building on, rather than the wholesale replacement of, existing skills. We argue that the contemporary understanding of what constitutes science education offers new possibilities for early years practitioners to make significant contributions to an authentic science experience for young children. Our long-standing interest in developmental progression underpins our view that science capabilities can be understood as gradually emerging from more basic, foundational or general skills. Just as children are building up domain-specific ideas about science phenomena, they are also building up ways of communicating, sharing and reviewing those ideas in their early interactions. Learning environments sensitive to these emerging capabilities can promote a culture in which the exchange of ideas is valued and understood as central to learning. We suggest how the encouragement of gradually increasing interactive, reasoning and communicative skills can be nurtured in ways consistent with more current ways of characterising science proficiencies. This strategy requires specification of developmentally appropriate activities that can become central to early years practitioners' interactions with young children. In turn, this stance implies the need for a practical agenda that builds on current best practices, and meets the requirements of an updated view of science education. To describe real possibilities of operationalising this viewpoint, we draw on quantitative and qualitative evidence derived from three relevant projects (children 3-7 years).

Review of authors' relevant project activity

Young children's developmental capabilities relevant to emergent science within early years holistic curricula and practices were explored in a recent assessment project. Construction of the Child Development Assessment Profile (CDAP, Welsh Assembly, 2011) necessitated defining and measuring psychometrically aspects of 'whole child development'. The developmental assessment criteria that were validated in the first study with a large-scale sample were illuminated by two further pieces of research to which we refer.

A second study looked at the qualitative interactions between children and practitioners in settings, drawing on qualitative data from a collaborative exploration of emergent science within the holistic early years practices of twelve settings. Teachers of children aged 3-7 years worked within their usual holistic approaches with their classes of children, with the authors operating as participant observers. Exchanges between teachers and researchers resulted in the gradual shaping of existing practices towards a focus on the collection of children's ideas using a variety of modes, including action, speech, drawing and 3D modelling. Once ideas were collected, children were encouraged to listen to each other's ideas and to explain their own reasoning. Data collected included examples of children's work, teachers' journal notes, teachers' writing and researchers' classroom visit notes. The study helped to trace, in the course of all-inclusive activities, developmental learning progressions between general and emergent science skill proficiencies.

Further evidence of synergy between early years practices and epistemic views of science was found in a third study, which explored the ways in which children expressed and exchanged ideas and the way they used mathematical tools to collect evidence to inform their thinking. This research-based design project involved ten schools, each focusing on teaching and learning within evolution and inheritance (4-11 years). Here, we draw on some of the qualitative evidence from four of these teachers having responsibility for children 4-7 years. Data collected included examples of children's work, teachers' journal notes, teachers' writing and researchers' classroom visit notes.

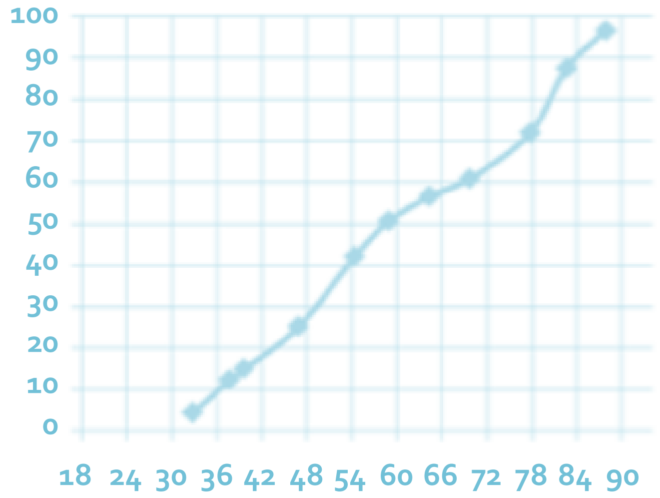
Evidence from outcomes of each of these projects helped the identification of approaches within existing early years curricula and practices that have the potential to offer a more authentic science experience to young children.

Quantitative evidence of early years practices relevant to authentic science

The 'Child Development Assessment Profile' (CDAP, Welsh Assembly, 2011) was a holistic baseline assessment profile to assess all children (3-5 years) on entry to foundation phase in Wales. A national pilot undertaken as part of the development involved 1195 children in 269 settings. Practitioners trained in the use of the CDAP assessed the children in their care in the course of their usual day-to-day interactions, referring to six Developmental Areas and a total of 114 items, each addressing an observable behavioural criterion. The retrospective review of the criteria identified behaviours of interest to science educators at three levels:

- 'General developmental' criteria accounted for about two-thirds of assessed behaviours. They were defined as those likely to be prerequisites to all learning.
- 'Science enabling' criteria, representing about one quarter of assessed behaviours, were defined as those that would support science-related activities without having been nurtured in a context readily identified as scientific.
- 'Science-specific' criteria (9 of the 114, or 8%) included showing curiosity, giving reasons, explaining how things happen, holding a point of view, describing logical sequences, planning inquiries and empathising with the listener (Russell & McGuigan, 2016a). These latter capabilities are essentially about thinking, reasoning and sharing understanding with others and are congruent with an epistemic view of science. Figure 1 exemplifies the form of item analysis undertaken on all 114 criteria.

Figure 1: Science-specific item: 'Gives reasons for why things have happened or are happening' (age norm 48-60 months).



Children's capability to offer explanations for changes that they see happening was assessed through this criterion. Located within the 'Thinking and reasoning' domain of the CDAP, causal reasoning is of foundational importance to the development of science understanding. (Percentage success on y axis, age in months on x axis.)

It is worth emphasising that these nine 'science-specific criteria', identified as relatively discrete and measurable entities, were revealed within a 'whole child' curriculum in which science did not feature as a separate subject. The developmental data confirm that the foundations of an epistemic approach can be found within a broad and balanced early years curriculum in which the focus was child-centred, experiential and play-orientated.

Qualitative evidence: expressing ideas; listening; and reasoning with evidence

The data drawn from the two qualitative early years research projects suggest some key instructional practices, which resonate with a simplified approach to argumentation that is both developmentally appropriate and consistent with the epistemic aspect of the NOS (Russell & McGuigan, 2016b). Together, the qualitative studies provide evidence of three developmental learning progressions that help trace the managed emergence of authentic and foundational science experiences for young children. Using illustrative evidence from these studies, three skill areas: 'expressing ideas', 'listening' and 'reasoning with evidence' highlight how all early years practitioners might support children as they make progress towards some of the social and communication skills valued in epistemic views of science.

Expressing ideas

On initial entry to settings, some children may be hesitant to express their ideas. As with spoken language, the conventions governing communication using different formats such as gesture, drawing and modelling have to be learned and their introduction managed by the supporting adult. Gradually children will gain the capability to exploit a range of representational formats and make choices about which best suits their intentions. Barely-formed ideas will be developed even as children represent and discuss their ideas. The ability to draw on a range of modes allows the same idea to be represented in different ways; the redundancy reveals nuances that may not be possible in any single mode. The triangulation of different modes is intended to generate richer understandings, not to avoid the oral mode.

The value of verbal expression is unquestionable, but can be extended and enriched by multimodal forms of communicative expression. Amongst the many examples gathered, in one class of 6 and 7 year-olds, a teacher invited children to make model pets to show their ideas of pet families ('babies' and their 'parents'). Children used feathers, art straws, paper and sponge balls to make their imaginary pets. They tended to make the offspring smaller than the parents, but with the same characteristic eyes, feathers, etc. Their 3D models provided an engaging focus for interactions designed to encourage the expression and sharing of meanings. With the help of a supporting adult, one child mentioned that the young pet would look exactly like its mother, only smaller. Others shared this view or thought that a boy pet would look exactly like its father. The concrete form of the 3D modelling helped children keep track of the focus of the discussion. In terms of science discourse, the ideas that children expressed, whether verbally or in drawings and models, could be understood as claims.

Increasingly, children become aware of their own beliefs as ideas to be expressed and shared with others. Children's tendency to offer the same idea as their peers will be likely to diminish with experience and encouragement. Creating a positive environment in settings, with the expression of ideas being explicitly valued by receiving praise and attention, will encourage their further expression.

Listening to others' ideas

Children are normally required to attend to adults when spoken to. Some settings might have a routine to focus children's responsiveness, for example, children wiggling their fingers in the air and turning to face the adult to signal attention. Similarly, the importance of listening to children and the modes of behaviour required in a discussion must be explicitly introduced to children by the managing adult as an integral part of most activities.

Initially, children tend to think that everyone shares the same idea. Adults can facilitate children's growing awareness of alternative viewpoints, by deliberately drawing attention to the diversity of ideas expressed, modelling reactions of interest and surprise and valuing any alternative viewpoints. For example, a class of 4 and 5 year-olds preparing for a farm visit shared ideas about some of the different animals that they expected to see. The practitioner made a class list of children's drawings and spoken ideas, which helped to bring the different ideas to children's awareness.

A step on from children accepting the diversity of ideas is active listening and responding in ways that demonstrate detailed and thoughtful engagement with the discussion. Active listening within these early exchanges might be revealed as children introduce relevant, albeit different – perhaps opposing – viewpoints, as well as additive, supportive expressions of ideas. The supporting adult must make the rules of these exchanges explicit, so that children learn to respond respectfully to the ideas of others in what might be described as an early form of peer review.

For example, a group of nursery children planting bulbs and deciding what bulbs need to grow (4 year-olds) were encouraged to respond to others' ideas by first saying, *'I like [Ruby]'s idea but I think…'*. All the children adopted this technique of explicitly referring to the name of the owner of the idea and first expressing a liking for the expressed idea, before introducing a gentle challenge to each idea or claim. The strategy helped to ensure that children experienced the sharing of ideas as a positive, enjoyable process. Once acknowledged by the teacher to be a regular and required feature of children's interactions, the tactic helped to ensure that children developed the ability to compare ideas and express counterclaims in ways that respected each other's right of expression.

Approaches that include the encouragement of listening actively to others and an increased awareness of the diversity of others' ideas constitute an authentic and valid approach to science. In their early interactions with children, supporting adults help children towards productive exchanges in which children become confident enough to express ideas, empathic and respectful in the giving of feedback and resilient in handling others' feedback. It is these early exchanges that resonate with epistemic science practices. We were reminded of the value of the early and gradual introduction of 'argumentation' skills by two Year 5 girls (aged 10), who had just experienced a lesson in which they had reviewed and critiqued each other's ideas for the first time. They had found the requirements to critique and perhaps disagree with others' ideas unfamiliar and disconcerting:

'I think it was quite weird arguing with my friends because, ermmm, we all like, agree with them most of the time, so it was a bit weird arguing with them.'

'I think it was a bit weird as well, because I normally agree with them and then I'm not agreeing with them today.'

Reasoning with evidence

Encouraging the giving of reasons marks a shift in science thinking towards self-awareness as to what and why a belief is held, rather than an alternative idea. This shift requires children to develop metacognitive skills through which they can reflect upon and manipulate ideas. The shift also requires children to develop the capability to use evidence to support their ideas. Initially, children's reasoning may take the form of assertions or assumptions of delegated authority, with statements such as *'I just know'*, or *'Everyone knows that!'*. In these instances, children may think that there is general agreement in relation to a particular idea, so there is little motivation to seek justifications to support thinking. Yet reasoning is important, because children can be helped to choose between ideas on the basis of the reasons given to back them up. Encouraging children's regular use of 'because' immediately following an idea helps to invite the giving of reasons. The reasons that children offer may draw on their own conceptual understanding, first-hand experiences or their imagination.

Our evidence suggests that, with practice, children show impressive competency to express ideas, to justify their ideas with reasons and to critique thoughtfully those of others. In this manner, they progress to comparing and modifying their own ideas through consideration of the reasoning and evidence they have heard.

In a class of 5 and 6 year-olds, children exploring materials outdoors climbed into an old boat in the school grounds to discuss their ideas about the materials that had been used to make it. The teacher made clear her requirements that children should listen carefully and decide whether they agreed or disagreed with each other's ideas, and why:

Teacher (T): *'We are going to listen very, very carefully now and think about whether we agree or disagree with each other's ideas about the materials used to make the boat, and why.'*
Jo: *'Screws are made out of metal and the green bit isn't.'*
T: *'Ok. What is the green bit made out of, Jo?'*
Jo: *'Wood, and screws are not.'*
Eleanor: *'I think Jo's idea is true but when you paint the metal it looks like it is made out of wood.'*
T: *'Ah! The metal looks like the wood because it is a painted the same colour as the wood.'*
Nerys: *'I know why they decided to build it from wood… because, to keep it waterproof.'*
T: *'Ah! So they decided to build the boat from wood to keep it waterproof. So, is wood a waterproof material then?'*
[The group responded in unison with either 'No!' or 'Yes!', suggesting that they were divided in their understanding as to whether or not wood is waterproof.]

