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Promoting Excellence in Science Teaching and Learning

why& how?
PRIMARY SCIENCE TEACHING TRUST

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why & how?
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Editorial

● **Amanda McCrory** ● **Suzanne Gatt**

Welcome to issue 16 of *JES*.

This issue presents the second part of the paper series from the 2017 ESERA Conference (first part published in *JES* 15), as well as a number of papers contributed by the Primary Science Teaching Trust (PSTT).

The ESERA Special Interest Group on Early Years promotes collaboration among researchers interested in early years science. We are happy to continue to support researchers by disseminating their work in early years science education. *JES* can thus act as a channel between research results and early years practitioners. It is essential for teachers and other practitioners to keep abreast of the latest advancements in education and learning.

To emphasise the link between practitioners and research, the contributions from PSTT provide a more practical aspect of science education, which can act as an inspiration to promote more science teaching among early years and primary teachers. The growing interest in early years science has led to increased knowledge and understanding about young children engaging with the world and in science as they investigate scientific phenomena, making it essential to bring together research and practice if we want children to engage in authentic and effective science experiences from a young age.

There are two central themes in this issue – the use of technology in science teaching, as well as a discussion regarding quality early years education in giving children authentic learning opportunities both in and out of the classroom. The use of technology in early years and primary classrooms in the UK has become a focus since computing became a core subject in the National Curriculum and it is gratifying to see that this is also a focus elsewhere across Europe. As the world continues to make technological advances, children will hopefully continue to benefit, as it is well documented that children are already interested and engaged in using technology in their own lives. Furthermore, we know that the use of technology in the classroom can impact positively on children by improving knowledge retention and encouraging individual learning and collaboration, whist promoting life skills. There are also benefits for teachers: technology and virtual learning environments can enhance traditional approaches to teaching and provide resources, lesson plans, subject knowledge support and a platform for shared ideas. Providing authentic learning opportunities for children in the science classroom is a key focus of science education and something upon which we have focused in previous issues of *JES*. The importance of providing this both in and outside the classroom cannot be underestimated, as we know that the significance of eliciting and promoting curiosity and scientific thinking in children is paramount if we wish to foster a life-long love of science.

In this issue, there are four contributions from the 2017 ESERA Conference. **Thorshag** examines the use of technology in construction play and interestingly uses variation theory to analyse data. Outcomes emphasise the important role that conceptual understanding of science concepts play in enabling children to explore scientifically and subsequently develop their understanding further via inquiry. The paper by **Kalogiannakis and Papadakis** examines and discusses the use of *ScratchJr* (software designed to be used as a tool for computational thinking) on pre-service teachers' teaching of science and computational thinking and the very positive impact this has on teachers' self-efficacy.

Kallery focuses on quality and describes a small study in Greece where early years teachers reflect on those factors that influence quality early years education provision in science. The paper provides insights into the balance between personal knowledge and competences, and external school factors on educational experiences created.

Cantó *et al* tackle pedagogical practices in and out of classrooms, and discuss the perceptions of Spanish teachers during their initial teacher training. Outcomes highlight pedagogical approaches to teaching science in the early years as traditional, with less hands-on, active exploration and inquiry as expected. The results of this paper are important not only for teachers of science in Spain, but also for teacher training educators, especially if scientific inquiry and authentic learning opportunities are to be provided for in the Spanish education system. This is exactly what **Ritchie *et al*** discuss in their interesting paper examining the oral capabilities of Year 2 (6-7 years) and Year 6 pupils (10-11 years) when exploring simple machines and their applications: outcomes highlight the importance of resources, language and questioning when providing children with authentic scientific learning experiences.

In addition to this, **Grimshaw *et al*** examine in particular the impact of outdoor learning on children whose first language is not English, as well as providing sensory learning opportunities for all children. Finally, **Wajrak *et al*** describe the experience of implementing PSTT teacher professional development programmes in Australia and their impact on primary teachers.

This issue brings an array of contributions that touch on various aspects, all of which are salient to early years science education. We hope you enjoy the articles in this issue and that they inspire your practice!

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Science in early childhood education: the perception of Spanish teachers during initial training

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- Antonio de Pro
- Jordi Solbes

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. ISBN 978-1-873769-84-3. Reproduced here with permission from ESERA.

Abstract

Science teaching is present in the curriculum at all levels of education. However, little research has been done into what content is taught, how it is taught and what pupils actually learn at the pre-primary stage. In this paper, we will study student teachers' perception about what science teaching is being carried out in Second Cycle of Childhood Education classrooms (3-4-5 years). Using their experiences from teaching practice, a number of pre-school education degree students have completed a questionnaire through which to understand better the educational reality under study. The results reveal the limited attention given to certain content areas and the absence of key activities through which to learn science at these ages. Lastly, attention is given to needs in teacher training, both initial and in practice

Keywords: Early childhood education, science teaching, initial teacher training

Introduction

Many studies have supported the teaching of science in Early Childhood Education (ECE), from 3 to 5 years. From the field of psychology, Piaget's theories provided a large number of contributions, amongst which are those by Kamii and Devries (1983) or those of IMIPAE (Moreno, 1986), which study the experimental behaviour of children at these ages. It is a fact that science is present in curricula at all levels of education. The objective of science at ECE is not to form a solid foundation for the future acquisition of scientific knowledge. Doing scholarly science, even post-compulsory education, is justified because it responds to needs that citizens have – whether they want to be scientists or not – to learn about themselves, for personal development, to understand the world around them, to generate healthy habits with respect to the conservation of the environment, and to make decisions in the face of social problems, among other aspects (French, 2004; Ginsburg & Golbeck, 2004; Eshach, 2006; Worth, 2010).

Teacher training has been a priority in educational research in Spain. Although it was for a long time focused on what secondary school teachers have to know and know how to make, in recent years there have been some investigations about teacher training in the early school stages: ECE and primary school (6-12 years) (Palmer, 2006; Pérez, 2008; Pro & Rodríguez, 2011; Siry, Ziegler & Max, 2012; Riviero *et al*, 2013; Martinez-Chico *et al*, 2014; Cantó, Pro & Solbes, 2017; McNerney & Hall, 2017).

In our opinion, there are many factors that must be taken into account when we study science teacher training in ECE: on one hand, it is important to understand the image that future teachers have of science and its importance in ECE. From our perspective, their interests and attitudes towards science should be kept in mind (Osborne, Simon & Collins, 2003; Pell & Jarvis, 2003; Cantó & Solbes, 2014). On the other hand, if we understand that the ECE is a stage with its own identity, then the nature and characteristics of science that are taught in ECE must be different from those at other educational levels. Therefore, the purpose of the training of professionals must reflect early years methods (boys and girls, 0-6 years) and consequently should be different from secondary science (Osborne & Simon, 1996; Oliveira, 2010; Arias, Alvarez & Alvarez, 2013).

It is also important to note that, in Spain, the academic background of the majority of students of the Degree in Early Childhood Education is one where the scientific component is not adequate. These deficiencies have been pointed out as the main reason for the little confidence that ECE teachers feel in their capabilities for teaching and including science activities (Greenfield *et al*, 2009). This situation should be changed through initial training. This is an argument used to justify why teachers' degrees aim to increase the level of scientific literacy of future teachers (Sanmartí, 2002; Garcia Barros, 2008).

However, it cannot be ignored that the curricular content of ECE in Spain is organised around three areas (Knowledge of yourself and personal autonomy; Knowledge of the environment; and Languages: Communication and representation) and all are included as scientific content (MEC, 2007). Therefore, it is necessary that future teachers, and teachers of ECE particularly, possess correct scientific knowledge in real life and in the classroom.

Many contributions about the Spanish context have been made with respect to the children of ECE age: resources that can be used in an ECE classroom, methodologies that can be applied, etc. However, despite these contributions, there is a significant deficit of research in Spain on the training of teachers of this educational stage: about their knowledge, about their beliefs and conceptions, about their classroom management, about their professional experiences (García Barros, 2008; Benarroch, 2012). This paper is part of wider research into science education in early childhood education in Spain, which starts by posing the question: what kind of science education is desirable and appropriate for these ages (Hadzigeorgiou, 2002; French, 2004; Eshach & Fried, 2005; Cantó, Pro & Solbes, 2017)?

For this reason, the main objective of this paper is to present the perception of future teachers of science teaching that is to be carried out in the Second Cycle of Early Childhood Education (SCECE) classrooms (3-4-5 years). In our case, as teacher trainers, we need to know how our students perceive the reality of SCECE classrooms in their first approaches to professional practice. Therefore, our research question is about our students' perception of science education in SCECE.

Methodology

Our research was implemented over three academic years (2011-2014) at the University of Valencia (Ontinyent Campus) with three groups of third-year Pre-school Education degree students. Using their experience of teaching practice for two months in a public school in the Valencia province, 120 students completed a questionnaire designed to obtain a better understanding of the educational reality of what is happening in schools:
(36 observations in a class of 3 year-old children,
40 observations in a class of 4 year-olds and
44 observations in a class of 5 year-olds).

Context

The Degree in Early Childhood Education of the University of Valencia is made up of 240 ECTS credits: 103.5 for basic training subjects; 73.5 for compulsory subjects; 12 for electives; 45 for external internships and 6 for work at the end of the degree. It is taught face-to-face and normally takes 4 years to complete.

In relation to the formation of scientific content, the curriculum includes two compulsory subjects: 'Natural sciences for teachers' (CNpM), worth 9 credits, and 'Teaching of the natural sciences in early childhood education' (DCN), worth 6 credits. CNpM is a common subject in the 2nd grade for pre-school and primary education, the purpose of which is that students complete their basic training in the content of scientific disciplines to improve their training as educators. At the time of collecting the information, the participants had already done this study unit: the average score was high – 7.5 (2011-12), 8.4 (2012-13) and 7.8 (2013-14), which reflects a certain success in this. DCN is specific to the Degree in Early Childhood Education and is aimed at studying the content that, in science, is covered in SCECE.

As for teaching practice, according to the curriculum it is *'an activity of a formative nature ...*

supervised by a tutor from the school and by an academic tutor of the University of Valencia. Its main objective is to allow students to apply and complement the knowledge acquired in their academic training while practising, at the same time, the acquisition of teaching competences, preparing them for developing competence in professional activities, to facilitate their employment and promote their entrepreneurial capacity'. It is distributed in three periods: 'School practice of early childhood education I' (7.5 credits, two weeks during 1st grade), 'Early childhood school practice II' (16.5 credits, 8 weeks in 3rd grade) and 'Infantile school education practice III' (21 credits, 15 weeks in 4th grade). The purpose of the second period (at the end of which the information was collected), according to the curriculum guide, is '*to introduce the students to systematic, grounded and critical reflection about the school reality, which allows them to consider the school as: (a) an organizational structure that is part of the school administration, (b) a space for citizen participation in an educational, social and cultural project, and (c) the framework in which processes of teaching and learning are designed, developed and evaluated'*. In addition, it is said that: '*...It is intended that students will progressively assume responsibility for the planning and execution of teaching experiences, and active participation in some of the activities of the school'*. For all these reasons, we consider that participants had enough knowledge and experience to answer the questionnaire with enough credibility and with more than sufficient time to make the observations (8 weeks).

Questionnaire

We wanted to know what was the perception of future teachers about teaching of science in SCECE after carrying out their teaching practices. For this, we designed a questionnaire with 100 questions in order to analyse the following aspects at this educational stage:

- General treatment observed regarding science;
- Content of science work included in the Spanish curriculum;
- General and specific methodology used;
- Technical and manipulative activities carried out; and
- Specific activities related to scientific methodology.

To facilitate its implementation, students only needed to indicate whether they had observed by means of three possible answers: Yes, No and NS (do not know). Before the students answered the questionnaire anonymously, they could ask about the questions and any doubts that arose regarding their interpretation were resolved. The questionnaire took a 90-minute session to complete and took place immediately after the end of 'Early childhood school practice II'.