Erin: *'No, because it's not a soft material.'*
T: *'Because it is not a soft material. So are waterproof materials soft?'* [Note the reflecting back of the expressed idea and its reformulation as a question.]
Erin: *'Yes'.*
T: *'Has anyone else got anything to say about Erin's idea?'*
Anna: *'I don't think that that's true because I only think waterproof materials are made out of plastic.'*
T: *'Anyone got anything else to say about those ideas?'*
Nerys: *'I am beginning to change my mind because actually I think plastic is waterproof.'*
T: *'But what about wood?'*
Nerys: *'Wood can rot in the rain so I don't think it is waterproof.'*
Anna: *'Plastic doesn't rot down so I think Nerys's idea is true.'*
T: *'What do you think about wood, then? Do you think wood is a waterproof material?'*
Anna: *'Wood is not, because if you leave it outside for a long time, it will rot down.'*
T: *'Has anyone got anything else that they could say linked to that?'*
Harry: *'If you jump on the boat it will just break because it is plastic.'*
T: *'What do you think the boat is made of?'* [Teacher seems to be checking out the child's understanding.]
[Harry knocks the boat to check or test his ideas: *'Out of wood'*. [Tapping the boat shows the child is looking for evidence through testing as part of the conversation.] (Russell & McGuigan, 2016b)

In such exchanges, children are being inducted into a process whereby they can explain why they believe one idea in preference to others and, importantly, use evidence to support their own view. The supporting adults must be active in probing responses and encouraging children to think about others' ideas along with their own, and to require them to explain their reasons.

This process helps to bring about changes in understanding as weaknesses and strengths in ideas are recognised. In the example, we see children exchanging and building on each other's ideas thoughtfully and showing remarkable capabilities to acknowledge the influence of each other's ideas on their own reasoning.

Conclusions

On first stepping out of the home into their early years settings, many children may be reticent in expressing themselves and interacting with others' ideas. With adult support, they display a developing capability to express their ideas confidently, to listen actively and to critique positively the ideas of others. Through practice routines, they gradually learn to adopt strategies that help them to challenge the ideas of others, sensitively and with respect. As they progress, they demonstrate an awareness of how they know and why their ideas have changed, cognitive growth aligned with an epistemic aspect of the nature of science. Our analysis seeks to link general early years practices to these authentic science approaches, by tracing developmental learning progressions between general behaviours and the emergence of more science-specific behaviours.

Our collaborative research with practitioners has revealed some of the ways in which these approaches can be supported seamlessly in early years practice. The aim is not to promote heuristics that will encourage disparate, discrete science skills, but rather to show how the interactions arising in some of the experiences provided in early years settings might be thought of as enabling of the broader epistemic and communicative view of contemporary science.

Focusing on science education within the whole child framework of early childhood practitioners reveals the potential alignment between early years curricula and practices and current views of contemporary science. While acknowledging the advantages that a specialist training in science confers on practitioners, there are messages to be drawn for all, including those with more limited access to professional development and training. Our research signals some tentative practical guidance for all early years practitioners, embedded in their whole child approaches to early years education. The task ahead is to disseminate these possibilities.

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Teaching science in Australian bush kindergartens: Understanding what teachers need

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Abstract

Across 2015-2017, we conducted research at four Australian bush kindergartens to understand the teachers' science pedagogy and practice. The initial results were presented back to the participants at a teachers' professional development day. Forest kindergarten research exists, but is limited in the Australian context and little consideration of teacher professional development directly associated with bush kindergartens exists. As we live in a society that constantly changes, teacher professional development or professional learning is essential for ensuring that teachers in all sectors of education continue to address their students' learning needs. Our study involved the theoretical framework of 'capacity-building', where improvement in teachers' knowledge, skills and dispositions is critical to improving children's science understandings. The intention of capacity building is to generate change in current practice. This research used a mixed methods approach over two stages. Initially, observations of six early childhood (EC) teachers' science strategies and practices were recorded and discussed with the teachers. Then, a pre-intervention survey of bush kindergarten teachers was delivered, aimed at understanding teacher science knowledge and development needs within the context of the provision of science professional learning. This research reports on the initial observations of EC teachers' practice and strategies in science in bush kindergartens, and their articulation of their needs through the survey.

Keywords: Early childhood, bush kindergarten, science professional learning

Introduction

Professional development, or professional learning, is essential to ensure that teachers in all sectors of education continue to address their students' learning needs in a society where change is continuous. Effective professional learning is both complex and difficult. A 'skills and knowledge' approach has been shown to be quite ineffective in supporting more fundamental aspects of teaching practice (Pickering, Daly & Pachler, 2005). Campbell and Chittleborough (2014) highlight the need for professional learning to connect with learning priorities or the direct needs and concerns of participants, and to be planned around a long-term and systematic approach. Professional development sensitive to the needs of teachers and their contexts is necessary to support teacher development.
In particular, early childhood (EC) teacher professional learning needs to be a reflective process, whereby EC teachers have the ability to reflect critically on their beliefs, understandings and practices (Nolan & Mekonnen, 2017). However, the science professional learning needs of EC teachers arise from emerging challenges in their professional practices. Darling-Hammond, Hyler and Gardner (2017) indicate that teachers use their experiences as resources for new learning; however, science experiences tend to be limited in teachers' backgrounds (Campbell & Jobling, 2010).

This research used the theoretical framework of 'capacity-building'. Capacity building refers to the development of a teacher's capability to make changes to his/her practice and includes changes to *'dispositions, skills, knowledge, motivation and resources'* (Fullan, 2005). These changes to teachers' practice underpin the improvement of children's science understandings.

Science in EC settings

There is a large body of evidence suggesting that science is not often 'taught' in Early Childhood (EC) settings; however, this is not to indicate that science experiences do not occur – particularly through play (Campbell & Jobling, 2010). As far back as 2005, researchers were starting to think about the reasons for introducing science to very young children. Eshach and Fried (2005, p.319) articulated that there were at least six reasons that science education should become part of an early childhood setting:

- Children naturally enjoy observing and thinking about nature;
- Exposing children to science develops positive attitudes towards science;
- Early exposure to scientific phenomena leads to better understanding of the scientific concepts studied later in a formal way;
- The use of scientifically-informed language at an early age influences the eventual development of scientific concepts;
- Children can understand scientific concepts and reason scientifically; and
- Science is an efficient means for developing scientific thinking.

Their research described the circumstances in which these reasons hold true in early childhood settings. However, an additional reason that arose through discussions with teachers is that, with science all around us, in so many ways, young children's learning is impoverished if they are not engaged in learning science (Campbell & Jobling, 2010). Saçkes, Trundle, Bell and O'Connell (2011, p.217) further write that *'experiential science education in early childhood is of great importance to many aspects of child development, and researchers suggest that science education should begin during the early years of preschool'*. They determined that not only did young children's basic understanding of science and fundamental processing skills develop in early childhood, but that these skills and knowledge remained with children through later education (Saçkes *et al*, 2011).

Much of the science learning in kindergartens develops from children's play situations in which children are involved in explorations and creative activities (Davies, 2011). Science learning builds on children's own questions and wonder about the world around them. These early play experiences in science help to develop positive attitudes to science. Thulin and Pramling (2009) have found that children want to know more about their world and are comfortable with new language, new worlds and new concepts. Research by Duschl, Schweingruber & Shouse (2007, p.2) indicates that young children already have *'substantial knowledge of the natural world'* and that their thinking is quite sophisticated. They suggest that children can use a wide range of reasoning processes, which underpin scientific thinking.

However, there is little research into science learning in bush kindergartens, although international studies have provided some background understanding in more general terms. For example, research (Borradaile, 2006; Elliot, 2013) indicates that there are multiple benefits associated with taking children to these natural settings. Children have autonomy over their choice of activity, freely exploring the settings and accepting challenging situations that cannot be duplicated in a normal kindergarten setting. The most significant benefit in terms of science learning is that participation helps children to appreciate and care for their natural environment. Honig (2017) identified a number of learning dimensions, particularly with young children, which exist in natural environments – learning new concepts (mathematics, science, language, environment) was mentioned.

In Australia, the 'forest kindergarten' movement has translated into 'bush kindergartens'. Whilst some research in Australia around the benefits of a bush kindergarten approach has occurred (Elliot, 2013), it has tended to focus on the positive aspects in terms of children's biophilia and risk-taking behaviour.

A compounding issue for science education in EC settings and specifically bush kindergartens is that EC teachers have indicated a lack of confidence in their own science understanding and in teaching science (Torquati, Cutler, Gilkerson & Sarver, 2013; Edwards & Loveridge, 2011). With teachers' subject matter knowledge a predictor of student engagement in science learning (Saçkes, 2014), it is critical that support is provided to teachers to improve their science pedagogical content knowledge (Appleton, 2006). A study by Saçkes (2014, p.181) provides evidence that *'limited content knowledge and low efficacy for teaching affects teachers' decisions about what content to teach and how frequently to teach science concepts'*.

Many EC teachers undertook their training when the idea of 'teaching' very young children was not considered the responsibility of EC centres, and therefore would have received little training in science other than 'nature study' or 'integrated studies'. Current EC Bachelor degrees offered by universities now include science education in some form, sometimes standalone, or linked to another area of learning. Previous research (Campbell & Jobling, 2010) indicates that many EC teachers lack qualifications that deal specifically with science and that they would like more science-orientated professional learning. Research by Saçkes *et al* (2011) highlighted that the limited time and limited nature of instruction provided to early cognitive experiences (in science) related to reduced achievement (in science).

Children try to make sense of their world through their own play explorations; however, they are limited in how far their discovery can aid understanding. For this reason, it is crucial that EC teachers have a basic understanding of the underpinning science. The research sought to understand EC teachers' professional learning needs in the belief that teachers who are attuned may recognise the science in spontaneous events and can make use of these to develop children's deeper understandings.

Our research questions are:

- How is science teaching and learning being enacted in and across the bush kindergartens?
- What professional learning issues arise in discussion with EC teachers about science education?

The research project – methods

The research involved the development of a case study for each of four different bush kindergarten settings. Our data gathering involved two distinct data collection points. Firstly, between 2015 and 2017, we visited and observed the teachers and children on 3-5 separate occasions at each site. Data were gathered for an hour for each visit. The site visits allowed us to gather data that supported our understanding of the overall programmes, the science experiences of the children in the bush settings and to illuminate science learning through play. Since this represented an interpretive study of a system that was 'bounded' in both time and space, case study was identified as the most appropriate methodology. The research used a qualitative, interpretive approach and data were collected through:

Field visits – interviews with teachers

Formal interviews were undertaken with six teachers prior to the first researcher observations. These interviews were conducted to understand their philosophy when running the bush kindergarten. The questions included:

- How is science learning and teaching being enacted in a bush kindergarten?
- What is available in the play environment that provides opportunities for exploration related to science?
- How do educators scaffold children's science play in the physical environment?

Informal interviews occurred as children undertook activities that researchers were observing and recording. EC teachers were asked to comment on what they observed as science in children's play. Questions included:

- Can you tell me what is happening here?
- What are the children doing here?
- What is the purpose of your involvement here?

The informal interviews were recorded as part of the video-recording of children's activities.

Field visits – researcher observations

Over the 3-5 sessions, researchers observed and recorded children's science play and explorations for an hour at a time. These recordings were initially described in narrative style, such as *'four children climbing trees'* or *'two girls making potions'*. They were then categorised according to the guide on the next page.

Due to the extent of children's science play, the observations in each session tended to exceed the

Observation Guide			
Session/date	**Observation tag**	**Context – children at play**	**Time during session in which the observation took place**
Session One	Observation One	Physical sciences – e.g. balancing	
	Observation Two	Chemical sciences – e.g. mixing mud pies	
	Observation Three	Biological sciences – e.g. plant or animal engagement	
	Observation Four	Something unusual	

table parameters. That is, there were more than four observations of science play in any single hour. Children were not interviewed/questioned or any aspect of children's involvement recorded.

Pre-intervention survey

Our second data collection point occurred preceding a series of six professional development sessions that we provided for the teachers between 2016 and 2017. Prior to the first of the six sessions, we asked the teachers to complete a paper-based survey (pre-intervention survey), which allowed us to understand their development needs in science teaching. Using a range of Likert-style and short-answer questions, we were able to develop our own understanding of this group of teachers' needs and how we could best support these teachers in identifying opportunities upon which to act. Examples of these questions included:

- How do you incorporate science into your programme?
- Indicate your level of knowledge in science topics, including *Electricity, Forces, Matter (Chemistry), Energy, Plants, Animals.*
- Indicate your level of enjoyment in teaching science topics.
- When planning a science topic, indicate your level of use of the following resources, such as: *Science continuum P-10 resources, Internet, Centre-based resources, other resources.*

Then, at the completion of the six professional development sessions and using the same survey question and, again, in paper-based form, we surveyed the teachers to allow us to understand if any change had occurred in their understanding of science-based concepts. There were deficiencies in this process in that we had a significant disparity in the number of individuals who completed the first survey (28), in comparison to the second survey (9), due to attrition in those who attended all six sessions. As a consequence, we were unable to use aggregated data for the second data collection point (post-interventions survey).