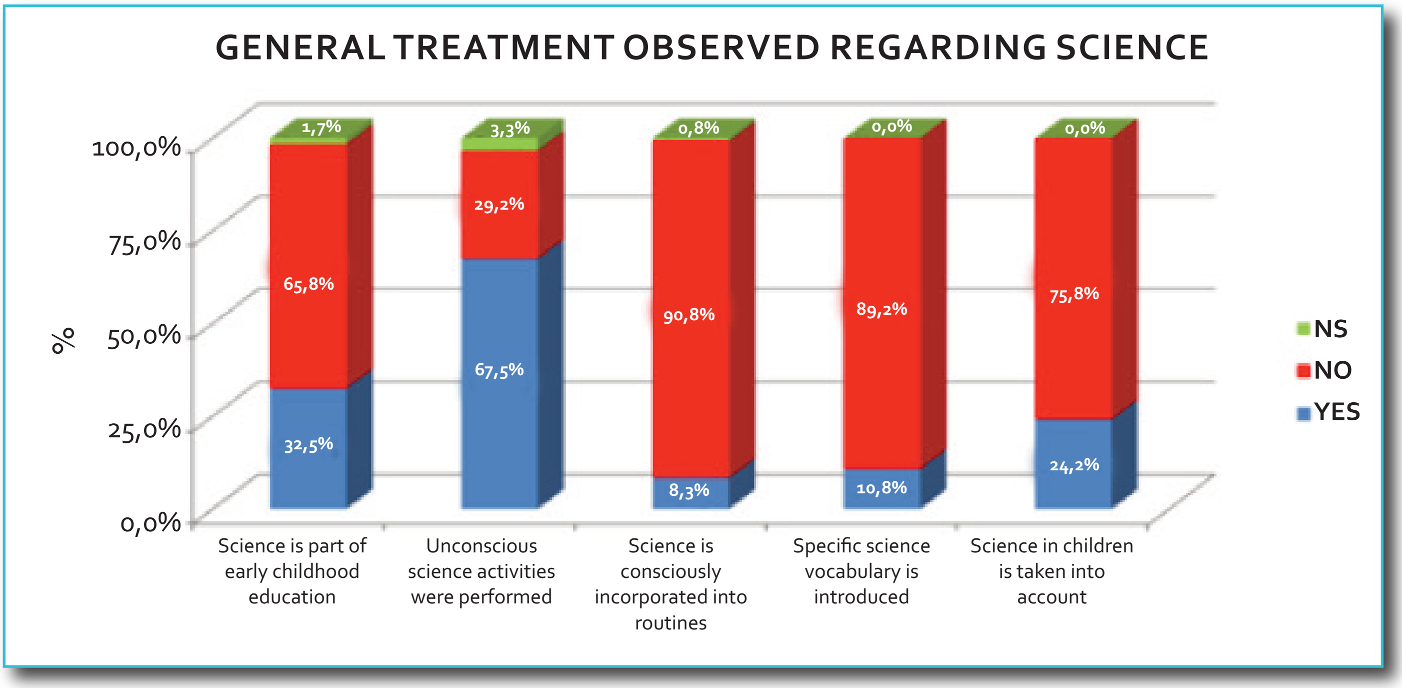
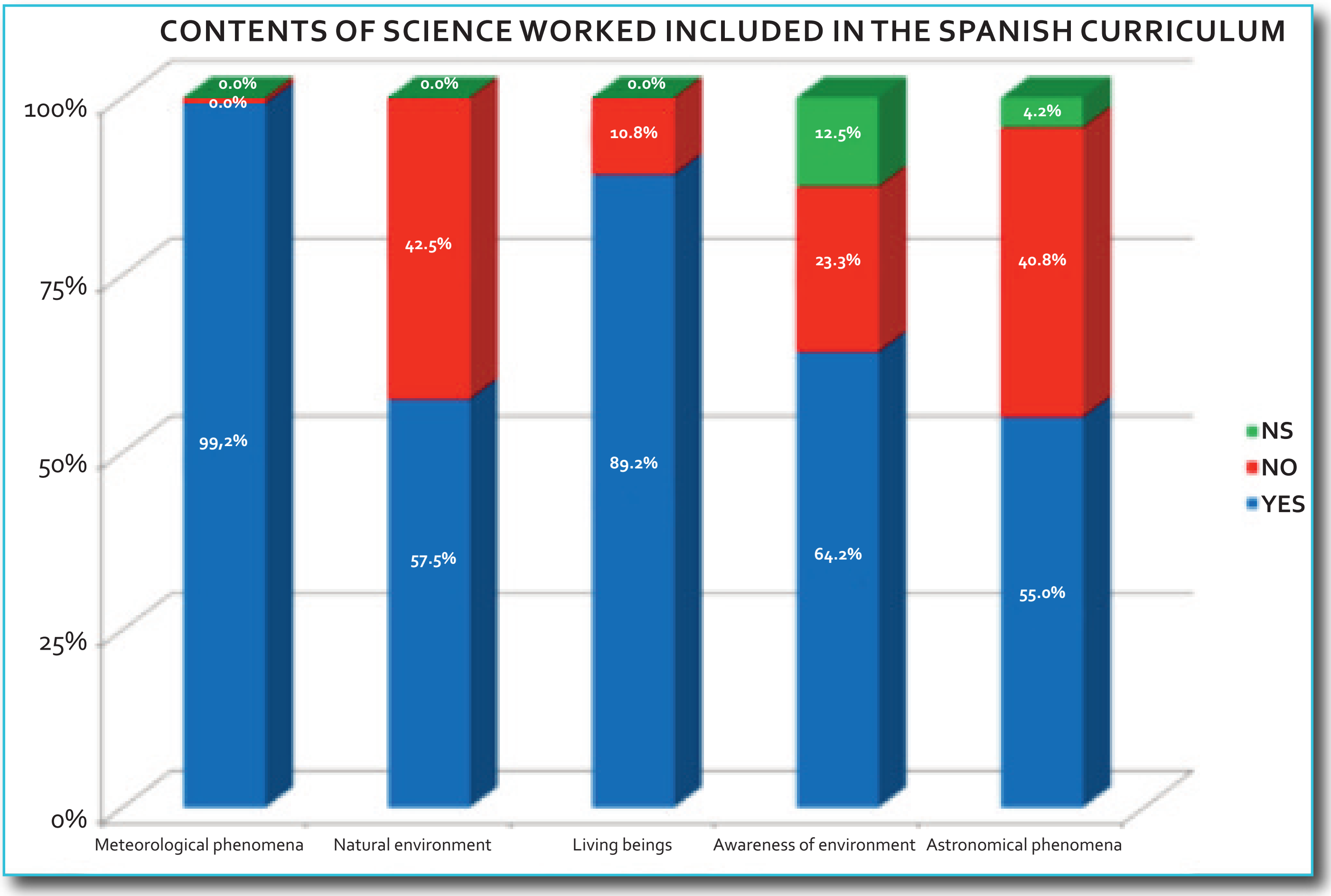


Figure 1: Results about the role given to science.

Figure 2: Different content of science covered in the Spanish curriculum.



Results

The results reveal (from the official Spanish curriculum reviewed in this paper) that there is limited importance attached to some content areas and that there is an absence of key activities through which to learn science at these ages. In Figure 1 we show the results for the general treatment observed regarding science.

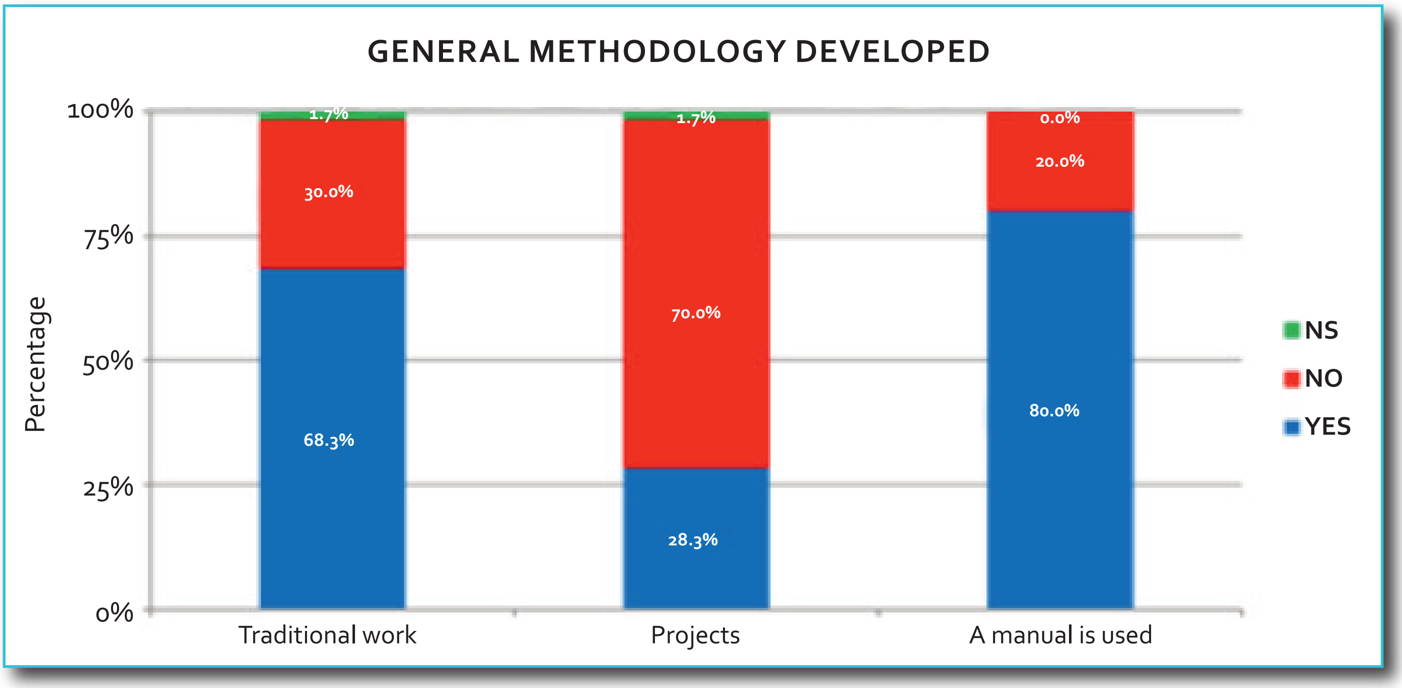
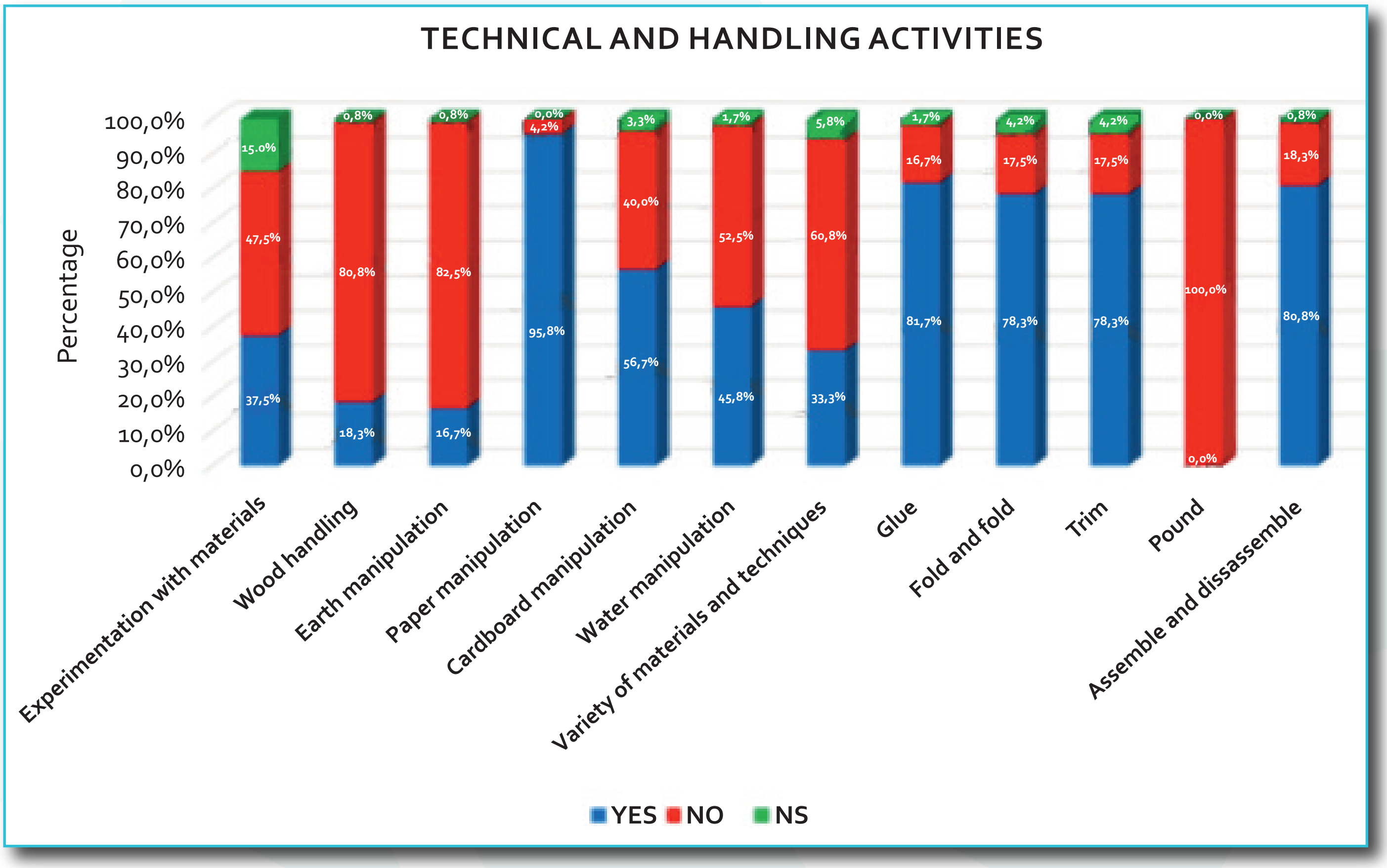