Results

Field visits – interviews with teachers

Formal interviews were undertaken with six teachers and four other educators (non-qualified) prior to the first researcher observations. All were enthusiastic about the opportunity for children's involvement through a bush setting.

The initial discussions revealed a slight variation in the demographics of the kindergarten communities, but that seemed to have little effect on the teacher expectations of the children and their learning. Teachers anticipated that the learning would encompass a strong element of science, especially biological science.

Interviewee 1 – *'I believe that what we're doing here is a partnership with the sciences, they go hand in hand. A lot of the things I originally assumed this might mean have taken a totally different path.'*

Interviewee 2 – *'So there's insects, bugs, I know there's a new word for that now – Little live creatures. Plants, environment, weather.'*

Informal interviews – These interviews occurred as children undertook activities that researchers were observing and recording. EC teachers were commenting on what they observed as science in children's play, but were also asking for additional information from the researchers and questioning whether they had provided enough or the right information to children. The informal interviews were recorded as part of the video-recording of children's activities.

Teacher 1 stated: *'I know the science, but don't know quite how to put it into words for the kids…'.*

Teacher 2 commented: *'I am not sure how to integrate my understanding of science into play activities for children… do I do enough… it concerns me.'*

Teacher 3 stated: *'I don't' really know much science, other than biology… I'm not sure what to do sometimes.'*

Researcher: *'I can see lots of science in what they're [the children] doing and, as an educator, I'm tempted to go in and talk to them but I noticed most of the staff stepped out of things like this. Did you want to make a comment on this?'*

Teacher 4: *'I suppose initially, because it is a new environment, we're letting the children explore it and finding out things for themselves. Unless it is specifically or extremely dangerous… we will step in at this point … we understand the children's abilities at this stage but it's just seeing them extend it and extend it on their own. Then, looking at that from a learning point of view, then we would probably extend into more specifics with the children, like whether it's a group discussion for them to approach different concepts, whether it be gravity and support and that type of thing, or whether it's imaginative-based, whether there's a certain routine patterns that they do and repeat their physical skills.'*

A teacher, Jasmine (pseudonym), who indicated that she followed a Reggio Emilia approach, tended to stand back from involvement and stated: '…*We are truly guided by the children. You really almost couldn't make a plan for out here. It is truly led by the children's interests. The only thing I think I could do better is the writing up of the stories each week' (Jasmine, teacher interview, August 2015).* Another teacher commented on Jasmine's practice:

'Jasmine gives the children a lot more freedom, she allows them to self-discipline themselves. The other group are more defined… They don't do as much exploration, they've got more solid boundaries, a more cautious teacher… Jasmine has a lot more freedom, she always has had that in her classrooms.'

During informal discussions, all educators/teachers expressed a desire to know more science.

Field Visits – researcher observations

During our field visits, we observed science experiences and explorations as undertaken by children (see Table 1). These occurred many times across the multiple visits and at different sites.

Overall, we observed that the scaffolding of children's science experiences varied from one educator to the next. Scaffolding in bush kindergartens took on the roles of interaction and communication and depended on an educator's personal philosophy. Some teachers 'stood back' with a strong belief in allowing the children to discover things for themselves. Interaction took place when the children called on the educator for assistance. However, other educators would step in to introduce new science language or ideas as they saw a need. At one bush kindergarten site, the teacher was quite proactive in that she would frequently engage in science exploration herself and call on children to join her. At other times, she moved from group to group, asking questions, focusing discussion and engaging others in the activity. In some cases, she supplemented the environment with additional resources (e.g. magnifying lenses, containers for collection).

Occasionally, some teachers took the bush kindergarten experiences into normal kindergarten sessions, to reinforce the learning, but this was reported to occur infrequently.

Pre-intervention survey

Following our observations, we conducted a pre-intervention survey with 26 teachers, to more specifically hone in on their science learning needs, following an initial professional learning session.

Table 1: Researcher observations of children's science experiences.

	Children's observed activity	Science concept or skill involvement
1	Classifying	Science skill
2	3D building with rocks	Technology skill
3	Balancing	Forces/gravity/friction
4	Climbing	Forces/gravity/friction
5	Testing branch strength	Forces/gravity/friction
6	Jumping	Forces/gravity
7	Small animal observation	Science skill – observation
8	Small animal ethical behaviour	Science skill – safe handling
9	Mixing mud	Chemistry - mixtures
10	Digging	Forces
11	Planting	Growth characteristics and requirements
12	Nature walks	Ecosystems - knowledge
13	Rock pooling	Ecosystems - knowledge
14	Language development	Science skill - communication

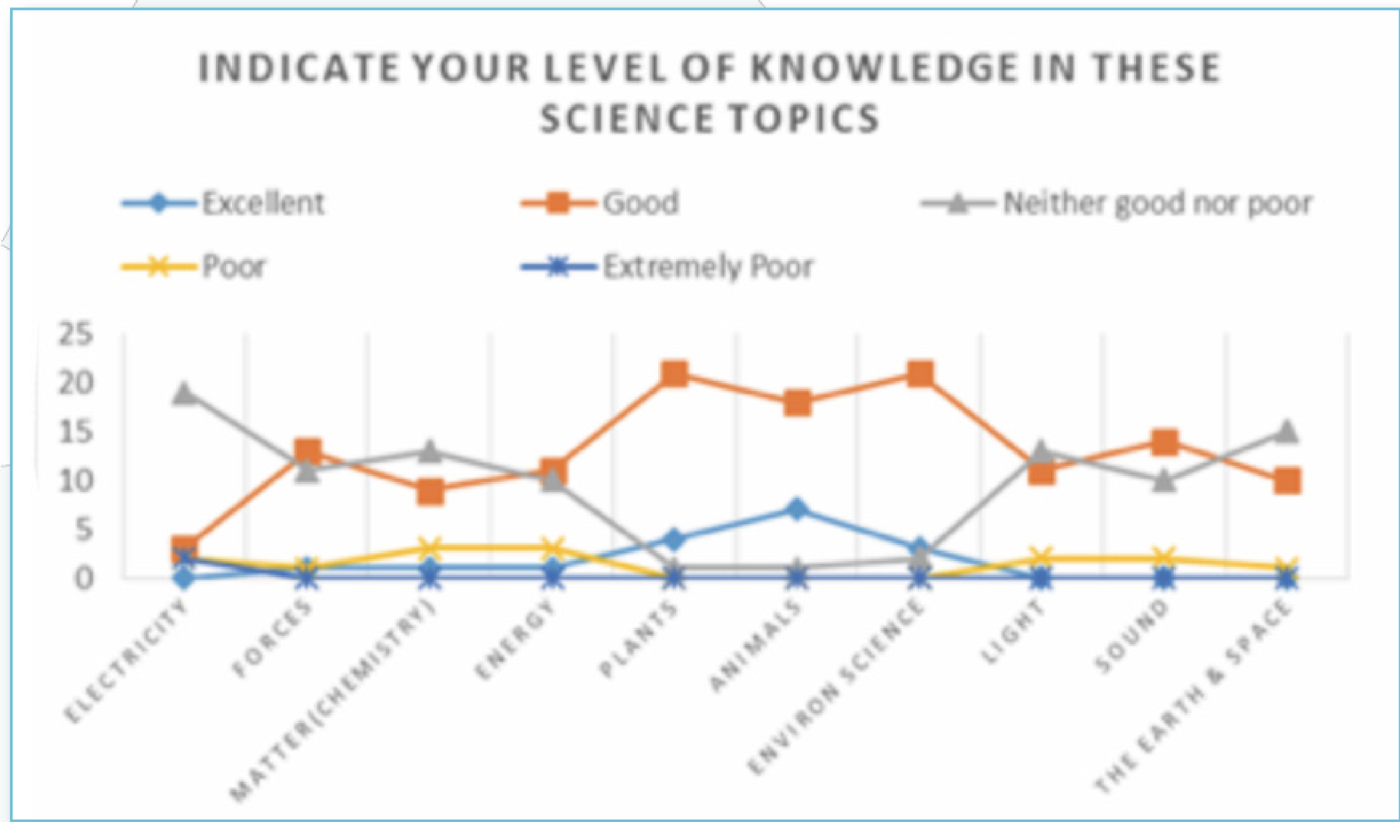
The survey data, some of which is captured in Table 2 and Figure 1, revealed some interesting insights into teachers' perceived strengths and weaknesses in their science knowledge:

- > 20/26 teachers felt comfortable with their knowledge of plants, animals and environmental science – a few teachers felt that they had excellent knowledge;

	Excellent	Good	Neither good nor poor	Poor	Extremely poor	No response
Electricity	0	3	19	2	2	0
Forces	1	13	11	1	0	0
Matter (Chemistry)	1	9	13	3	0	0
Energy	1	11	10	3	0	1
Plants	4	21	1	0	0	0
Animals	7	18	1	0	0	0
Environmental Science	3	21	2	0	0	0
Light	0	11	13	2	0	0
Sound	0	14	10	2	0	0
The Earth & Space	0	10	15	1	0	0

Table 2: Teachers' perceived level of knowledge in a range of science topics.

Figure 1: Teacher responses to the request 'Indicate your level of knowledge in each of these science topics.'



- half the teachers indicated that they didn't feel comfortable with forces, chemistry, energy, light, sound, Earth and space, and some indicated that their knowledge was poor;
- Two teachers indicated that their knowledge of electricity was extremely poor; and
- Teachers indicated that they had some knowledge of all science areas.

As indicated previously, the post-intervention surveys were not statistically viable to use as data; however, the general response of the 9 surveys was positive – that teachers/educators felt more confident in their science knowledge and practice after the science professional development sessions.

Discussion

Bringing together these two very different methods of data collection allowed us to develop an understanding of the teachers' interpretation of their own development needs. It also allowed us to incorporate both the survey feedback and our earlier participant observation during the fieldwork, to create a varied evidence base through which we could support the development of the teachers.

Results from the data collected before any observational visits indicated that teachers were aware that science would be part of the bush kindergarten experience. They expected that it would form a large component of children's explorations. The subsequent observations at each site confirmed that this was indeed the case – a large number of children's play activities were comprised of science explorations or experiences.

These observations highlighted the richness of the different bush kindergarten environments for providing multiple types of science experience.

However, the data from the observations of teacher involvement appear to be a little contradictory, with some teachers choosing not to engage in the science activities with the children, even though all of them had previously recognised how much of the children's explorations involved science. For these teachers, was it that their philosophy dictated their lack of intervention? Was it that they didn't recognise the science, or was it that they didn't know how to scaffold appropriately? For example, the teacher Jasmine indicated that part of it was her teaching philosophy, grounded in a Reggio Emilia approach.

Others indicated that they held back until they felt that children had enough time to fully explore the environments themselves. Some teachers were more active in their scaffolding, with one engaging strongly in science. However, some of the in-field informal interviews presented a picture of teachers and educators who were not certain of how and when to scaffold science explorations. As expressed by all teachers, they felt that more understanding of science was necessary.

The pre-intervention survey results clearly highlighted what some research was stating – that teachers lacked both the confidence in and knowledge of science to actively contribute to children's science learning (Torquati *et al*, 2013). While some areas of science biological or ecological knowledge were strong, other areas were perceived to be weak or not as strong (Saçkes, 2014). With teachers indicating such lack of confidence in their understanding in some science areas, they would probably lack the confidence to interact in children's science learning in those particular areas. This was confirmed to some extent by the informal interviews with some teachers/educators, but also through other research results (Saçkes, 2014).

Conclusion

The current study was limited in some respects. Teachers' and educators' understanding of science content was in the form of self-reports or based on their personal perceptions. Additionally, the study focused on the type of science content and did not consider aspects such as skills, or the quality of interactions and science play activities. However, there are strengths in the study, stemming from the rich descriptive data arising from the observations and the opportunity to speak with teachers and educators 'in the moment'.

In conclusion, we return to the initial research questions:

- How is science teaching and learning being enacted in and across the bush kindergartens?
- What professional learning issues arise in discussion with EC teachers about science education?

We found that science teaching and learning across the four bush kindergarten settings varied considerably and tended to be determined by the teachers' science understanding, but was also based on a broader philosophy of pedagogy and intervention. In considering what professional learning issues arise, the following teacher needs were identified through interview: they needed to be able to integrate science into bush kindergarten teaching scenarios, and to be able to translate knowledge into the appropriate level explanation.