Figure 3: Results in the general methodology developed in the classrooms observed.

Figure 4: Results relating to technical and handling activities developed in the classrooms.



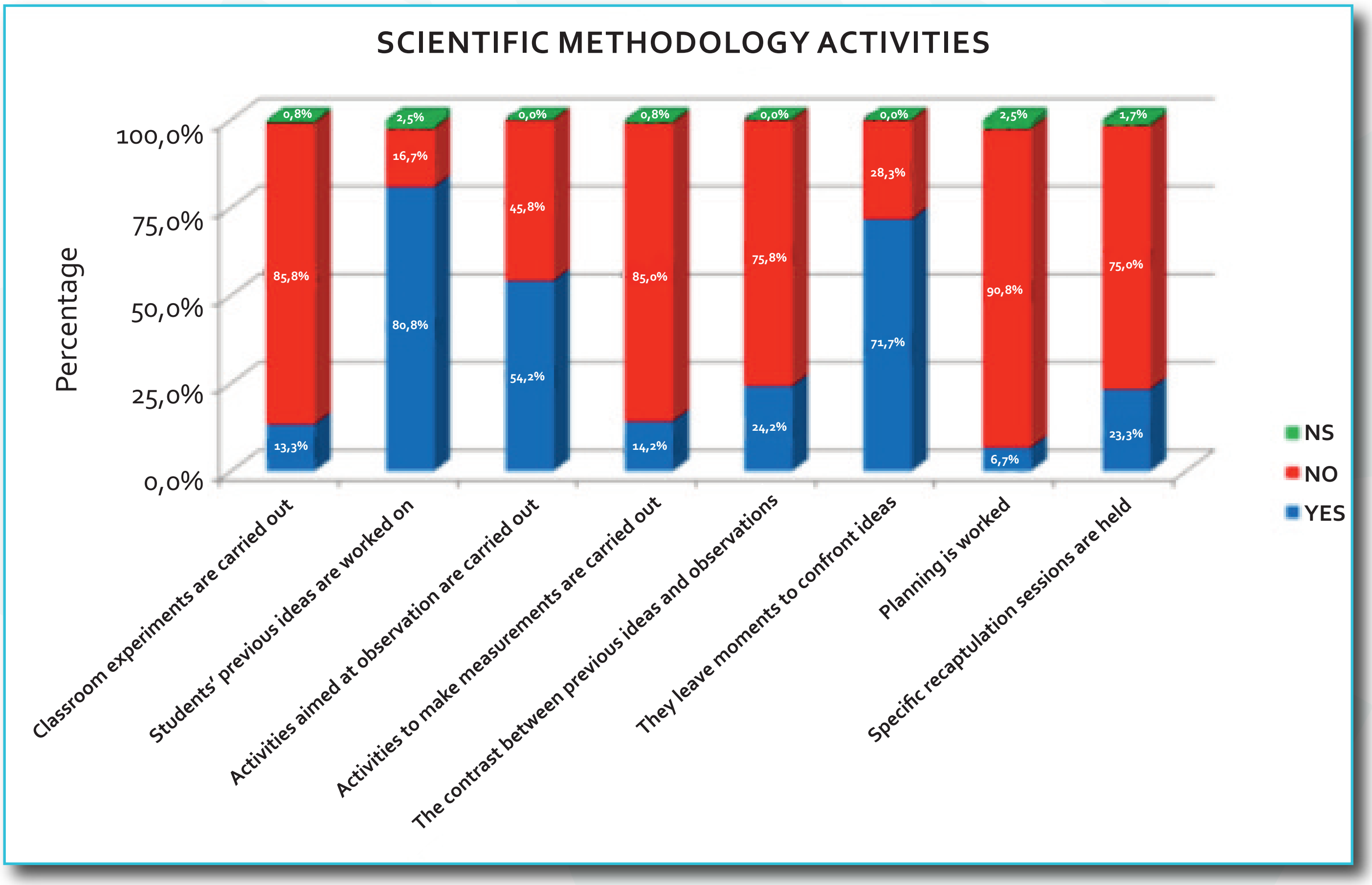


Figure 5: Results relating to scientific methodology activities observed.

It seems that the science does not have an 'intentional presence' in the classrooms; that is, they work but without an explicit purpose, which is both surprising and worrying. We emphasise this as all the answers go in that direction, with percentages higher than 65%.

With respect to the science curricular content that is included in the classroom, four areas were identified: Natural environment; Living beings; Environmental awareness; and Astronomical phenomena. Figure 2 shows the results obtained with respect to the presence of these areas as observed by our students during the practice. Regarding the general methodology used in class, three distinctive approaches were identified: a traditional methodology based on the use of worksheets; the use of general projects that encompass different aspects; and the main use of a manual or textbook. The results, with respect to these aspects, are shown in Figure 3.

As to the technical and manipulative activities related to materials observed by our students, the results are shown in Figure 4.

Finally, in Figure 5, we present the results regarding the activities for scientific methodology.

Conclusion

The answers obtained from our students allow us to have a 'picture' of the situation regarding science in SCECE classrooms in Spain. Thus, we have been able to see that:

- Science does not have the desired presence in many cases. However, it must be acknowledged that our students may have had difficulty in detecting scientific content when it is not presented in the form of didactic units, or with the disciplinary format (not holistically);
- Scientific content has a heterogeneous presence. There is no clear profile of omissions: cyclical nature of certain phenomena or of living beings, activities with plants and animals, not visible realities, simultaneity, measures of lengths and masses;
- As for the general methodology, desirable activities were observed being carried out (work in groups, use of ICT, etc.) but, in parallel, overall there were more traditional ones (using textbooks, etc.);
- Regarding the methodology used to teach science, teachers miss the typical activities of scientific learning: experiences, experiments, games, specific corners of this subject etc.; and
- In terms of activities, there are many technical activities, but less presence of scientific methodology and argumentation; the reasons for this could be attributed to the complexity of the skills required by approaches not used, as well as to the lack of training of the teacher who has to use them.

In conclusion, if this perception reflects the reality in Spanish schools, we should next consider why this is happening, what we can do in the initial training to tackle the situation, and how we can change it.

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References

Arias, A., Álvarez, M. & Álvarez, F.J. (2013) 'Concepciones del profesorado en FI sobre los roles de docents y discentes en el aprendizaje de las ciencias en EI y EP. IX', *Congreso Internacional sobre Investigación en Didáctica de las Ciencias* (pp.194- 201). Girona: Revista Ens.Cien. (núm. extra)

Benarroch, A. (2012) *La investigación en Didáctica de las Ciencias Experimentales en las etapas educativas de Infantil y Primaria. XXIV Encuentros de Didáctica de las Ciencias Experimentales (32-52).* Baeza: Ser. Pub. Univ. Jaén

Cantó, J. & Solbes, J. (2014) *Qué les interesa a los futuros maestros de infantil de la Ciencia? Actas XXVI Encuentros de Didáctica de las Ciencias Experimentales (852-857).* Huelva: Ser. Pub. Univ

Cantó, J., Pro, A. & Solbes, J. (2017) 'Qué resultados de aprendizaje alcanzan los futuros maestros de Infantil cuando planifican unidades didácticas de ciencias?' *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, **14,** (3), 666–688. DOI: 10498/19515 http://hdl.handle.net/10498/19515

Eshach, H. (2006) *Science literacy in primary schools and pre-schools.* New York: Springer. DOI: 10.1007/1-4020-4674-X

Eshach, H. & Fried M.N. (2005) 'Should science be taught in early childhood?', *Journal of Science Education and Technology*, **14,** (3), 315–336. http://dx.doi.org/10.1007/s10956-005-7198-9

French, L. (2004) 'Science as the center of a coherent, integrated early childhood curriculum', *Early Childhood Research Quarterly*, (19), 138–149

García Barros, S. (2008) *La formación del profesorado de Educación Infantil. XXIII Encuentros de la Didáctica de las Ciencias Experimentales (pp. 248-255).* Almería: Universidad

Ginsburg, H.P. & Golbeck, S.L. (2004) 'Thoughts on the future of research on mathematics and science learning and education', *Early Childhood Research Quarterly*, **19,** (1), 190–200. DOI: 10.1016/j.ecresq.2004.01.013

Greenfield, D.B., Jirout, J., Dominguez, X., Greenberg, A., Maier, M. & Fuccilo, J. (2009) 'Science in the preschool classroom: A programmatic research agenda to improve science readiness', *Early Education and Development*, (20), 238–264

Hadzigeorgiou, Y. (2002) 'A study of the development of the concept of mechanical stability in preschool children', *Research in Science Education*, **32,** (3), 373–391 http://dx.doi.org/10.1023/A:1020801426075

Kamii, C. & Devries, R. (1983*) El conocimiento físico en la educación infantil*. México DF: Ed. Siglo XXI

Martínez-Chico, M., López-Gay Lucio-Villegas, R. & Jiménez Liso, M.R. (2014) 'Es posible diseñaun programa formativo para enseñar ciencias por Indagación basada en Modelos en la formación inicial de maestros? Fundamentos, exigencias y aplicación', *Didáctica de las Ciencias Experimentales Sociales*, (28), 153–173. DOI: 10.7203/DCES.28.3153

McNerney, K. & Hall, N. (2017) 'Developing a framework of scientific enquiry in early childhood: an action research project to support staff development and improve science teaching', *Early Child Development and Care*, (187), 206–220

MEC (2007) 'REAL DECRETO 1630/2006, de 29 de diciembre, por el que se establecen las enseñanzas mínimas del segundo ciclo de Educación infantil', (BOE nº4, 4 de enero de 2007, pp. 474–482)

Moreno, M. (1986) 'Ciencia y construcción del pensamiento', *Enseñanza de las Ciencias*, **4,** (1), 57–64

Oliveira, A.W. (2010) 'Improving teacher questioning in science inquiry discussions through professional development', *Journal of Research in Science Teaching*, **47,** (4), 422–453

Osborne, J. & Simon, S. (1996) 'Primary Science: Past and Future Directions', *Studies in Science Education*, (27), 99–147

Osborne, J., Simon, S. & Collins, S. (2003) 'Attitudes towards science: A review of the literature and its implications', *International Journal of Science Education*, (25), 1049–079

Palmer, D. (2006) 'Durability of changes in self-efficacy of preservice primary teachers', *International Journal of Science Education*, (28), 655–671

Pell, A. & Jarvis, T. (2003) 'Developing attitude to science education scales for use with primary teachers', *International Journal of Science Education*, (25), 1273–1296

Pérez, M.P. (2008) 'Competencias adquiridas por los futuros docentes desde la formación inicial', *Revista de Educación*, (347), 343–367

Pro, A. & Rodríguez, J. (2011) 'La investigación en la Didáctica de las Ciencias Experimentales', *Educatio Siglo XXI*, **29,** (1), 248–255

Rivero, A., Hamed Al-Lal, S., Martín del Pozo, R., Solís, E., Fernández, J., Porlán, R., Rodríguez, F. & Solís, C. (2013) 'La formación inicial de maestros de primaria: qué hacer y cómo en didáctica de las ciencias', *Enseñanza de las Ciencias*, Número Extra: 3045–3050

Sanmartí, N. (2002) 'Necesidades de formación del profesorado en función de las finalidades de la enseñanza de las ciencias', *Pensamiento Educativo*, **30** (julio), 35–60

Siry, C., Ziegler, G. & Max, C. (2012) '"Doing science" through discourse-interaction: Young children's science investigations at the early childhood level', *Science Education*, (96), 311–326

Worth, K. (2010) 'Science in early childhood classrooms: Content and process'. In *Early Childhood Research and Practice*, Collected Papers from the SEED (STEM in Early Education and Development Conference), Vol. 10

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The impact of knowledge of the knower: Children exploring physical phenomena and technology in construction play

- **Kristina Thorshag**

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Abstract

This article contributes knowledge about technology education in pre-school, a research field that is still undeveloped. The aim is to study pre-school children's ways of discerning a physical phenomenon (equilibrium) during collaborative construction play. Two different activities have been studied: playing on a homemade seesaw made of a log and a plank, and building towers with blocks. In the first activity, 3 children aged 4-5 years from one pre-school participated. In the second, 4 children aged 3-5 years from another pre-school participated. Data consist of video-recordings of the two activities and field notes. The video-recordings are analysed based on variation theory. In both activities, children discerned and explored the phenomena of equilibrium, centre of gravity and balance. Three children tried different ways to spread their mass over the seesaw. They distributed the weight both by crawling to the middle and by standing on the ends of the plank. In the building activity, a group of four children tried to build high block towers and discerned the importance of the weight distribution for stability and for the construction not to collapse. The results showed that the children who had discerned more aspects of the phenomenon of equilibrium were able to use and develop their knowledge during the activities to a greater extent than children with less knowledge. They also shared knowledge with other children by making them notice aspects needed to understand the activity, thereby participating in a more active way. The results can be used by pre-school teachers to design collaborative play activities for learning science in pre-school.

Keywords: Pre-school, technology education, science learning, variation theory

Introduction

Though research about technology education in pre-school is limited, it is developing (Mawson, 2013; Turja, Endepolis & Chatoney, 2009). Primarily, the research conducted involves children aged 8 years and older. The Swedish Schools Inspectorate (2017) carried out an assessment on the state of science education in Swedish pre-schools and concluded that, although construction play is the most common technological activity in pre-school, it is seldom seen as a learning opportunity where the staff intentionally interact to promote learning. Construction play often concerns spontaneous games where the children play by themselves out in the school grounds or in the 'building space' (Swedish Schools Inspectorate, 2017). Play is related to children's cognitive development, especially in the early years (Bagiati & Evangelou, 2016). During play, children develop many different skills, such as social, creative and cognitive skills. Including tangible objects in play seems to benefit children´s cognitive development. Children explore and structure their environment.

In addition, playing with a variety of materials can help children to observe and explore how artefacts are constructed. When building, children can discuss design and explore concepts such as size, weight and balance; they also develop their motor skills. An important part of construction play is the trial-and-error behaviour (Van Meeteren & Zan, 2010). This is necessary for children to be able to develop spatial reasoning and a working understanding of physics. Van Meeteren and Zan (2010) conclude that children have for a long time been recognised as young scientists as they explore and try to make sense of their environments.

Results indicate the need for a pre-school teacher who is able to intentionally direct the children's attention to defined learning objects in science to enhance their learning (Hallström, Elvstrand & Hellberg, 2014; Mawson, 2013). Children need challenging questions and to be confronted with different materials in order to visualise science phenomena during play (Siraj-Blatchford, 2009). Furthermore, Turja *et al* (2009) and Parker-Rees (1997) argue that children also need to have rich opportunities to play with different materials, tools and techniques to develop their technological understanding during construction play. Parker-Rees (1997) maintains that free play is the foundation of the development of design and technology. Fantasy develops during play activities. It helps children to engage in playful and critical ways of thinking and to use earlier experiences.

For children to be able to do the above, pre-school teachers have an important role to play. Mawson (2013) argues that teachers have to develop the ability to provide children with everyday experiences in the field of technology and use it as a starting point for learning about technology. If the teachers have a 'scientific attitude' they create a learning environment at pre-school, where the children can learn scientific concepts as an everyday experience (Fleer, Gomes & March, 2014). Other researchers point out the importance of teachers being aware of children's knowledge. Eshach and Fried (2005), who have studied how children's previous experiences affect their involvement in play, claim that even small children can learn new concepts in science, as windows of opportunity to learn new concepts are created in the early years. To take care of these learning opportunities, pre-school teachers need to have both deep knowledge about the learning object/material, and how the child discerns the same learning object (Eshach & Fried, 2005; Thulin & Redfors, 2016; Kesner, Baruch & Mevarech, 2013). Setting the scene for developing a scientifically curious child requires teachers to possess knowledge of materials and how to design activities that challenge the child's interest. In their discussion of what constitutes a curious child, Spektor-Levy, Kesner Baruch and Mevarech (2011) claim that this is a child who explores different phenomena and who is open to discovering things it wants to know more about. If the child is given the possibility to investigate and understand how things work, not only is there more learning, but also more complex learning occurs. They found that almost all children who investigate an observed phenomenon asked more questions. In this study, the focus is on how different children interact and investigate scientific phenomena during construction play.

The aim is to study pre-school children's ways of discerning and sharing knowledge of a physical phenomenon (equilibrium) during collaborative construction play in pre-school. The results contribute new knowledge regarding how teachers can design and act to enhance children's collaborative learning during play. The research questions asked to fulfill the aim are as follows:

1. What characterises children's knowledge development during construction activities in collaboration with other children?
2. In what way do children with knowledge notice when and how to share this knowledge with children who have yet to obtain the knowledge?
3. What characterises children's sharing of embodied and expressed knowledge during construction play?

Knowledge and knower

In this study, knowledge is understood as the human relation to the environment and how the environment is experienced. Marton and Booth (1999) state that a 'knower' is able to distinguish different aspects and relations of a phenomenon. The more you learn about something, the more aspects of the phenomenon can be discerned. The context is crucial for what knowledge can possibly be developed, through offering the learner the opportunity to discern new aspects of what is supposed to be learned. In the Swedish curriculum for pre-school, where this study takes place, (National Agency for Education, 2016), four aspects of knowledge are defined (Carlgren, 1994; Carlgren, Forsberg & Lindberg, 2009). These aspects include: facts; understanding; familiarity; and skills: all interact with each other and are considered as nonhierarchical. Knowledge refers both to theoretical and practical knowledge. Facts refer to the purely informative aspect of knowledge and are with the ability 'to know'. Understanding refers to the ability to interpret and explain, i.e. to 'know why'. Skill focuses on practice or acting and means 'knowing how'. Familiarity is based on experience and 'knowing what'. Learning always takes place in a context where these different forms of knowledge interact with each other. To learn, both cognitive knowledge and sensory experiences are needed. Different individuals use different forms of knowledge to varying degrees. Thus, it is important not to consider the forms of knowledge as a step-by-step development (Carlgren, Forsberg & Lindberg, 2009).

The statements in the curriculum are based on research definitions about knowledge. Familiarity, according to Molander (1996) and Schön (1983), is described as knowledge-in-action where both practical and theoretical skills develop. Knowledge is developed by doing things on a regular basis and by gaining many experiences. Familiarity is defined as 'silent knowledge'. According to Polanyi (1962), knowledge has a foreground and a background. The foreground is the focus on which attention is being directed. In the background, there is experience, which is not pronounced, but which becomes a quiet part of the knowledge. It is in the interplay between foreground and background that learning takes place and which also influences how the outside world is perceived and understood. Polanyi (1966) uses the term 'tacit knowledge'. Gustavsson (2002) considers that in the notion of the knowledge of skills there is implicitly some form of reflection. In order to reflect, one needs to be able to put words on the knowledge, thus it is no longer silent. Practical action develops through reflection in an interplay between seeing and doing, and between theory and practice (reflection-in action). Consequently, theory is not overarching practice, but they are developed together through interaction (Schön, 1983).

Ryle (1949) talks about 'knowing that' and 'knowing how'. He makes a distinction between knowledge and knowing, where knowing is connected to the activity and practice. 'Knowing that' is the theoretical knowledge and 'knowing how' is the practical, embodied knowledge. Ryle (1949) relates that knowing how is not only about the practical skill, but also about understanding what you are doing and about acting with a purpose; the acting person is still learning. Merleau-Ponty (1945/2002) considers knowledge and intellectual ability as linked to the brain, as well as to the entire body. Increased body perception and body movement not only lead to better health, but also provide increased learning ability (Gustavsson, 2002). It is evident when researching young children that they show in action before communicating with words, having conquered the bodily and sensory knowledge (Gibbs, 2006; Pramling Samuelsson & Sheridan, 2016). They learn by observing and gaining real experience to learn how to act; and they learn in and through action. In many ways, the knowledge is embodied and shared with other children by moving and acting during play without verbal communication.

Scientific and technological knowledge

In this study, science is defined as subjects, or as sciences used to describe and understand nature and the surrounding world (Sjøberg, 2010). Humans have always been curious and have wanted to describe and understand the phenomena in the physical world. Science is based on empirical measurements, and new research contributes to new knowledge. To be considered scientific, the research has to be systematic and free from contradictions. The theoretical models are universal and can be used in many contexts (Harlen, 2010).

In this study, an aspect of science is studied – technology – and, even more precisely, construction play. There are differences between scientific and technological knowledge. According to Sjøberg (2010), the fundamental difference between science and technology should be that scientific knowledge is meant to understand the world, while knowledge is more theoretical and abstract. For technology, the goal is to solve practical problems. While science produces thoughts, rules and theories, technology produces products. Science is to 'know why', while technology is to 'know how', as it is applied and interdisciplinary. The word 'technology' comes from the Greek word *Têchne* and is used for arts, crafts and skill. Technology in this context is an activity that aims to accomplish something more than the activity itself, and it has a certain result or product (Gustavsson, 2002). Björkholm (2015) has a slightly different understanding of technological knowledge than Sjöberg (2010). Björkholm sees technology as both practical and theoretical knowledge. The theoretical knowledge is mostly silent, and knowledge is expressed both in physical and mental terms. Technological knowledge means different ways to discern and experience aspects of what to learn. It is a process where the individual develops a differentiated view and way of doing when discerning more aspects of the object. In this study, technology is understood as both theoretical and practical knowledge, where the theoretical knowledge is expressed by practical actions.