The surveys indicated that teachers perceived that they needed to have deeper understanding of science content. This building of teachers' capacity relies on changing their dispositions, skills, knowledge, motivation and resources. With greater understanding of science concepts comes the ability to 'see' more science in a vast range of children's experiences and this may provide teachers with strategies to promote science understanding in children's play. Being more familiar with science enables an EC teacher to integrate science more successfully into bush kindergarten exploration and to develop children's understanding. The findings of this small-scale study demonstrate that more targeted professional learning, supporting the contexts of bush kindergartens, is needed.

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Reflections on and analysis of the use of drama techniques and dialogic practices in teaching science in primary school

- Clarysly Deller

Abstract

This reflective article examines science learning, experienced in a primary school, in light of theories of social constructivism and how they can illuminate and explain learning experienced within an innovative project. This project sought to combine the use of drama techniques to teach tricky concepts in science with discussion, collaboration and peer support. Having established the background to the project, this article examines some of the theories of social constructivism evidenced in the project. Its purpose is to reflect upon learning so as to usefully promote similar approaches in the future. Its findings point to the usefulness of social collaboration in learning, the value of dialogic practices and the use of scaffolding to enhance and deepen understanding.

Introduction

Effective primary science education should support children to change their ideas and forge new learning in order to produce a better understanding of the world around them (Skamp & Preston, 2015). From 2010 to 2016, I was involved in a Primary Science Teaching Trust (PSTT)-funded project using drama techniques to deliver aspects of the primary science curriculum, with researchers from Oxford Brookes University and Staffordshire Entrust. Although using drama is not a new concept (Littledyke, 2004; Precious & McGregor, 2014), the project promoted diverse opportunities for children to engage directly with scientific processes and concepts. They worked collaboratively with peers, developed argumentation and discussion skills, and the project promoted curiosity, creativity and inclusion (McGregor & Precious, 2015). It led the children to connect what they learned in science with their experiences in life, promoting ownership of their learning. The researchers argued that *'Drama can support constructivist learning because the children become active agents of their own learning'* (McGregor & Precious, 2015, p.23).

Talk and discussion was a major part of this process, helping the children to be more aware of the benefits of dialogic talk in their learning to aid problem-solving and to develop their science understanding (Mercer, Dawes & Staarman, 2009; Alexander, 2010). This article represents my reflections on the learning experienced in the school, using social-constructivist learning theory to shed light on the outcomes I observed. I found that many of the activities spawned deep learning involving discussion, exploration and modelling, which enabled the young learners to understand new concepts, and develop their own scientific understanding.

Background

An old-fashioned and clichéd model of teaching, where an instructor relays knowledge to a fairly passive student, has changed over the last 20 years. The introduction of the National Curriculum in 1988 and its subsequent reviews have promoted a much more dynamic and child-centred curriculum. The 2013 curriculum review introduced 'Working Scientifically' as a major part of the science curriculum, which has further promoted child-led learning and practical investigations as integral to a child's education in primary schools (Department for Education, 2013). Reports such as the Wellcome Trust's recommendations for reviving primary science (The Wellcome Trust, 2014), alongside Ofsted reports on maintaining curiosity, may have been influential in effecting this change (Ofsted, 2013). Employing techniques that involve children in active science learning, which are transferrable across the curriculum, are therefore useful (McCallum, Hargreaves & Gipps, 2000). Mastery in the new curriculum, which involves consolidation, practice and discussion of an idea by reviewing and revisiting learning, is encouraged (Department for Education, 2013). Practices that allow for the testing of ideas and promote the assimilation of previous knowledge are key in promoting mastery, as are active experiences that facilitate and enhance learning (Archer *et al*, 2015). Conceptual understanding must be an integral part of the learning (Skamp & Preston, 2015). I will reflect on how children's social interactions also facilitated deeper learning; the dramatic activities used within the science project were rich in social interactions.

Methodology

Learning in the context of using drama activities is by and large a social learning experience, with children working collaboratively and coming up with ideas and theories expressed in new and different ways. I have oriented this paper around learning theories to illuminate and help explain the learning experienced. I will reflect upon learning evidenced in light of social constructivist theories, in which connection-building using scaffolds for learning, and dialogue to promote deeper understanding, are key. Dewey's (1859-1952) theories of practical learning through creativity and collaboration; Bruner's (1915-2016) scaffolding of learning to enhance development; and Vygotsky's (1896-1943) zone of proximal development, where the potential for learning beyond the child's usual means is facilitated via knowledgeable others, will be used to help understand the learning. Bruner's ideas of allowing children to construct ideas and knowledge through doing – learning being a process of discovery – are also important. The drama activities incorporated in the children's learning allowed all the facets of their learning to be polished and showcased, and led to enjoyment, enthusiasm and deeper learning.

By using reflection to examine the teaching and learning experienced within the Dramatic Science project, I am aiming to engage in continuous professional learning. It has enabled me to recognise and examine assumptions and patterns of learning behaviour in the children, allowing exploration of their learning. The process has enabled me to become more aware of how children learn, the links to social learning theory and the importance of dialogue and peer interaction in meaning-making.

Analysis and discussion

This project included thinking, discussion and reflection at its core. New units would often be introduced with a dramatisation of a monologue, based on a scientist relevant to the field of study. Example monologues can be accessed in *Dramatic Science* (McGregor & Precious, 2015). Having listened to a dramatic monologue about a leading scientist in the field who the children were studying, they worked together at the start of a topic to create a tableau (Figure 1). This allowed them to demonstrate their thoughts and ideas about how the scientist may have worked. It would seem that the discussion about a scientist's qualities and collaboration in working scientifically inspired children to fully engage in the activities. It helped them to understand that scientists are real people like us, and have struggles to go through in order to attain their goals. Children expressed that it made them feel that *'I know that I can be the scientist that I want to be'* ('Clare', 2017).

Dewey (1938) argued that learning should be based on inquiry, where pupils experience real life, practical workshops in which they can demonstrate their knowledge through creativity and collaboration (Jennings, Surgenor & McMahon, 2013).

Figure 1: Children forming a tableau demonstrating the qualities of a scientist.

Figure 2: Modelling cotton growing with counters representing nutrients in the soil.

After the dramatic monologue starter, children would then move on to practical investigations based on real life examples. Dewey stated that practical work gave '*...the student a better hold upon the educational significance of the subject-matter he is acquiring*' (Dewey, 1904, p.2). He advocated that pupils should be provided with opportunities to think for themselves and articulate their thoughts, working in depth on any topic. The experiences of learners in the dramatic science project adhered to this principle.

For example, while studying a plants topic, the work of George Washington-Carver (Biography, 2018) was explored via dramatic monologue before thematic work undertaken. Having learned about the decreasing yield for the cotton farmers over time, the children then modelled cotton seeds growing, employing counters on the floor to represent nitrogen in the soil (Figure 2).

Each child became a 'seed' and, as it grew, a counter was picked up. Once there were no more counters, the new seeds ceased to have the nutrients to grow healthily. They then modelled peanuts growing, fixing new nitrogen in the soil by replacing counters. This enabled the children to conceptualise how certain plants deplete the soil's vitality, while others can replace minerals. They then discussed and modelled how crop rotation serves to replenish the soil's fertility.

This discussion then led the children to examine the school's surrounding farmland. Some had noticed that different crops were grown on the field beside the school each year. This discussion led to the children suggesting that they try growing the same plant in the same soil repeatedly, to see what happened (Figure 3). Radishes were chosen, as they crop quickly. After several rounds in the same soil, the children saw how the radishes were poorer in size. This led them to develop a crop rotation plan for the school garden. Further practical inquiry was used as the children went on to explore different ideas for uses of a plant, in the same way that George Washington-Carver had come up with over 150 ways of using the peanut.

They practically tried and tested product design for their ideas, linking to design and technology objectives, and used discussion to link their everyday ideas towards a more scientific viewpoint

Figure 3: Growing repeated crops in same soil.

Figure 4: Modelling seed germination.

(Mercer *et al*, 2009). Other cross-curricular links were drawn, linking to Black History Month and employing their science learning in their creative writing. This practical exploration of the theory and practice of a famous scientist led the children to develop individual learning ideas gained from hands-on work and drama exploration (Claussen & Osborne, 2013). Experiential learning afforded the children the ability to imagine themselves as real scientists, such as George Washington-Carver (Fisher, 1998). They were able to articulate their learning, linking the theories of how plants grow and develop to practical applications, such as the crop rotation plan for the school garden, broadening the scope of their learning and framing their learning experiences. Indeed their shared discussion deepened their understanding (Turner *et al*, 2012) and provoked a desire to care for the soil and the local environment, leading many to join the school's Eco Club and take an active interest in caring for their local environment.

The drama project used the spiral nature of the National Curriculum, where topics are revisited at a deeper level as the children mature, to its advantage. Prior knowledge and previously-remembered learning were examined, helping children to remember, revisit, rebuild and construct new knowledge. Bruner (1915–2016) held that all things can be taught to children and proposed that children should revisit the same ideas as they mature, presenting knowledge appropriate to the age of the learner (Wall, 2012). He advocated that children should be involved in teaching activities that enable them to explore and develop their own knowledge, based on prior learning (Bruner, 1974). As an advocate of Piagetian thinking, he initially described stages to learning, citing 'tabula rasa' based on Aristotle's idea that learning is gained by experience as a starting point, although he came to believe more in the social, cultural and historical influences on learning and that the learner *'rather than being a creature of experience, selects that which [he] is to enter'* (Bruner, 1985 p.6).

In the drama project, children's prior knowledge about a topic was often assessed by children enacting prior understanding using their bodies. For example, in a plants topic, children may have been asked to model how a seed germinates, allowing identification of misconceivers and correct conceivers (Allen, 2014).

In this example (Figure 4), the child has not modelled that a root is the first part to appear, after the seed swells. There is cognitive dissonance in the construction of his idea. During the session, when he has seen what others are doing, and explored and observed practically how seeds germinate, looking at cress seeds planted on consecutive days using a Digi-scope, he revised his ideas and adapted them, so developing a new understanding. For the teacher this was a useful tool, as his ideas could be clearly seen.

This helped in planning subsequent teaching to effectively address alternate conceptions identified (McGregor *et al*, 2017). Mansour and Wegerif (2013) proposed that children need a place in their lessons where they can discuss and listen to a range of often tentative views so as to develop their learning. These ideas that have previously been held as truth, or used to make sense of the world, are challenged via drama and discussion, leading children to re-form their thinking (Driver, 1988). Revisiting a modelling activity such as this, after the children had had further learning and exploration on the topic, enabled the teachers to see whether the child had changed his/her ideas and developed new learning. Learning experiences that incorporate multiple perspectives and involve reflection lead to effective knowledge acquisition (Mansour & Wegerif, 2013, p.81) and the drama activities facilitated this.

Excitement and curiosity were evident in the learners during sessions using drama activities. Bruner advocated goal-directed learning driven by curiosity and held that social interaction lies at the heart of good, effective learning (Jennings *et al*, 2013). Curiosity in learning is also set out in the National Curriculum (Department for Education, 2013, p.144), which urges that *'pupils should be encouraged to recognise the power of rational explanation and develop a sense of excitement and curiosity'*, advocating that children's learning be curiosity-led. Ofsted (2013, p.4) stated that *'the best science teachers… set out to "first maintain curiosity" in their pupils'.*

Bruner's later work expanded on the idea that knowledge is socially constructed. Within the project, we found that the social and collaborative aspect of the learning enhanced the children's curiosity and inquiry skills. They were able to incorporate discussion and co-operation in their learning, thence producing new ways to solve problems. This discussion was dialogic in nature, with reciprocal interchanges between pupils. The dialogic repertoire of the children was expanded, as they delved into interrogatory and exploratory talk alongside their learning talk (Alexander, 2010). For example, in designing a method of windborne seed disposal for a 'paper-clip' tree, the children first watched clips of seeds being dispersed, explored some different seed carriers themselves, and then modelled with their bodies how seeds might travel. They subsequently designed their own seed carrier together. They were able to refine and improve designs via discussion and interaction, looking at others' methods and making prototypes to try (Figure 5).