Theoretical framework

This study is based on the framework of variation theory (Marton & Booth, 1997; Marton, 2015). Variation theory is a learning theory that describes the conditions necessary for learning. The theoretical assumptions are that variation, discernment and simultaneity are intertwined and needed to make learning possible. Variation is required for discernment and, by simultaneous variation of different aspects of a learning object, discernment is possible. This study rests on an analysis where aspects that children have discerned are captured, and aspects not yet discerned are seen as critical aspects (Marton, 2015). Variation theory has been used to study pre-school children's learning (Björklund, 2014; Björklund & Pramling, 2014; Holmqvist Olander & Ljung-Djärf, 2012; Holmqvist, Brante & Tullgren, 2012), as well as by teachers learning about pre-school children's learning (Ljung-Djärf & Holmqvist Olander, 2013). The aim is to study pre-school children's ways of discerning equilibrium during collaborative construction play.

Participants and method

This study is conducted in two Swedish pre-schools. In Sweden, pre-school is a separate school for children aged 1-5 years. It is voluntary and the municipality is required to provide pre-schooling for children from the age of one. The task of the pre-school is based on the interaction between care, education, nursing and learning. Children's development and learning should be stimulated, and pre-school is to have children's interests and needs as a starting point. The learning opportunities are to enable the children to create, learn and explore. Learning should be playful and based on the children's perspective (National Agency for Education, 2016). Play and joyful learning, along with creativity, are emphasised. Furthermore, children are to be given the opportunity to use many different abilities and ways to learn (Pramling Samuelsson & Asplund Carlsson, 2014). The role of the pre-school teacher is to create conditions for children to be active and to have the opportunity to get to know their surroundings by interacting with other children and with adults. Although there are no achievement goals in the curriculum, a number of overarching aims exist where children's abilities to develop their understanding of the close environment are treated. In the curriculum revision 2010 (National Agency for Education, 2016), the goals to strive for in science and technology were clarified and the two former goals became five. One of the overarching goals for technology is to create the opportunities to build, create and construct using different techniques and materials (National Agency for Education, 2016).

In the study, two activities were identified and analysed from a richer data collection (Table 1). From the total sample of 34 children aged 3-5 years from two pre-schools, two activities with 3 and 4 children are the unit of analysis (Table 2). The pre-schools are situated on the west coast of Sweden. They have declared an interest in working with science and technology.

Pre-school A is situated in the countryside and has 10 age-homogenous departments for children aged 1 to 5 years. The pedagogical base is Reggio Emilia, and the school building has teaching studios and squares for children's play. The school grounds are seen as an extension of the main building, and are divided into different facilities for activities and sensory experiences. There are many different materials for the children to use for construction play. Finally, the two educators who are responsible for teaching science and technology are certified 'outdoor educators'.

Pre-school B is adjacent to a residential area close to a forest. It consists of six departments and a total of 120 children. Two departments are toddler departments. The other four departments have older children (aged 3-5 years), one of which is a

Pre-school	Children (N)	Mean age (Y) children	Video-recordings and field notes	Teachers (N)	Meetings
A	1	4,7Y	November: field notes	2	3
	9	4,7Y	December 2016: 39:36 min		
B	4	4.9Y	November 2016 22:45 min	2	3
	25	4,4Y	November 2016 46:04min	4	

Table 1: Participants and data collected.

participant in the study. This department has a clear interest in working with science and technology, with a particular focus on sustainable development.

The methods used were field notes, video-recorded observations and meetings. The video observations of the children's two activities were analysed qualitatively. Firstly, the video recordings were analysed to capture the activity. Thereafter, they were analysed from each participating child´s perspective. This was done twice for each child, with the focus on each child's verbal and body language. Finally, each child's activity with other children was analysed.

In the analysis, video clips have been selected to show cases of critical moments where children showed knowledge and guided other children in the activities, as well as the sequences where children develop their own knowledge. All video recordings have been transcribed verbatim and analysed based on variation theory (Marton, 2015), which means that aspects that the children have discerned were studied in relation to the object equilibrium.

The ethical aspects and considerations of the study were handled according to current ethical principles for research (Swedish Research Council, 2016). The names in the results are fictitious in order for the children to remain anonymous.

Pre-school	Activity	Number of children (N)	Mean age	Participating teachers (N)	Activity duration (time)
A	The seesaw	3	5,1Y	0	1m 11s
B	The tower	4	4,9Y	1	22m 14s

Table 2: Participants and data collected.

Results

Activity A: The seesaw.

Activity A takes place in the pre-school yard, where there are many different materials to use for building and constructing. A few days earlier, the children and the staff constructed seesaws made of logs and planks. Now the three boys are playing on one of the seesaws. In the video clip, they are exploring how to make the seesaw move up and down when all three are swinging simultaneously.

Activity B takes place in the building space. A girl starts to construct a tower, while a pre-school teacher is building one beside her. Another girl is supplying them with blocks, but she does not want to build. Two boys are playing. When one becomes inspired to join in, he also starts to build a tower. The other boy is playing beside the construction activity.

During these two analysed activities, the children have the possibility to explore the phenomena of equilibrium, centre of gravity and balance (Table 3). The results of the analysis focus on: 1) the children's knowledge development during the activity, 2) how children notice when and how to share knowledge, and 3) the character of children's shared embodied and expressed knowledge. The analysis is based on the framework of variation theory, thereby identifying what aspects the children discern and the pattern of how the aspects vary simultaneously. The excerpts chosen to illustrate the results show both verbal and embodied knowledge expressions.
The results are compiled in themed categories following the research questions.

In the first activity, the children are exploring movements of the seesaw. Aspects made possible to discern during the seesaw activity are as follows: the movement of the lever, the centre of gravity and the turning point. In the second activity – the tower – the children try to make the tower stable. Aspects possible to discern are the following: centre of gravity, gravity in relation to height, and balance (Table 3).

Children's knowledge development during construction activities

The first research question focuses on the children's knowledge development during the activity. During the seesaw activity, the focus of knowledge is strongly connected to embodied knowledge. The children move along the seesaw to adjust and explore in what way they can affect the movement as they wish. As there are three children moving at the same time, they have to collaborate

Activity B: The tower.

Activity/ Phenomenon	Pursued goal of the activity	Aspects made discernible		
A The seesaw	Movement	The movement of the lever	Centre of gravity (position of the bodies)	Turning point
B The tower	Stability	Centre of gravity	Gravity/height	Balance

Table 3: Discerned aspects of the phenomenon.

to make it work. One of the children, Arvid, has developed more knowledge of how to move to make the seesaw swing. Oskar has limited knowledge in relation to Arvid, which is expressed through him not noticing the other children's movements. Finally, Calle has not discerned how to move to affect the seesaw's swing or how to estimate the other children's movement to move in accordance with them. He has difficulties establishing balance, falls off the seesaw, and then asks the others to help him.

At the beginning of Activity A, Oskar's focus on his own body is expressed by him standing on the seesaw balancing with his arms in order not to fall off, and him not recognising the movements of Arvid, who has taken control of the swing. After a while, he discovers how his own movements on the seesaw affect the swing. When he is standing in the middle, he can have an affect by moving his foot one step aside, thereby getting that side of the seesaw down. Calle is the one who develops the most knowledge. At the end of the activity, he has discovered that, if he swings his knees and lies down at the furthest end of the board, he gets more power to lower it. This is expressed in a non-verbal way:

> **Excerpt 1:** *Tries to climb with the right foot, then left foot, but realises instead that he can sit on the board. Looking happy and points back with one hand as he puts the furthest out and gets down the board onto the ground. Rolls off the ground* (Calle, 5:0)

Arvid is the one with most pre-knowledge, but he does not seem to develop knowledge during the activity.

In Activity B, Agnes is the one who has developed most knowledge about constructing towers. This is expressed by her building a high tower and telling the other children how to place the blocks to establish a stable construction. She has experienced the importance of the centre of gravity and equilibrium to be able to build a straight tower, as the risk of the tower collapsing increases with its height. She constructs a new phrase to describe a tower in danger of collapsing; she says that it is 'oblique high'.

> **Excerpt 2:** *My tower can be even higher. It can get more oblique high!* (Agnes, 5:6).

After having two towers collapse, she uses her knowledge concerning the importance of building as straight as possible. When constructing her third tower, she builds at an even pace and is more careful how she places the blocks. David develops his knowledge the most during the activity. He studies Agnes carefully and is also inspired by her enthusiasm. He tries again when the first tower collapses. He manages to build higher each time. Both Agnes and David have the knowledge that a larger support area enables a more stable construction, and the first layer of blocks is placed flat on the floor. The children constantly adjust the blocks, as they know that the weight distribution is important for stability. They also have the knowledge that bricks that are thicker make the tower collapse. This knowledge is embodied. By just feeling the blocks in their hands, they can tell that they are thicker:

> ***Excerpt 3:*** *Agnes: They are too thick. Then it doesn't work, the whole construction can collapse. David: Because they are too thick… too fallish* (Agnes, 5:6, David, 4:3).

Erik does not develop his knowledge about constructing in the activity. He has no knowledge about how to create a stable construction, and he gets very frustrated when trying to build:

> ***Excerpt 4:*** *I can never build. Mine turns very easily. I cannot build more than 3cm because then it falls immediately. I think it is very boring to build this. I think it is very boring* (Erik, 5:1).

How children with knowledge notice when and how to share their knowledge

In Activity A, Arvid notices most of the other children's knowledge and their need for help. He shares his knowledge by facilitating for the others to join in. Oskar looks at Arvid to learn, and he also teaches Calle, who does not notice the others to a large extent; rather, he focuses on his own development.

Arvid has the knowledge that he controls the centre of gravity by moving his upper body and his feet forward or backwards. He sees the relationship with how the other children place themselves, and he acts with his body to compensate their weight. At the beginning of the activity, Calle has not discerned the connection between how he is placing his body and the movement of the lever. Then the other two boys help him. For example, Arvid steps off the seesaw to lower it, which enables Calle to climb on. By studying Arvid, Oskar discerns, after a while, that how he places himself affects how the seesaw is moving. He notices that by placing himself in a different position on the seesaw he can help Calle join in.

In Activity B, Agnes and David build their own towers, and they focus on their construction. There is an ongoing conversation about the construction of the towers and the importance of equilibrium and centre of gravity while building. David often stops and listens when Agnes and the teacher discuss how to build. Agnes and David notice that Erik wants to build a tower, and they try to instruct him, both verbally and by showing him how to start building. Erik tries to build according to their instructions. Because he has not yet discerned the critical aspects for the stability of a construction, he does not succeed in building a tower.

Children´s sharing of embodied and expressed knowledge

During Activity A, on the seesaw, the children's verbal communication takes place through sound, and only a few words are uttered. They communicate mainly with body language. Arvid notes and clarifies his movements to make it possible for the others to see what to do. He shows with his body where and how one must place the body to get the board moving up and down. Oskar notes not only Arvid's attempts to help Calle, but also Calle's needs, which means that he can help Calle. Consequently, Calle is a recipient. When he does not know how to negotiate the seesaw, Calle shares his frustration verbally to get help from the others.

In Activity B, the tower, the communication between the children is both verbal and through body language. Agnes shares her knowledge verbally in her conversation with the teacher. She also shares her knowledge by her enthusiasm when constructing towers. While building, she shows and tells the other children how to build for equilibrium and of the importance of the centre of gravity not shifting. She stacks a block and adjusts it before she places the next one on top. This is repeated. She shares her experiences from earlier occasions. She also notices when David needs help to read out the numbers on the ruler when measuring the height of his tower.