This type of activity helped the children to develop reasoning skills, as they discussed and justified their designs collectively. The collaborative nature of their learning seemed to be an effective tool in developing deeper and more critical approaches to problems. Vygotsky (1930) proposed a number of theories that *'emphasised social processes as the means by which all reasoning and understanding arises'* (Jordan *et al*, 2008, p.59). He held that, through interaction with others, knowledge is created and then internalised. Tools such as language and social interaction were seen as vital to the development, creation and assimilation of ideas and learning (Vygotsky, 1962). However, where Dewey and Vygotsky base the development of new thought processes on language, Bruner felt that there is not one single way, thus, by equipping students with a whole menu of learning strategies from which they can choose, successful education is unlocked. Self-motivation and curiosity empower the learning alongside support, courage and risk-taking (Bruner, 1985). Vygotsky emphasised the role of language and culture in cognitive development, where learning is essentially a social phenomenon and children actively construct learning as they interact with others (Wray, 2014). Vygotsky's key idea of the 'zone of proximal development' (1930) led many psychologists to develop the belief that learning can be enhanced by scaffolds to support a depth of learning greater than that achieved without support (Rochford, 2016; Wray, 2014). He advocated that social interaction is the means by which effective reasoning and good understanding is achieved. This 'zone of proximal development' described how providing support helps learners to progress further than if they work in isolation (Vygotsky, 1930). A key strategy in the drama activities was the use

Figure 5: Collaborating to test refined prototype for seed dispersal.

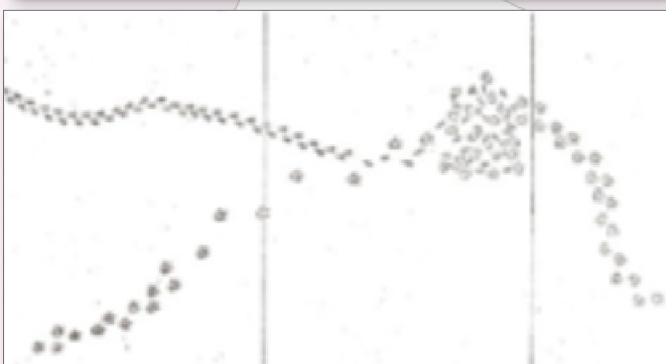
Figure 6: Illustration of fossilised footprints found in a Staffordshire mine.

and support of knowledgeable others accompanied by frequent discussion of their ideas amongst peers. During the drama project, each technique used was examined reflectively.

After some sessions, children were interviewed to ask how the strategy helped them to learn. This enabled analysis of the learning encountered and provided a child's voice on the learning process. For example, some children discussed their learning of how electricity travels in the torch circuit. In the group was a child who had previously taken a torch apart, and had seen the circuit in detail and developed his own ideas as to how it worked. The knowledge of the physical layout of the internal workings of a torch facilitated the group to arrive at a much more accurate model of the process than the other groups who had no 'knowledgeable other'. Another example within a plants topic, where prototype seed carriers were made, used the knowledgeable voice of the Science Governor to help them refine methods of making paper aeroplanes that flew well. These initial ideas were then improved and taken further by the group via collective discussion, leading to a more effective seed carrier than if they had been left to their own devices. This enabled the children's potential for development to be tapped through collective actions, hence building new learning.

Dialogic techniques

The importance of discussion in science learning cannot be underestimated. Many of the activities undertaken in the project helped the children to develop ways of expressing their ideas, a willingness to listen to others, explore differing ideas and adapt their own thinking in the light of shared experiences and new discoveries. They had 'talking science' sessions (Eley, 2003), where listening and open discussion were modelled and practised, so that they could better articulate their knowledge development and learning. This is a method that also explores argument as a teaching and learning strategy for primary science. It required the children to engage with the language of science, but also generate and justify their claims to knowledge (Eley, 2012). An example from the project evidencing this, within a rocks and fossils topic, comprised discussion revolving around an activity that I devised, using the fossilised footprints of two animals (Figure 6). Children were asked to hypothesise what could have been happening, using evidence from the picture to draw their conclusions. One child hypothesised that the larger footprints showed the animal beginning to run. To justify his view, he demonstrated walking and running, illustrating the size of stride for each. The children then used this information to discuss what could be happening and predict what the next set of footprints would show. This was accompanied by



Figures 7 & 8: Photograph and diagram of the full set of footprints uncovered in a Staffordshire mine.

children using clear arguments, with justification and evidence to support their claims. Each group came up with different scenarios, which they could clearly defend.

In this lesson, two further slides were gradually added (Figures 7 & 8), and children asked to re-form and justify their refined views. This further illustrates the dialogic nature of the learning, where Alexander's principles of collective, reciprocal, supportive, cumulative and purposeful learning were evidenced (Alexander, 2010).

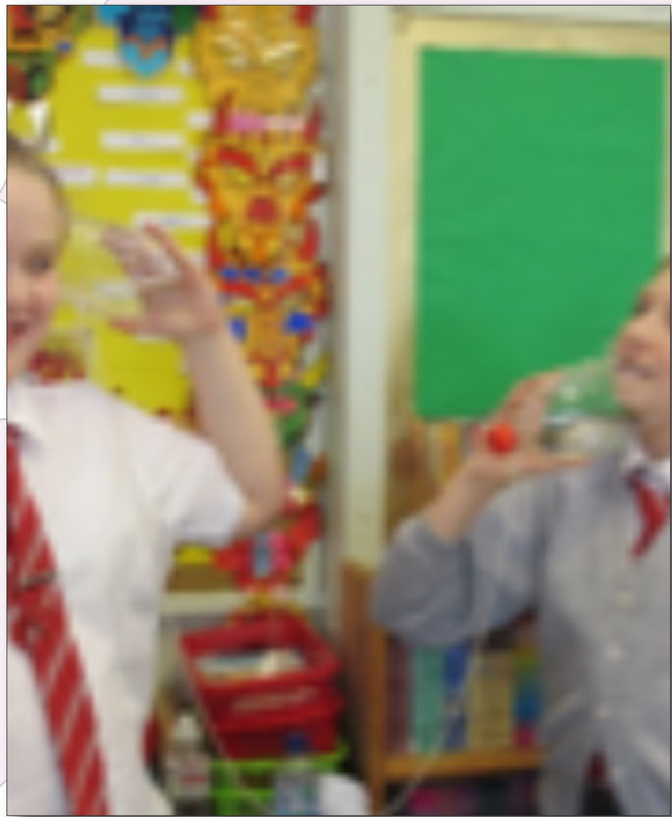
Within the project, an emphasis on discussion and trying out new ideas using drama strategies enabled the children to express their new ideas as they formed, refining and improving on their developing theories. They gravitated towards new groups within the class, as children with similar ideas teamed up. These learning groups, or communities of practice, are a key idea in Wenger's theories (1999). He argued that we are all part of communities of practice when we share and interact in an activity together and with the world around us (Wenger, 1997). The learning community formed by children engaging in scientific drama activities united them and gave them a sense of community as they negotiated new meaning together. For example, when children were investigating burrs, following the work of George de Mestral (Biography, 2018b), they came up with their own models and ideas as to how the burrs cling and grip (Figure 9). Reflecting on this activity, children demonstrated an ability to use past experiences of how things grip and cling, to devise mechanisms that the burrs might use. They built on their own past experiences as well as modelling and discussing possible means by which burrs could cling and release. As groups began to discuss and refine their own ideas, they formed strong bonds with each other, because all the participants felt ownership of their group's shared vision.

Although building on what children currently know is an important idea held by constructivist theorists, effective learning also moves children from where they currently are, addressing misconceptions on the way, arriving at a goal via a child-led path, which deepens both knowledge and understanding (Driver & Oldham, 1986). Ausubel (1918-2008) placed great emphasis on what the learner already knows, with the construction of

Figure 9: Children modelling how they understand Velcro to work, so creating new meaning together.

new concepts and enlarging of held knowledge occurring via shared learning experiences. He also advocated that the learning, dependent upon the individual's knowledge base, be meaningful (Ausubel, 1969). This is where the science project was effective, as each child articulated their own knowledge through drama, which could then be collaboratively altered and consolidated as they learned and shared new ideas together. As illustrated earlier in this article, examples of meaningful learning, with real life application, enlarged the children's knowledge and understanding of the world. When looking at George Washington-Carver's work, his amazing inventiveness and ingenuity spurred the children into inventing many different products from one source – as George had done with the peanut. This real life example helped the children to understand better the diverse work of scientists. They chose an object, for example an onion or a plastic bottle – and had to invent as many ways of upcycling or repurposing this. Paper, dye, food, insect repellent and polishing metal were some of the uses they came up with for an onion.

Figure 10: Using ingenuity to invent new purposes for plastic bottles.



Plastic bottles generated many new products (Figure 10), and forged links with sustainability and using the planet's resources wisely. Where our experiences move away from Ausubel's theory, however, is his lack of stress on practical learning, in which he states that there is an *'unwarranted belief…that discovery learning is invariably meaningful'* (Ausubel, 1977, p.163). The experiential nature of the learning evidenced in the project demonstrated the value of discovery learning.

Society, and the children's ideas of how our society has changed and functions, is another important factor in children's learning. Wenger (1997, p.38) argued: *'It is doing in a historical and social context that gives structure and meaning to what we do'.* Learning about scientists from different eras through dramatic monologues also helped the children to better understand how society and culture affect their learning and enabled them to gain respect and understanding for scientists' contributions to knowledge. The renewed National Curriculum (DfE, 2013) states the importance of using scientists' work and its significance to children's lives today. The use of drama activities and collaborative work provided shared meanings and understandings negotiated and rationalised through discussion (Jordan, Carlile & Stack, 2008). In fact, the dramatic monologues took the children back in time, where they could experience some of the trials and difficulties faced by the scientists studied, via role play. For example, when studying Jenner (1749-1823) and his smallpox vaccine, having watched a video monologue (BBC, 2012), children acted out the immunisation of the first child (Figure 11), which then led to debate and discussion about ethics at the time and what this would look like in today's world. Children, when asked to create a tableau of the characteristics needed by the scientist, could try to adopt these qualities in their own inquiry. Their learning became culturally sited, as they explored, via drama, the times and culture of the scientist.

When children construct their own idea of a scientist's qualities, and add to their ideas by tapping into their peers' insights, they begin to exert their power of expression. They bring to the tableau their cultural understandings of both the present and the past, as presented via the monologue. They adapt what they think the scientist would have had to do in the face of historical cultural differences, helping them further understand the changes that our world has undergone. In the context of drama activities, the children did appear to construct their own ideas and interpretation of the activities presented. By using drama activities to structure their own ideas of events, then learn more about them in further research and study, children exploited a scaffold to learning, such as Vygotsky proposed in his 'zone of proximal development' (Vygotsky, 1930) and to

Figure 11: Children enacting Jenner's work.

which Wood, Bruner and Ross gave the metaphor (Wood, Bruner & Ross, 1976).

One of the main building blocks of the drama project was the idea of scaffolding learning, introduced by Bruner in the 1950s (Wood, Bruner & Ross, 1976). This aims to bring about understanding, *'providing or scaffolding learning experiences, from which emerge, or are presented, phenomena to feel, see or hear (i.e. to sense) and be reflected upon'* (McGregor & Precious, 2015, p.22). Models can be considered as flexible ways to understand children's knowledge constructions, as they provide scaffolds to guide their understanding of concepts that are difficult for the children to physically experience (Acher *et al*, 2007). Ideas such as the way planets orbit the sun, how the blood travels through the heart, the transfer of micro-organisms in poor hand-washing or the process of fossilisation, can be enacted and modelled to help the children to understand through physical means, helping them engage with and understand a fairly abstract idea (Harlen *et al*, 2015).

Developing thinking skills through skilful questioning to further probe what the children are expressing in their models also helps new learning to develop (Cullinane, 2010). Early social constructivists proposed that children could learn beyond their developmental age, but within their potential of development, by using support from adults and peers and scaffolds (Lee *et al*, 2016). Many of these ideas have subsequently been developed (Driver, 1988), but this idea of modelling in the drama project (Wood *et al*, 1976), where children imitate and try out things themselves to help them clarify thinking and come up with solutions has, on reflection, been seen to be effective. This active and participatory learning can draw on the children's social resources, acting as a scaffold to their learning (Littledyke, 2004).

Conclusion

Reflecting on diverse learning experienced over the several years of the project, and situating it within theorists' and scholars' views, has enabled me to form a clearer understanding of how drama can enhance and support learning in primary schools. The active, collaborative nature of the learning was inclusive and enabled all children to access experiential learning. The diverse opportunities for discussion, as well as development and refinement of ideas, increased their capacity for dialogic learning and reinforced my own understanding of the benefits of dialogic teaching methods. The enthusiasm, curiosity and engagement evidenced in the children's learning have further reinforced my impression that this type of approach is valuable and productive for all children. Incorporating drama into lessons has indeed supported the children to change their ideas and forge new learning in order to produce a better understanding of the world around them, one of the goals of effective primary science education. My reflections upon the learning should hopefully promote similar approaches being used in many other primary schools in the future, as the usefulness of social collaboration in learning, the value of dialogic practices and the use of scaffolding to enhance and deepen understanding are all evidenced.

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why & how?
PRIMARY SCIENCE TEACHING TRUST

Teachers' attempts to improve assessment practice in primary science are influenced by job role and teaching experience

• Isabel Hopwood-Stephens

Abstract

Recent changes to assessment policy in England have brought the development of primary teachers' assessment literacy in science to the fore. The TAPS pyramid is a tool to help teachers and schools improve their assessment practice in primary science. It has been downloaded thousands of times across 45 countries, but little was known until now about its impact upon the assessment practice of the teachers using it.

This report analyses quantitative data from an online survey of 96 teachers using the TAPS pyramid to show that changes in practice vary across job role and teaching experience. These differences are explored with reference to changes in national assessment policy, but also the wider international research into developing primary teachers' assessment literacy. Finally, an argument is made for school leaders to consider the diversity in assessment literacy present among their teachers when developing primary science assessment practice.

Keywords: Assessment practice, primary science, role, experience, variation.

Formative assessment in primary science

Formative assessment has been defined by Klenowski (2009) as: *'[the] everyday practice by students, teachers and peers that seeks, reflects upon and responds to information from dialogue, demonstration and observation in ways that enhance ongoing learning'* (p.264).

The proven power of formative assessment to improve teaching and learning across the curriculum (Black & Wiliam, 1998a, 2009) has led to a gradual shift in attention from summative written assessment as the way to judge pupil progress, to the ongoing use of formative assessment by teachers to *'identify specific student misconceptions and mistakes while the material is being taught'* (Kahl, 2005, p.11).

In the UK, today's primary school teachers are expected to be skilled practitioners of formative assessment (Ofsted, 2013). Indeed, the importance of developing teachers' assessment literacy during initial teacher training has been both recognised for its importance and lamented for its variability (Carter Review, 2015).

Formative assessment is an intentional form of assessment (Hondrich *et al*, 2016). Unlike a written test with a fixed marking scheme, it is a dynamic process mediated by the teacher, who will plan appropriate opportunities to use strategies such as questioning or elicitation, reflect upon their outcomes and use those to shape further input, both 'on the fly' while teaching (Serret *et al*, 2017) and afterwards, while marking students' work or planning further lessons.

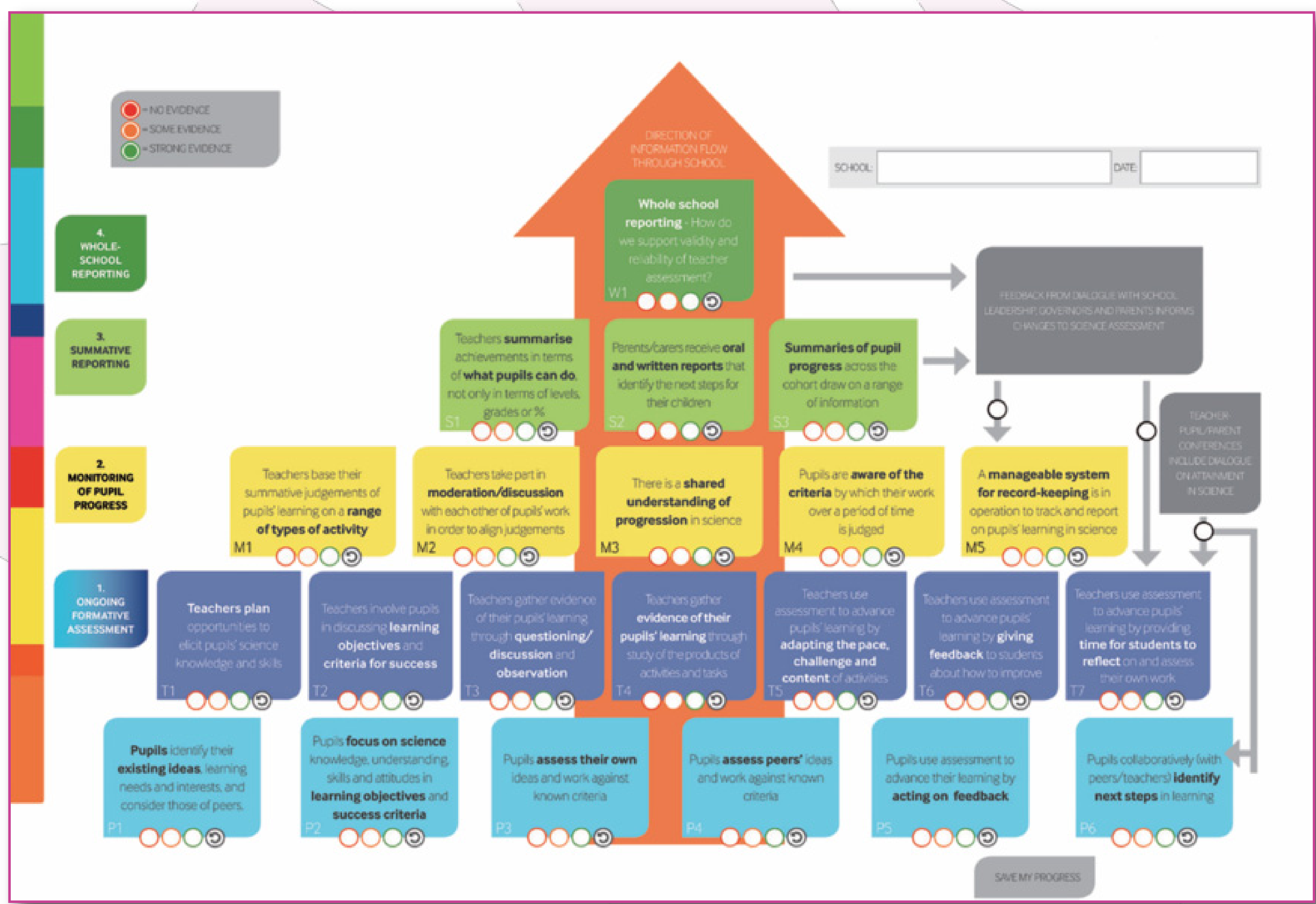
Subject-specific guidance on how to use formative assessment effectively in the teaching of primary science has been available for over a decade (Black & Harrison, 2004), and various formative assessment strategies appropriate to the teaching of primary science have been identified in the literature (Hodgson & Pyle, 2010).

UK primary teachers have been shown to use formative assessment strategies considerably less in primary science than in other core subjects, however (Hodgson, Pyle & Shamsan, 2009). To understand why this issue might have arisen, it is useful to understand recent changes to assessment policy and the curriculum for primary science. Thirty years ago in England, summative judgements of pupil progress were produced by the class teacher, using a range of sources and examples of work. This changed in 1988 when, in an attempt to standardise the criteria used and the judgements themselves, learning outcomes for primary school pupils in science were assessed through externally administered high-stakes written tests in the final year of primary education. Progress towards these final summative tests was monitored using a system of best-fit descriptors of ability in various skills and knowledge areas, a process known as levelling. The perceived need among school leaders to achieve good outcomes for their pupils in these national high-stakes summative tests, as well as to demonstrate progress against the levelling descriptors, led many schools to rely upon regular written testing of knowledge to demonstrate that learning was taking place (Tymms, Bolden & Merrell, 2008).

Concern about how such testing was distorting the primary curriculum led to the abolition of summative assessment by high-stakes written test in 2009 for primary science, although it remained for the other core subjects of literacy and numeracy. And, while the abolition of national testing in science may have led to a broader and more balanced science curriculum in some schools (Wellcome Trust, 2011), the diminished relative status of primary science led to a reduction in resourcing for the subject in others, with 40% of surveyed schools reporting static or decreasing budgets (SCORE, 2013), and less subject-specific professional development for teachers and Science Subject Leaders (SSLs) alike (Wellcome Trust, 2014).

A further government overhaul of assessment policy in 2014 (Department for Education, 2014) led to the abolition of assessment of pupil progress by levelling. Teachers were now required to reach a summative judgement of pupil progress based on a range of data sources, which might *include* written tests, but *not be limited* to them (Commission on Assessment Without Levels, 2015). This presented an opportunity and a risk to all primary schools: the opportunity to develop an assessment framework that produced a well-rounded summative teacher judgement of progress, and the risk that, without any central guidance on how to do this, the bespoke assessment frameworks developed by schools would not be as rigorous, reliable or manageable as the written tests used previously (Earle, 2017).

Figure 1: The TAPS pyramid.



The role of the TAPS pyramid

The TAPS pyramid is a tool to help teachers and school leaders understand how rich formative assessment data can be collected and used for summative judgement processes (Davies *et al*, 2014) and is based upon an existing model for the flow of assessment data through a school (Nuffield Foundation, 2012). The TAPS pyramid builds upon this model by specifying the types of assessment activities that would be appropriate at each level, from collecting formative data in the classroom to using it to form summative reports of pupil progress (see Figure 1). As such, it provides individual teachers and schools with a tool for evaluating their existing assessment practice and taking steps to improve it, while also exemplifying an assessment framework that fits the current English assessment policy of using teacher judgment to define pupil progress.

The TAPS pyramid has been presented at conferences, seminars and meetings of science subject specialists, and downloaded many times in the UK and abroad (Hopwood-Stephens, 2017). But how exactly has it been used, and by whom? And what impact has it had upon the assessment practice of the primary teachers using it?

Methodology

This research analyses an excerpt of data from an online survey to discover where and how the TAPS pyramid had been used in schools.

Dissemination

The TAPS pyramid user survey was hosted on a third party website and was live between December 2016 and February 2017. A link to the survey was disseminated through the website of the Primary Science Teaching Trust (PSTT) and their College Fellows network. It was also disseminated to schools applying for the Primary Science Quality Mark (PSQM), and by contacting people who had attended professional development events where the TAPS pyramid had been presented.

Design

The thirteen ongoing formative assessment activities specified in the blue layers of the TAPS pyramid (see Figure 1) were rationalised and presented as nine statements. These rationalised statements of assessment activities were reviewed by an expert panel and pilot tested before inclusion in the survey. The statements are listed in Table 1 for reference. Survey participants rated their engagement with each of the assessment activity statements by choosing from three possible responses: *I was doing this already; I do this as a result of TAPS pyramid; I don't do this yet.*

Respondents were also asked to select their most senior current job role from *Teaching Assistant; Class Teacher; Science Subject Lead; and Assistant / Deputy / Headteacher* (henceforth referred to as Leadership). They also indicated how long they had worked in primary school teaching, from the

Table 1: Rationalised assessment activities in the online survey, taken from the TAPS pyramid.

Key	Assessment activity
A	I plan opportunities for eliciting children's science knowledge and skills
B	I discuss the learning objectives and success criteria for science lessons with my class
C	I gather formative assessment data from observations, questioning and / or discussion
D	I gather evidence from a range of different science activities for assessment
E	I use formative assessment to adapt the pace and challenge of science lessons
F	I give children written or oral feedback on how to improve
G	I give the children time to reflect upon their science work
H	I judge pupil progress in science by looking at a range of formative data
I	I have a manageable system for keeping and using formative data

following groups: *0-3 years; 4-7 years; 8-13 years; 14-19 years; 20 or more years.* The groupings for years in teaching were based upon changes to national assessment policy and curriculum guidance, hence their irregularity.

Procedure and ethics

The survey took between five to ten minutes to complete. In line with British Education Research Association ethical guidelines (BERA, 2011), the purpose of the survey was made clear to participants on the first page, as well as how the data would be used. Participation was voluntary and participants could leave the survey at any time without completing it. The last page of the survey also gave the contact details for the researcher, in the event that the participants had questions or wished to withdraw their data. No requests to withdraw were received.

Analysis of responses

Once incomplete data sets were removed, the data contained 96 complete sets of responses. Descriptive statistics were generated using third party survey analysis software, with all percentages rounded to the nearest whole number.

Results

The following section describes the overall results, and the results when grouped by job role and years' experience in teaching.

Overall impact upon individual practice

Figure 2 shows the percentage of respondents stating that they now use the assessment activities listed in Table 1, as a result of their use of the TAPS pyramid.

The data show that, overall, as a result of engagement with the TAPS pyramid, activity has increased across the specified range of assessment activities. This is most obvious for assessment activity G, *I give the children time to reflect upon their science work*, with almost half of the respondents indicating that they now do this as a result of using the TAPS pyramid. Forty-two percent also report that they now *judge pupil progress in science by looking at a range of formative data* (H). This is triangulated by the finding that over one third also report that they now *gather evidence from a wide range of different science activities for assessment* (D).