David has some knowledge from building on earlier occasions. Although he knows how to start building, he needs more knowledge to construct a high tower. Because he notices that Erik needs help to get a more solid construction, he gives him advice on how to start his construction. Agnes also shares her knowledge with Erik when he has problems with the tower falling down.

To summarise the findings of this study, the following conclusions are drawn:

In both activities, the repeated actions are of great importance for knowledge development. It is also obvious how the children inspire each other to try over and over again. Children with the most knowledge show more self-confidence in the activities. They can focus on themselves and share their experiences with the other children. In the activities, however, they did not develop their knowledge to a large extent. Both Oskar (Activity A) and David (Activity B) developed their knowledge by studying the children with more knowledge. They also developed their knowledge by noticing and sharing with the ones who have less knowledge. The children with less knowledge – and who had not yet discerned the critical aspects – expressed their frustration both verbally and bodily.

On the seesaw, a critical aspect to discern is where to place the body in relation to the others on the lever to make it go up and down. Arvid has discerned this aspect from the start of the activity. For Oskar and Calle, however, it takes some time to do so. For Calle, a critical aspect is also to discern how to climb the lever. At the end of the activity, Calle has developed knowledge of how to get down the seesaw by placing himself at the furthest point on the board, and he shows his understanding with his body. The seesaw is made of a board and a log, and the turning point is not fixed. This causes the board to move. Consequently, the lever arms become unequal in length and the equilibrium is unbalanced. This is a critical aspect not discerned by the boys.

To construct a stable tower, critical aspects are how to place the blocks to create a large supporting area at the bottom and how to stack the blocks to keep the equilibrium. Another critical aspect to discern is the higher the tower gets, the greater is the risk that it will collapse if the centre of gravity shifts. Agnes has most knowledge from earlier experiences, and she manages to build a high tower. David has less knowledge and less experience, but he develops his knowledge in the activity and manages to build his highest tower. As Erik has not discerned the aspects, he does not succeed in getting his tower higher than three layers of blocks before it collapses.

Seesaw	Arvid	Oskar	Calle
Knowledge development	-	+	++
Notice when and how to share knowledge	++	+	-
Sharing of knowledge	++	+	-

Table 4: Discerning and sharing knowledge – seesaw.

Tower	Agnes	David	Erik
Knowledge development	+	++	-
Notice when and how to share knowledge	++	+	-
Sharing of knowledge	++	+	-

Table 5: Discerning and sharing knowledge – tower.

Discussion

The results show that children who had discerned more aspects of the phenomenon of equilibrium were also able to use their knowledge during the activities to a higher extent than children with less pre-knowledge. The former needed some kind of input from their classmates to discern aspects important for understanding. The children with knowledge made it possible for the other children to explore the phenomenon and participate in the activity by acting as 'models' during play. By repeating their method of how to play, they visualised for the rest of the children how to discern aspects. The results implicate the great importance of rich opportunities for children to have repeated experiences of different phenomena to deepen their knowledge and understanding in science in pre-school (Thulin, 2011; Spektor-Levy *et al*, 2011). In the studied activities, children's knowledge plays a role in the volition to start an activity and to implement it. To promote learning among children with knowledge, it is important that pre-school teachers utilise activities that make it possible for the 'knowers' not only to play in the same way, but also to challenge and develop new knowledge (Mawson, 2013; Hallström, Elvstrand & Hellberg, 2014).

The pre-school teachers' role is to encourage and challenge the children to discern new aspects of the learning object that are crucial in learning opportunities that children meet. The boys in Activity A did not discern the different length of the lever arms. Therefore, they did not adjust the plank to get it balanced at the turning point. With a teacher present during the activity, leverage could have been put in the foreground as a learning aspect to explore further. According to Mawson (2013), it is important to take advantage of such experiences to develop children's learning in technology.

The tower construction resulted in more children at the department being inspired to build towers. The children continued to build towers, and they explored how high they were able to build. The results were posted on a list on the wall to compare the height of the towers. After some practice, David managed to build even higher than before, with the tower reaching almost one metre. Agnes built one over 2 metres, with her tower reaching the ceiling. The trial-and-error behaviour is an important aspect of learning in construction play (Van Meeteren & Zan, 2014). Construction play is also a way to develop spatial reasoning and motor skills, which are important factors when, for example, constructing.

In the studied activities, it has also been shown that children learn by observing. Moreover, when they get the opportunity to try to do things, they learn in and through action. Just as Gibbs (2006) and Pramling Samuelsson and Sheridan (2016) claim, it is obvious – as seen in Activity A – that the children's knowledge is in many ways embodied and shared during play without verbal communication.

The teachers at both pre-schools in this study possess a positive scientific attitude (Fleer, Gomes & March, 2014). These teachers work deliberately with science at an everyday level. They take advantage of opportunities when children show interest in different phenomena in the environment. Moreover, they design the pre-school for informal science learning to provide the children with experiences and to get them engaged in science (Fleer, Gomes & March, 2014). This attitude offers good conditions for children's learning in science and technology.

Conclusion

In view of the results in this study, I agree with Thulin (2011), who maintains that children need to repeat the same construction activity several times to get a deeper knowledge and understanding of the phenomenon. The more knowledge they get, the more interest they develop in the phenomenon. Like Thulin (2011), Mawson (2011) believes that children need to work for an extended period of time with the same area of knowledge. It is important that teachers have the knowledge and experience to support and challenge children as they play and learn.

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References

Bagiati, A. & Evangelou, D. (2016) 'Practising engineering while building with blocks: identifying engineering thinking', *European Early Childhood Education Research Journal*, **24,** (1), 67–85. DOI: 10.1080/1350293X.2015.1120521

Björkholm, E. (2015) *Constructions in function – a study of technical knowing in primary education.* (Doctoral dissertation, Stockholm University)

Björklund, C. (2014) 'Powerful teaching in preschool – a study of goal-oriented activities for conceptual learning', *International Journal of Early Years Education*, **22,** (4), 380–394

Björklund, C. & Pramling, N. (2014) 'Pattern discernment and pseudo-conceptual development in early childhood mathematics education', *International Journal of Early Years Education*, **22,** (1), 89–104

Carlgren, I. (1994) Kunskap och lärande. *Bildning och kunskap*.

Carlgren, I., Forsberg, E. & Lindberg, V. (2009) *Perspektiv på den svenska skolans kunskapsdiskussion*. Stockholms Universitets förlag

Eshach, H. & Fried, M.N. (2005) 'Should science be taught in early childhood?', *Journal of Science Education and Technology*, **14,** (3), 315–336

Fleer, M., Gomes, J. & March, S. (2014) 'Science learning affordances in preschool environments', *Australasian Journal of Early Childhood*, **39,** (1), 38

Gibbs Jr, R.W. (2005) *Embodiment and cognitive science*. Cambridge: Cambridge University Press

Gustavsson, B. (2002) *Vad är kunskap? En diskussion om praktisk och teoretisk kunskap.* Stockholm: National Agency for Education

Harlen, W. (2010) *Principles and Big Ideas of Science Education.* Hatfield: Association for Science Education

Holmqvist Olander, M. & Ljung-Djärf, A. (2012) 'Using Learning Study as in-Service Training for Preschool Teachers'. In *Early Education in a Global Context* (pps. 91-107), Emerald Group Publishing Limited.

Holmqvist, M., Brante, G. & Tullgren, C. (2012) 'Learning study in pre-school: teachers' awareness of children's learning and what they actually learn', *International Journal for Lesson and Learning Studies*, **1,** (2), 153–167

Ljung-Djärf, A. & Holmqvist Olander, M. (2013) 'Using learning study to understand preschoolers' learning: Challenges and possibilities', *International Journal of Early Childhood*, **45,** (1), 77–100

Marton, F. (2015) *Necessary conditions of learning*. Abingdon: Routledge

Mawson, W.B. (2013) 'Emergent technological literacy: what do children bring to school?', *International Journal of Technology and Design Education*, **23,** (2), 443–453

Merleau-Ponty, M. (1945/2002) *Phenomenology of perception.* London: Routledge

Molander, B. (1993) *Kunskap i handling.* Göteborg: Daidalos

National Agency for Education (2016) *Curriculum for preschool.* www.skolverket.se

Parker-Rees, R. (1997) *Learning from play: design and technology, imagination and playful thinking.* Conference paper from 1997 IDATER Conference, Loughborough University

Polanyi, M. (1966) *The Tacit Dimension.* London: Routledge & Kegan Paul

Pramling Samuelsson, I. & Sheridan, S. (2016) *Lärandets grogrund.* Lund: Studentlitteratur

Ryle, G. (1949/1966) *The concept of mind.* Aylesbury: Penguin Books

Schön, D. (1983) *The reflective practitioner. How professionals think in action.* New York: Basic Books

Sjøberg, S. (2000) *Naturvetenskap som allmänbildning – en kritisk ämnesdidaktik.* Lund: Studentlitteratur

Spektor-Levy, O., Baruch, Y.K. & Mevarech, Z. (2013) 'Science and Scientific Curiosity in Pre-school – The teacher's point of view', *International Journal of Science Education*, **35,** (13), 2226–2253

Swedish Schools Inspectorate (2017) *Förskolans arbete med matematik, naturvetenskap och teknik.* Stockholm: Skolinspektionen

Turja, L., Endepohls-Ulpe, M. & Chatoney, M. (2009) 'A conceptual framework for developing the curriculum and delivery of technology education in early childhood', *International Journal of Technology and Design Education*, **19,** (4), 353

Van Meeteren, B. & Zan, B. (2010, May) 'Revealing the work of young engineers in early childhood education'. In *Collected Papers from the SEED (STEM in Early Education and Development) Conference*

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In quest of teaching quality in pre-school science: teachers' views of factors influencing their work

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Abstract

This study explores experienced early years teachers' views of factors that may influence the quality of their teaching performance in science. Planning for the improvement of science instruction should take these into consideration, as teachers usually hold strong personal beliefs about what they view as good teaching. The study was carried out in Greece. Six teachers of the lower grades of education participated: one from early primary and five from pre-primary education, all with long experience in teaching science. One take-home written task, one group interview and one questionnaire constructed by the teachers themselves were used for data collection. Qualitative analysis of teachers' written protocols, interview and the questionnaire revealed a significant number of findings, which were organised into four broad themes related to: teacher, student, situational factors and initiatives for personal professional upgrading. A significant number of teacher-related factors concern different categories of teacher knowledge.

Teachers also consider that the quality of their teaching in science can be influenced by other teacher characteristics such as emotions, personality, motivation and attitude. Teachers also mentioned a number of situational factors, but they believe that some of the situational difficulties can be overcome depending on the teacher characteristics. Student-related factors include ideas of concepts and phenomena, interest in the subject (can be triggered by teacher), attitude (can be influenced by teacher), motivation (can be developed in class), singularities and emotions. While findings should be interpreted within the limits of a small-scale exploration study and a study of teachers coming from a single country, they may be used to guide research of early years teachers' views and experiences in other countries as well. This would produce a pool of interesting and useful information that could contribute to a holistic approach to the improvement of science instruction in early years education.

Keywords: Early years' science, teachers' views, pedagogical content knowledge, affective and emotional factors, teacher's personality-related factors

Background

In this paper we present and analyse the views of in-service teachers of the lower grades of education concerning factors affecting their teaching in science. Research has shown that early years teachers have weak background knowledge in science (e.g. Kallery & Psillos, 2001), have problems in implementing the science curriculum (Kallery & Psillos, 2002), and give science lessons that are fragmentary in character and fail to promote children's understanding and scientific thinking (Kallery *et al*, 2009).