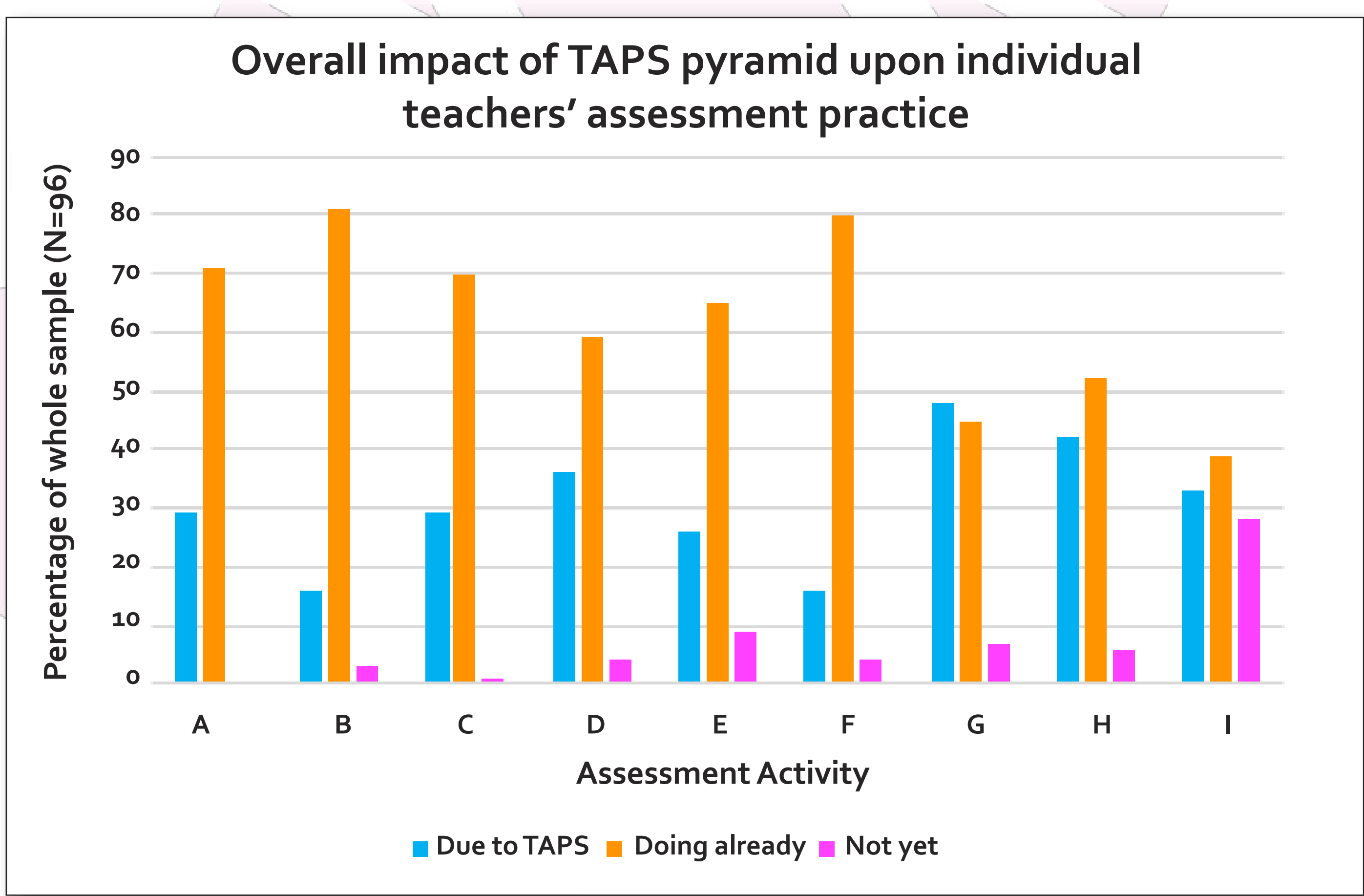


Figure 2: Overall impact of using the TAPS pyramid upon teacher assessment practice.

Taken as a whole sample, the TAPS pyramid seems to have had the least impact upon the following assessment activities: *I discuss learning objectives and success criteria for science lessons with my* class (B) and *I give children written or oral feedback on how to improve* (F). Eighty percent of all respondents indicate that they already engage in these assessment activities, possibly because they are already firmly embedded in lesson planning templates and school marking policies in many schools.

The activity that seems hardest overall for individual teachers to implement is I: *I have a manageable system for keeping and using formative data*, with 28% overall saying that they have not yet engaged with this assessment activity. Interestingly, this activity also has the lowest number of respondents indicating that they did this already.

Impact upon practice by job role

When respondents were grouped by job role, there were 12 class teachers, 73 SSLs and 11 in leadership positions.

It is clear from the graph in Figure 3 that the TAPS pyramid had the most pronounced influence upon the assessment practice of class teachers, followed by SSLs and then leadership. Sixty percent of the class teachers surveyed indicate that they now *plan opportunities for eliciting children's science knowledge and skills* (A), 60% indicate that they now *give children time to reflect upon their work* (G), and 50% report that they now *gather formative assessment data from observations, questioning and / or discussion* (C). Just under one third also report that they now *give written or oral feedback on how to improve* (F).

In comparison, SSLs are more likely to already be engaging in those assessment activities. Instead, they are more likely to report that they now *gather evidence from a range of different science activities for assessment* (D) and *use formative assessment to adapt the pace and challenge of science lessons* (E) as a result of using the TAPS pyramid.

Among leadership roles, the TAPS pyramid has had most impact upon *giving the children time to reflect upon their work* (G). Where it had no impact upon practice (activities F and I), it was due to respondents stating that they already engaged in those activities. The modest impact upon assessment activities such as *using formative assessment to adapt the pace and challenge of*

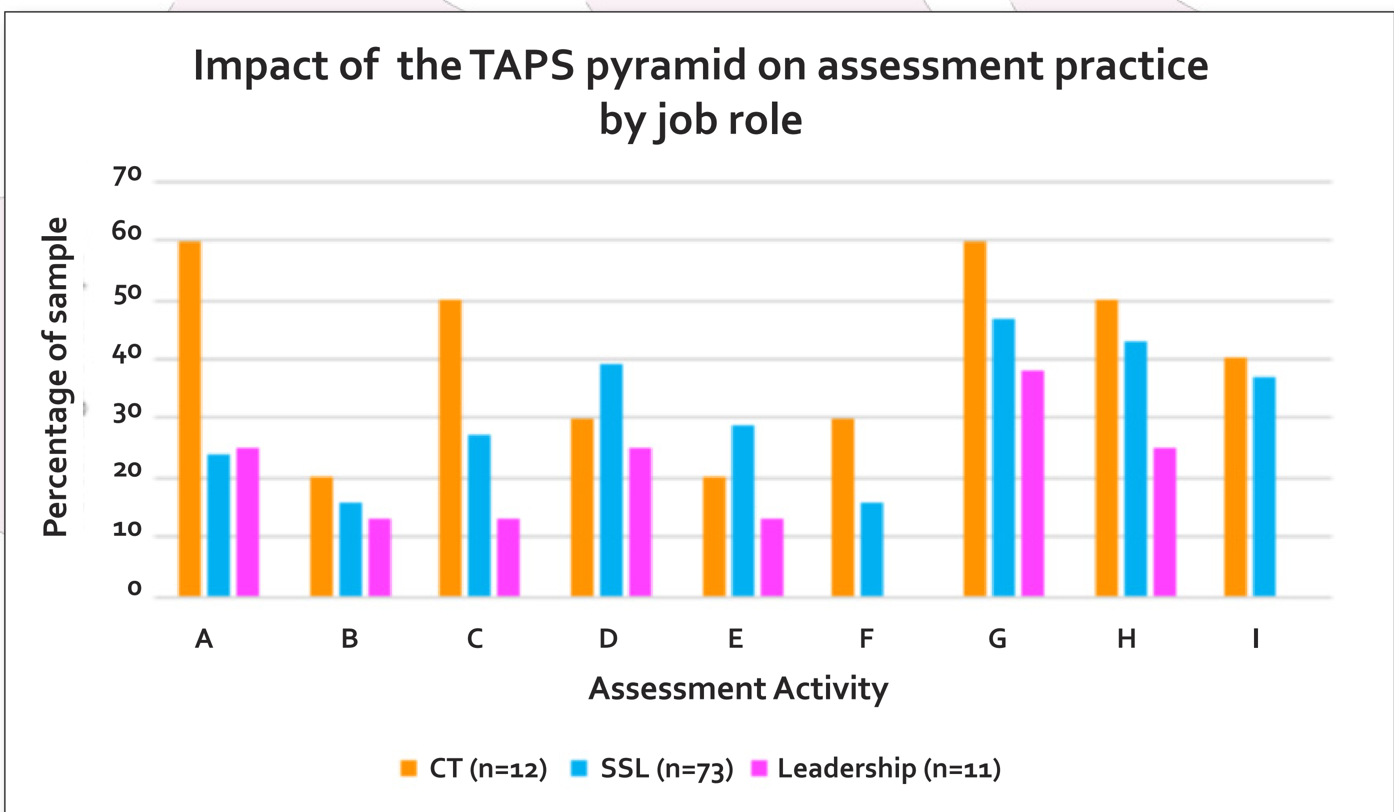


Figure 3: Graph to show the impact of the TAPS pyramid upon assessment practice, by job role.

lessons (E) may be partly due to these respondents having no class teaching responsibilities.

In summary, the impact upon practice seems to vary according to the job role and associated responsibilities of the person using it, with class teachers using it to develop their range of formative assessment strategies and SSLs using it to expand their use of the formative data that they were already generating. It has had the least impact upon the practice of those in leadership roles.

Impact upon practice by years in teaching

The line graph in Figure 4 shows the impact of each of the assessment activities across the respondents' years in primary teaching.

A prominent feature of this graph is the peak in impact among teachers who have been teaching for three years or less. For activities C: *I gather formative assessment data from observations, questioning and / or discussion*, G: *I give the children time to reflect upon their work* and H: *I judge pupil progress by looking at a range of formative data*, 80% of this group report that they now engage in these assessment activities as a result of using the TAPS pyramid.

A second, smaller, peak in impact can be seen in some of the assessment activities for teachers who have worked for between eight to thirteen years, such as *I have a manageable system for keeping and using formative data* (I) and *I give the children time to reflect upon their work* (G).

There is a further spike in the impact upon practice for respondents who have taught in primary schools for the longest (twenty years or more); the only activities that show a decline in impact upon practice for this group are *I plan opportunities for eliciting children's science knowledge and skills* (A) and *I give children written and oral feedback on how to improve* (F).

Overall, it looks as though the TAPS pyramid has influenced assessment practice most in those teachers who are newest to the profession, followed by those who have worked in it for the longest.

Discussion

The following themes identified in the results will be explored in this section: the changing impact upon practice as job role and years in teaching change, and also the diversity of assessment literacy among the primary workforce.

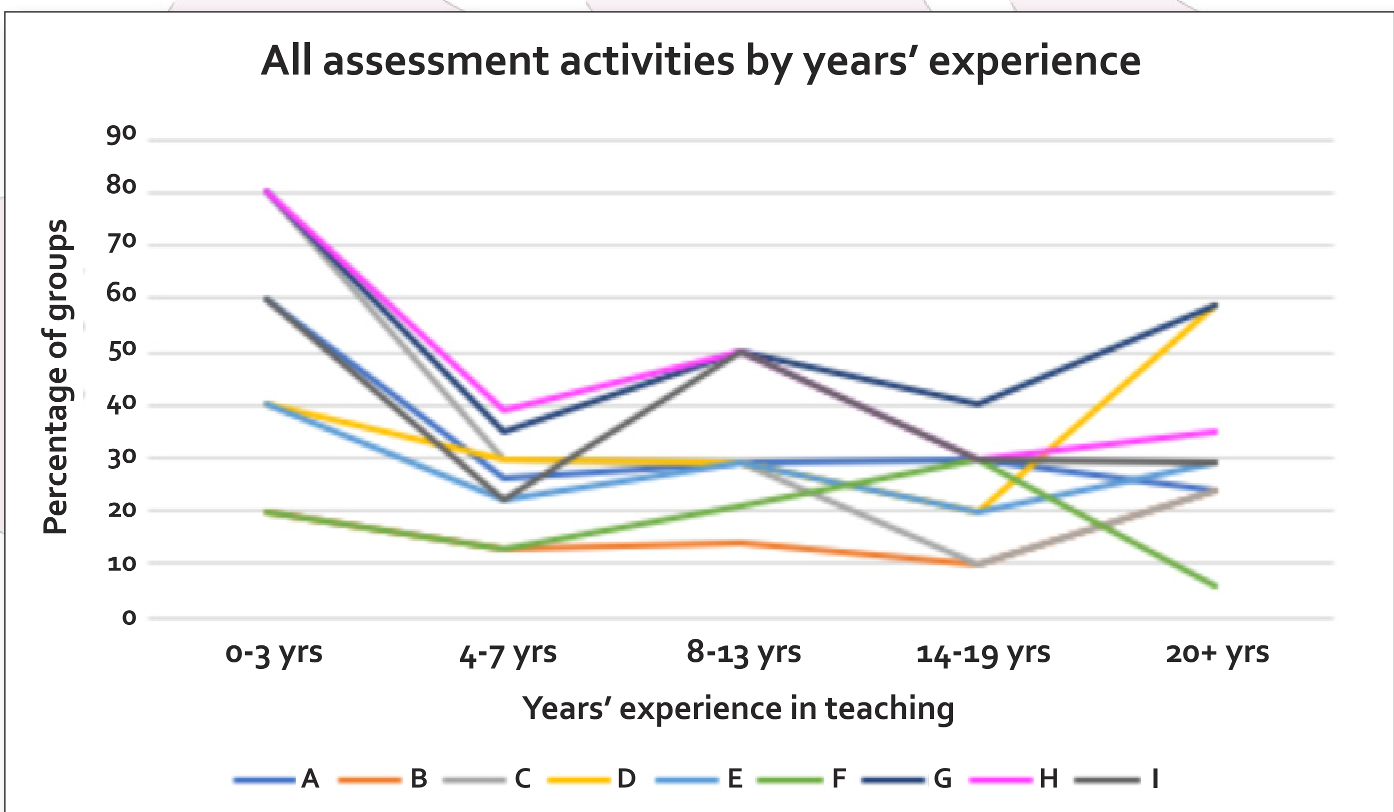


Figure 4: Line graph to show impact of TAPS pyramid across years in teaching.