The importance of teachers' knowledge and its relation to teaching practices has been stressed by researchers and educators (e.g. Shulman, 1986). Still, events in the classroom do not entirely spring from teachers' personal characteristics and the qualities they bring into the classroom, while aspects of their work that are outside their control, such as the influence of situations, have often been overlooked (what is called *attribution error*) (see Kennedy, 2010). Social psychologists, Kennedy

(2010) notes, tell us that teacher behaviour tends to be more influenced by the situations they face than by their own personal qualities although, as she observes, some teachers are better able than others to accommodate situational strains they may face in their work.

Other researchers (e.g. Van Driel & Berry, 2012) note that the development of teachers' knowledge, especially Pedagogical Content Knowledge (PCK), is not a linear process and could be influenced by teachers' specific professional contexts and support for professional development, and that teachers hold strong personal beliefs about what they view as good teaching. What is needed is a closer examination of individual teachers' views on what they think can influence their practices in the classroom. Planning for the improvement of science instruction should take these views into consideration.

It was against this background that the present work was undertaken. Specifically, the research questions leading the present study are:

1. What factors do expert early childhood teachers believe influence the quality of their teaching of science?
2. What factors do expert early childhood teachers encounter when performing activities with young children that influence the quality of their teaching?
3. What interactions do expert early childhood teachers perceive exist between these identified factors?

Methodology and sample

The study was carried out in Greece. Six teachers of the lower grades of education participated, one from early primary and five from pre-primary education, all with long experience in teaching science. The teachers were members of a work group that also included a researcher and science specialist (author of this paper). The partners shared the goal of developing science activities for young children.

The research reported in this paper was designed as a small-scale exploratory study, with data obtained using the following instruments: one take-home written task, one questionnaire constructed by the researcher, one group interview, and one questionnaire constructed by the teachers themselves, as a means of investigating the views of other colleagues on the same issues; this provided valuable data on factors that the teachers consider to have an important influence on science teaching. The instruments are presented in the Appendix. In the written task, teachers were asked to report and elaborate on what they believe may affect their teaching performance in science and what they actually encounter when introducing activities to young children. To supplement and clarify the information derived from the written assignment, a group interview was held. Prior to the interview, the author – who acted as researcher as well as interviewer – conducted preliminary analyses of the teachers' written protocols in order to identify the predominant themes. This assisted the researcher in deciding the focus of the interviews and in forming probing and clarifying questions during their course.

Data were collected in the following order:

1. Teachers completed the written task individually.
2. Teachers constructed the questionnaire.
3. Teachers completed the individual questionnaire.
4. The group interview was held.

Data analysis and results

Qualitative analysis of the teachers' written protocols, interviews and the questionnaire revealed a significant number of findings, which were organised into four broad themes:

- ❒ Teacher-related factors;
- ❒ Pupil-related factors;
- ❒ Situational factors; and
- ❒ Initiatives for personal professional upgrading.

Representative findings for each of the above themes are reported in the rest of the paper.

The ***teacher-related factors*** were organised into five domains:

- ❒ Knowledge;
- ❒ Affective;
- ❒ Emotional;
- ❒ Personality; and
- ❒ Experiences.

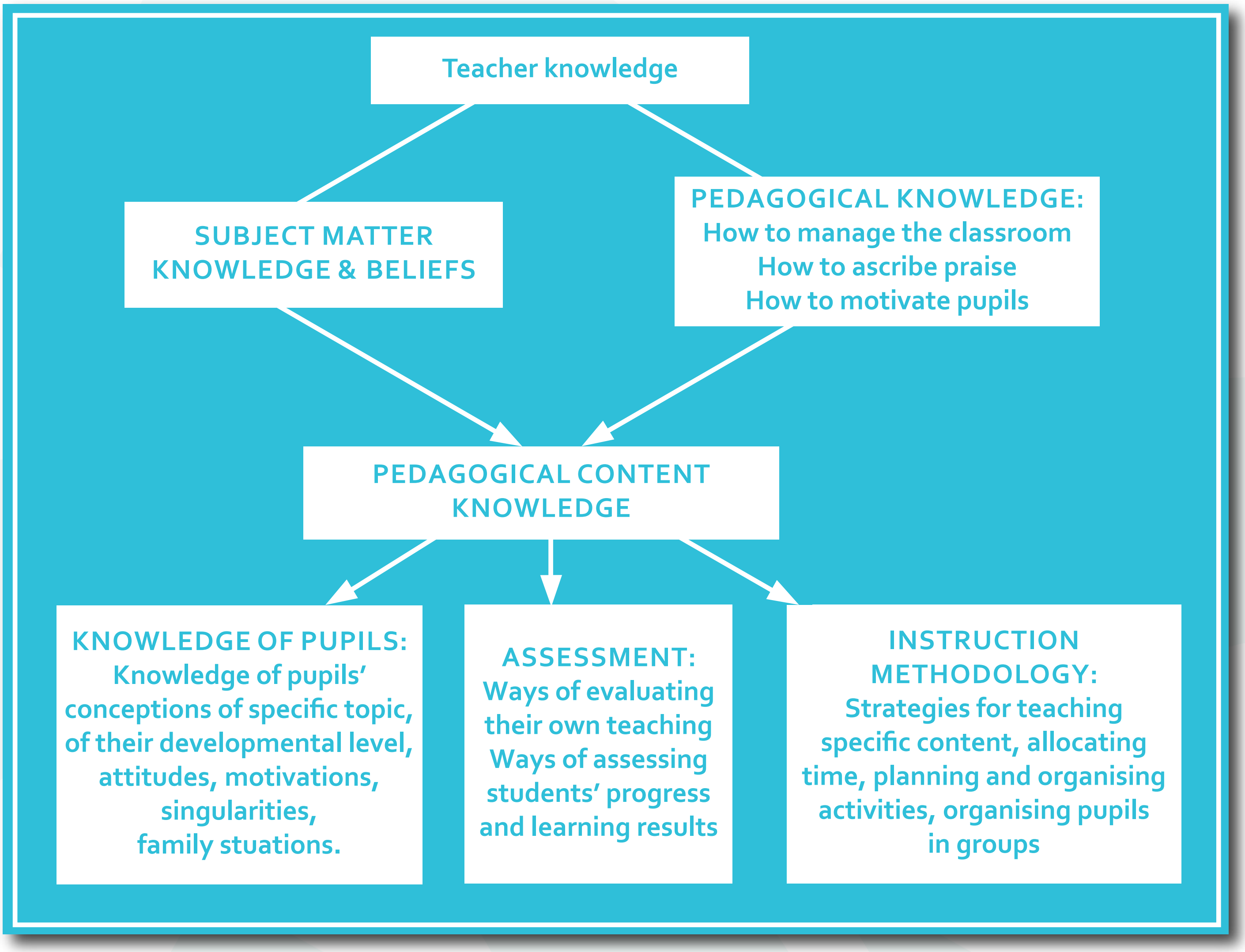

Figure 1: Relationships among the factors related to teacher knowledge reported by the participating teachers.

In the domain of teacher knowledge, apart from the explicitly mentioned subject matter knowledge, teachers spoke of a number of other factors comprising two categories of teacher knowledge: Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK). These factors and their interrelationships are presented in diagram form in Figure 1 above.

Three of the reported teacher-related factors belong in the affective domain: *Interest, Motivation* and *Attitude.* In their interviews, teachers noted that these factors can increase their effectiveness when planning and delivering activities. Emotional factors include rewards (joy coming from children's successes and interest in science activities), sureness, safety, anxiety, fear and disappointment (see also Zembylas, 2004).

Teachers elaborated on these factors. They related 'sureness' to their own subject matter knowledge and their knowledge of the children. 'Safety' was related to their knowledge of the subject and knowledge of teaching methodology and 'anxiety' was related by the teachers to the level of their knowledge of the subject (degree of sufficiency) and to situational factors.

Teachers talked about 'fear' and related it to insufficient knowledge that may lead to unsuccessful science activities and also to difficulty in managing the class.

The teachers found 'disappointment' a very important factor, which may hinder their motivation for work and which may be stemming from their unsatisfactory performance in the activities, from situational factors such as the acceptance and recognition of their work by other colleagues and by parents.

Teachers' experiences were distinguished as those coming from their years of work (contributing

Themes	Findings
Student-related factors	❍ Ideas of concepts and phenomena ❍ Interest in the subject (*can be triggered or stimulated by the teacher*) ❍ Attitude (*can be influenced by the teacher*) ❍ Motivation (*can be developed in class*) ❍ Students' singularities ❍ Emotions
Situational factors	❍ School infrastructure: available physical space for science activities, available materials ❍ Available time for science ❍ Number of students in class ❍ The curriculum (*flexible, explicit or very broad*) ❍ Teacher manuals and teacher guides (*existence, coherency and consistency*) ❍ School situation (*communication and collaboration with the rest of the staff*)
Initiatives for personal professional upgrading (concerns teachers' initiative regarding participation in a work group yielding the following advantages contributing positively to their teaching)	❍ Collaborate with specialist in the subject ❍ Participate in the development of instructional materials ❍ Participate in research (*the teacher as researcher*) ❍ Reflect individually and collectively, interact and communicate ❍ Overcome difficulties

Table 1: Student, situational and teacher initiative-related factors.

positively) and those from their own schooling (mostly contributing negatively).

Classified as teachers' personality-related factors were: communication style, creativity, flexibility, taking initiatives, self-esteem, sense of responsibility and confidence.

Teachers consider that the way they communicate with children, but also with parents, can affect the quality of their work.

Regarding flexibility, teachers related this to their ability and readiness to handle situations that may arise, such as responding to children's difficult science questions and other difficulties during activities. They noted that these require good knowledge of the subject, as well as availability of alternatives, especially in cases of unexpected activity outcomes. They also mentioned responsibility and related it to their professionalism.

An overview of the most interesting factors falling under the other headings is presented in Table 1 above.

Concerning the ***student-related factors,*** as these are presented in Table 1, teachers believe that the most important of these, which can affect their teaching in science, are the students' ideas of concepts and phenomena, their interest in and attitude towards the subject, their motivation, their singularities and their emotions.

They noted that students' interest in the subject can be triggered or stimulated by the teacher, that students' attitudes can also be influenced by the teacher and that teachers can motivate students