Impact upon practice changes with seniority of job role

These data show a noticeably higher level of impact upon the assessment practice of class teachers, compared to SSLs or leadership roles. This might be partly explained by a lower baseline level of assessment literacy among this group but, if so, what has caused this?

As previously discussed, primary science has been demoted in status from a core subject with regional training centres and staff development budgets (Harlen, 2008) to a lower priority core subject with no national summative testing programme for all pupils. Reductions to school funding since 2010 have also severely curtailed school budgets for training and professional development (Teacher Development Trust, 2017) and the increased autonomy of schools to set their curriculum leaves primary science vulnerable to the preferences and priorities of school leaders (Ickowitz-Seidler, 2017). Class teachers working within this context may not be given access to the subject-specific training in aspects of primary science that are offered to their subject-leading peers, nor be aware of local subject support networks for primary science. A possible explanation for the study results is that, due to constrained resources and science's deprioritised status in the primary curriculum, class teachers are a neglected group within the school for receiving professional development in this subject.

This notion is lent further weight by analysing the impact of the TAPS pyramid upon the assessment practice of SSLs. This group reported that they were already using many of the assessment activities that had such an impact upon class teachers' assessment practice. By contrast, the biggest impact upon the assessment practice of SSLs was upon activities that put the rich formative data that they were already gathering towards further use, such as adapting the pace of the lesson as they taught it or forming summative judgements of pupil progress from a range of formative data.

The limited impact of the TAPS pyramid upon the assessment practice of the leadership group might be partly explained by the changes in assessment policy that they have worked under – 45% of this group had served in teaching for twenty years or more – but also the reduced likelihood that they have a regular teaching responsibility.

The changing influence upon practice as seniority of role increases can be seen as further proof that there is no 'one size fits all' in the professional development of a teacher workforce (Hargreaves, 1999). As such, it serves as a reminder to school leaders that their perceptions of the training needs and priorities in their school should not be defined by them alone, but in partnership with those teaching in the classrooms.

Impact upon assessment practice is influenced by years' experience of teaching

It has been argued above that one reason for a low level of assessment literacy among class teachers might be their limited access to subject-specific professional development and training. Another reason might be the adequacy of initial teacher training in the appropriate and beneficial use of formative assessment in primary science, however.

As mentioned earlier, variability of initial teacher training in the theoretical and technical aspects of assessment has been identified as an area for improvement among teacher training providers (Carter Review, 2015). The fact that so many recently qualified survey respondents indicated that their use of the specified assessment activities was due to using the TAPS pyramid may indicate that these respondents had not learned these skills – or realised their applicability to primary science – until they engaged with the resource. And while issues in initial teacher training in assessment practice for primary science might be partly explained in England by science's fluctuating status, it is worth noting that variability in developing teachers' assessment literacy is not limited to one country; this is a live international concern, which has also been explored in Holland (Heitink *et al*, 2015), Norway (Smith, 2011) and Thailand (Yamtim & Wogwanich, 2014).

In the mid-range of experience (eight to thirteen years' teaching experience), there is a smaller spike in impact upon assessment practice. Teachers in this group would have entered the primary workforce while levelling and best-fit statements for pupil progress were being used.

Now that assessment policy has shifted to teacher judgements and post-levels assessment frameworks, the TAPS pyramid might prove a useful resource for developing their repertoire of formative assessment strategies and their use of that formative data; indeed, 50% of this group say that, as a result of using the TAPS pyramid, they now judge pupil progress by looking at a range of formative data.

At the other end of the spectrum, the TAPS pyramid has had a noticeable impact upon some of the assessment activities for respondents with twenty years' or more teaching experience. Fifty-nine percent of teachers in this group report using evidence from a wide range of activities for assessment as a result of using the TAPS pyramid.

It would be interesting to know whether the recent changes in assessment policy outlined above have given these teachers the opportunity to dust off previously learned skills for forming a teacher judgement of progress that fell from favour during the era of levelling and best-fit statements, or whether they feel that they have learned these assessment skills anew.

Further qualitative inquiry is planned to tease out the complex reasons for how and why the teachers in this study chose to engage with the TAPS pyramid. It nevertheless remains clear from these data that the TAPS pyramid is a resource that can be adapted to the needs of the teacher engaging with it. As such, it can be considered a useful and well targeted tool for teachers wishing to improve their individual assessment practice in primary science.

Supporting diverse assessment literacy in the teacher workforce

The results of this study indicate that the TAPS pyramid has helped teaching staff in various job roles and with differing experience to evaluate and improve their assessment practice. The following quote from a survey respondent, however, illustrates the opportunities and limitations of the TAPS pyramid as a resource for professional development: *'I would like to use the TAPS pyramid better, but changing practice takes time. I'm not dissatisfied with the TAPS pyramid – I think it's great – but with my current usage of it.'*

This respondent, a Science Subject Lead, is keenly aware of the limitations on her practice following her engagement with the TAPS pyramid, but seems unable to put her desire to improve into action.

It must be remembered at this point that the respondents to this survey were a self-selecting sample, reached through primary science communication networks. If one of these respondents, with access to subject-specific support and training in their role as SSL, has found it hard to know how to implement more of the activities on the TAPS pyramid, it can be assumed that those without subject-specific training and support would also struggle. As such, this quote simultaneously represents the usefulness of the TAPS pyramid as a roadmap for improvement, and its insufficiency in providing detailed directions.

This does not indicate a shortcoming of the TAPS pyramid as a resource, however. Instead, it illustrates the need among teachers for ongoing mutual support to achieve lasting and sustainable changes to their practice (Gassenheimer, 2013). As the respondent states, changing practice takes time, and many interventions to develop formative assessment skills in primary science have run over several months (Hondrich *et al,* 2016; Serret *et al*, 2017). Faced with shrinking training budgets and changing assessment requirements, the TAPS pyramid represents a tool for school leaders and SSLs to provide bespoke professional development in assessment practice to their non-specialist teaching staff. But this provision depends in turn on their own assessment competency and understanding of the need for support. In their review of the prerequisites for implementing formative assessment in Dutch primary schools, Heitink *et al* (2015) underlined the importance of a supportive work culture that facilitates the teachers' learning and, in Thailand, Yamtim and Wogwanich (2014) noted primary teachers' preference for collaborative working and teamwork to develop their assessment literacy. Perhaps this is the missing piece in the puzzle of changing practice: if the aim is to transform the practice of not just some but all of our teachers, we need to provide not just the physical resources, but also ongoing peer support for those who cannot access and engage with those resources independently.

Limitations to the study

The high number of respondents holding the role of SSL means that the experience of class teachers, while present in the data, is under-represented by comparison. Splitting the responses by years' experience in teaching also produced some variability in group sizes. As such, all results should be viewed as indicative.

The quantitative analysis in this report has produced a useful snapshot of the impact of the TAPS pyramid upon assessment practice, but the nuanced explanations of why respondents implemented different activities cannot be discovered by this means. In the next phase of this research, case study data from schools using the TAPS pyramid will lead to a fuller understanding of the contextual, social and hierarchical factors that can affect the decisions of those attempting to improve their science assessment practice within a primary school environment.

The issue of variability in initial teacher training for assessment skills in primary science has been raised in this analysis. Although beyond the scope of this report, it would be a profitable avenue for further scholarly inquiry.

Conclusion

Baseline variations in primary teachers' training and experience of using formative assessment have created diversity in the ability of the primary teacher workforce to assess pupil progress in primary science. Teachers' timely access to relevant professional development in this area can be influenced by factors such as job role, changes to assessment policy and the fluctuating status of the subject. The impact of the TAPS pyramid upon teachers' assessment practice indicates that this resource is well targeted and useful but, if school leaders wish to use it to develop the assessment literacy of their staff in primary science, they will need to formatively assess the range of assessment skills present in their workforce before devising an appropriate intervention, because these data suggest a wide diversity among in-service primary teachers.

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News from the Primary Science Teaching Trust (PSTT)

Why and How?

The Primary Science Teaching Trust's termly newsletter

We are delighted to be able to share our newsletter. This is a termly digital production, available on our website at https://pstt.org.uk/what-we-do/why-how-newsletter

Our newsletter is very much **aimed at all teachers** and anyone with an interest in primary science.

Each issue has free pullout resources, ready for instant classroom use. These include a picture for talk in science, a whole school challenge and a piece on misconceptions and how to address them.

Please do also actively encourage others to pass our newsletter on to their networks and, if anyone would like to be added to the mailing list for it, please contact Amy Thorman on amy.thorman@pstt.org.uk

why & how?
PRIMARY SCIENCE TEACHING TRUST

The Primary Science Teaching Trust's International Science Education Conference (PSEC)

6th – 8th June 2019 in Edinburgh, Scotland

Over three days, in the beautiful city of Edinburgh, PSTT will be offering a varied and carefully chosen programme of what we know to be the very best in professional development for primary science education, delivered by experts. The programme includes: keynote speeches * practical workshops * reflective seminars * science shows * talks * social events * a primary-focused exhibition

We know that teachers value CPD sessions delivered by other practising teachers and we are delighted that our Primary Science College of award-winning teachers will be delivering workshops at PSEC. High quality contributions to the programme will also be made by our academic collaborators and strategic partners, and other world class experts in the field.

The Conference will cover the following themes:
Neuroscience and how we learn, play and early years, assessment, working scientifically, subject leadership, transition, evidence-informed practice, creativity, outdoor learning, STEM, SEND and EAL, gender bias, emotional and mental wellbeing, and information technology.

Our call for programme proposals opens in April 2018 and will close in September 2018.

Register your interest today by visiting the Conference website: https://www.primaryscienceconference.org/ and, to be included in our conference mailing list, please contact Amy Thorman on amy.thorman@pstt.org.uk

INTERNATIONAL PSEC

Contributing to JES

About the journal

The *Journal of Emergent Science (JES)* was launched in early 2011 as a biannual e-journal, a joint venture between ASE and the Emergent Science Network and hosted on the ASE website. The first nine editions were co-ordinated by the founding editors, Jane Johnston and Sue Dale Tunnicliffe, and were the copyright of the Emergent Science Network. The journal filled an existing gap in the national and international market and complemented the ASE journal, *Primary Science*, in that it focused on research and the implications of research on practice and provision, reported on current research and provided reviews of research. From Edition 9 in 2015, *JES* became an 'open-access' e-journal and a new and stronger Editorial Board was established. From Edition 10, the copyright of *JES* has been transferred to ASE and the journal is now supported by the Primary Science Teaching Trust (PSTT).

Throughout the changes to *JES*, the focus and remit remain the same. *JES* focuses on science (including health, technology and engineering) for young children from birth to 11 years of age. The key features of the journal are that it:

- is child-centred;
- focuses on scientific development of children from birth to 11 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

The Editorial Board of the journal is composed of ASE members and PSTT Fellows, 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.

Contributing to the journal

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 in length 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.

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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) with double spacing and with 2cm margins.

- The first page should include the name(s) of author(s), postal and e-mail address(s) 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

Vygotsky, L. (1962) *Thought and Language.* Cambridge. MA: MIT Press

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

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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.

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