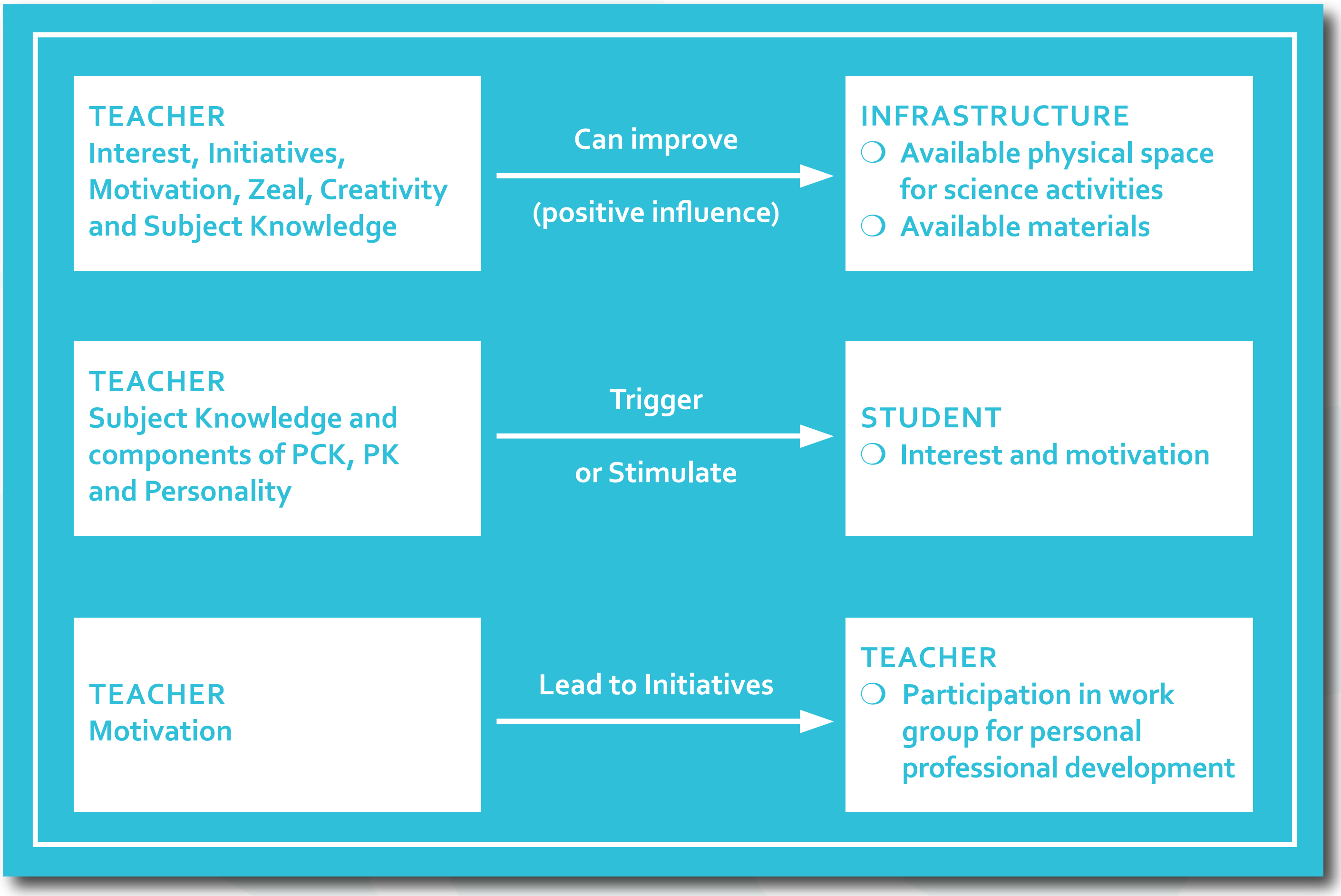

Figure 2: Interactions between factors expressed by teachers.

in class. They explained that students' singularities are related to students' personal characteristics and the problems stemming from them or from family situations.

Teachers referred to the students' emotions and the great significance of these for the quality of their work. Teachers said that emotions can, for example, be positive, such as their enthusiasm for the activities. In such cases, the emotions, as they stated, act supportively, but can also be negative and can be related to the students' personal problems.

Of the most important ***situational factors***, as shown in Table 1, teachers referred to the available physical space for science activities, available materials and time assigned to science activities, specific characteristics of the curriculum that either support or make their work in science difficult, the existence and quality of teachers' manuals, and finally the number of students in class.

Teachers also referred to specific situations in school, and specifically to the level and quality of communication and collaboration with the rest of the staff.

Regarding ***initiatives for personal professional upgrading***, the teachers consider that participating in a work group where they can collaborate with a specialist in the subject and, within the group, participate in activities such as development of instruction materials, act as researchers, interact and communicate with the other members of the group and have the opportunity to reflect, lead to factors that they consider to be advantages that can contribute positively to their teaching in science.

In their essays and interviews, teachers pointed out several interactions between the various factors, stating that their views about these interactions sprang from their own experiences; the most interesting of these interactions are presented in Figure 2. One of the important findings, as shown in the factor interaction diagram, is that the teachers believe that several of the situational difficulties can be overcome depending on the teacher's knowledge, interest, motivation, initiative-taking and personal work.

Conclusions and implications

The present study provides some insights into experienced early years teachers' views of what can potentially influence the quality of their work in science. The teachers consider that a variety of factors can contribute either positively or negatively to their teaching, most of them relating to the teacher him/herself, while a significant number of them concern different categories of teacher knowledge. As can also be gathered from the relationships between factors expressed by the teachers, it seems that they recognise their knowledge as playing a primary role in several of these relationships. They also consider that the quality of their teaching in science can be influenced by teacher-related characteristics such as emotions, personality, motivation and attitude. Teachers do mention situational factors, but do not seem to agree fully with the view that teacher actions and behaviours are more influenced by the situations they face than by their own personal qualities. Indicative of this is the view expressed by the teachers, springing from their own experiences, that some of the situational difficulties can be overcome depending on the characteristics of the teacher.

The research methodology employed in this study, with the combination of the four tools reported, was fruitful in making it possible to collect interesting data. While findings should be interpreted within the limits of a small-scale exploration study and a study of teachers coming from a single country, they may be used to guide research of early years teachers' views and experiences in other countries as well. This would produce a pool of interesting and useful information that could contribute to a holistic approach to improvement of science instruction in early years education.

References

Kallery, M. & Psillos, D. (2001) 'Preschool teachers' content knowledge in science: Their understanding of elementary science concepts and of issues raised by children's questions', *International Journal of Early Years Education*, (9), 165–179

Kallery, M. & Psillos, D. (2002) 'What happens in the early years science classroom? The reality of teachers' curriculum implementation activities', *European Early Childhood Education Research Journal*, (10), 49–61

Kallery, M., Psillos, D. & Tselfes, V. (2009) 'Typical didactical activities in the Greek early years science classroom: Do they promote science learning?', *International Journal of Science Education*, (31), 1187–1204

Kennedy, M. (2010) 'Attribution error and the quest for teacher quality', *Educational Researcher*, (39), 591–598

Shulman, L. (1986) 'Those who understand: knowledge growth in teaching', *Educational Researcher*, (15), 4–14

Van Driel, J.H. & Berry, A. (2012) 'Teacher professional development focusing on Pedagogical Content Knowledge', *Educational Researcher*, (4), 26–28

Zembylas, M. (2004) 'Emotion metaphors and emotional labor in science teaching', *Science Education*, (88), 301–324

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Appendix

Instruments

❐ *Take-home written task*

Which factors do you believe influence the quality and effectiveness of your teaching in science? As these factors are formed by your personal views and ideas as well as by your classroom experiences, please provide a description and elaborate briefly on them where possible to make them clearer.

❐ *Teacher-constructed questionnaire*

Please construct a questionnaire that you would use to investigate the factors that early childhood teachers of science believe may influence the quality of their teaching of science.

❐ *Individual questionnaire*

1. Do you think that the factors that you reported in your written task are related to each other? More specifically, which of these factors do you believe influence other factors and in what way?
2. Do you believe that these factors have been affected by your own education? How so?
3. Are there any affective factors mentioned in your written task? What are these affective factors and how would you describe them?
4. Do you think that a teacher's creativity is a factor that can contribute to the quality of his/her teaching in science? If so, how do you think it contributes?
5. In the case of implementing pre-designed science activities in the classroom, how do you think that a teacher's creativity can contribute?
6. Do you think that some of the factors you reported in the written task depend on the teacher's knowledge? If so, which types of teachers' knowledge?
7. Do you think that some of the factors you mentioned in the written task are topic-dependent, i.e. are related to the science topic you are teaching?
8. Do you think that teachers' knowledge of how to praise children is a factor that could influence the quality of your teaching in science? Was this mentioned in your written task?
9. Are there factors that are outside your control that can influence the quality of your teaching of science? If so, what are these factors?
10. Has the development of any instructional materials, or your participation in any research activities related to your work, influenced the quality of your teaching of science? If so, what were these activities and how did they influence your teaching?
11. Do you have any other comments on what factors may influence the quality of your teaching of science?

❐ *Focus group interview*

Questions will be formed by the interviewer on the basis of results coming from the preliminary analysis of the written task. Are similar to the individual questionnaire and will generate discussion from the participants.

Pre-service kindergarten teachers' acceptance of *'ScratchJr'* as a tool for learning and teaching Computational Thinking and science education.

- **Michail Kalogiannakis** • **Stamatios Papadakis**

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Abstract

The innovative educational programming environment called ScratchJr offers young children the possibility to programme their own interactive stories and games. This study aims to investigate the acceptance of ScratchJr by pre-service kindergarten teachers as a tool with which to produce interactive, multimedia learning content for science teaching, as well as a tool for learning and teaching Computational Thinking. Also, the effects of using ScratchJr for future teachers' attitudes in terms of perceived ease of use and usefulness are explored. The study was conducted during the winter term of the academic year 2016–2017 at a university department of early childhood education in Greece. The results show not only that the use of ScratchJr has a statistically significant increase in pre-service kindergarten teachers' self-efficacy in Computational Thinking, but also that they are willing to use it in their future daily practice for science education. Also, the study reveals that pre-service teachers have positive acceptance scores in terms of usefulness and ease of use of ScratchJr. Additionally, no significant difference between the acceptance scores of the participants in terms of programming background, and their studies in the high school from which they graduated, as indicators of programming experience was found. Preliminary analysis of the data shows that ScratchJr is an appropriate educational environment for pre-service kindergarten teachers to learn programming basics as well as a platform for the development of educational resources to support the learning of science teaching.

Keywords: ScratchJr, pre-service kindergarten teachers, Computational Thinking

Intruduction

Several western countries are in the middle of changes regarding school curricula as they see the value of introducing topics such as programming and Computational Thinking (CT) (Bean *et al*, 2015; Duncan, Bell & Tanimoto, 2014). Especially, CT has clearly become an interdisciplinary concept based on, but not limited to, Computer Science (CS) (Saltan & Kara, 2016). As a result, learning programming as well as the development of CT is a teaching subject in many departments of tertiary education that are not necessarily related to CS or technology directly (Fesakis & Serafeim, 2009). Among these, the departments of education, in which pre-service teachers get acquainted with programming and CT, are included. The goal for pre-service teachers is either to teach children the basics of programming or to utilise the knowledge gained for the creation of interactive and multimedia-enhanced learning material, or to teach other subjects such as science education. However, there are risks for teaching programming: if a student is taught programming by a teacher who lacks confidence, there is a possibility that the student will create a negative impression of the subject (Duncan *et al*, 2014; Bean *et al*, 2015). For that, it is necessary for pre-service teachers not only to develop CT, but also a positive attitude and a strong degree of interest and confidence in using programming in their teaching. The present study investigates the effect of familiarity with *ScratchJr (Scratch Junior)* on pre-service kindergarten teachers' opinions and attitudes regarding the usefulness and ease of use of *ScratchJr.* Additionally, it investigates the contribution of *ScratchJr* to pre-service teachers' self-efficacy in CT, as well as the acceptance by pre-service teachers of the use of *ScratchJr* as a tool for learning and teaching CT and science education.

Method

Study purpose

The purpose of this study was to investigate pre-service kindergarten teachers' acceptance of *ScratchJr* as a tool for learning and teaching CT. The research questions for this study were as follows:

1 To what extent has *ScratchJr* contributed to pre-service teachers' self-efficacy in utilising CT within their future teaching endeavours in programming and science education?
2. To what extent do pre-service teachers accept the usage of *ScratchJr* for learning and teaching CT and science education, in terms of perceived ease of use and perceived usefulness?
3. Is there a difference in acceptance of *ScratchJr* related to programming experience, and the secondary school direction (humanities, science and technology) from which the pre-service teachers graduated?

The sample

The study was conducted during the winter term of 2016-17, at the Department of Pre-School Education of the University of Crete, Greece. The sample comprised 122 female pre-service kindergarten teachers. The students had registered for an optional IT course and voluntarily participated in the study. The *ScratchJr* was chosen as the programming environment. The intervention was carried out in an amphitheatre, where students sat together in small groups (of 2-4) using tablets, and could observe one another succeeding in the task. The first 10 lessons were divided into two parts. In the first part, the students were engaged in an open activity with *ScratchJr*, which introduced a new programming concept or a new *ScratchJr* characteristic. In the second, the students were engaged in group work and were supervised by the teacher.

We carefully selected experiences from the science field that would be both attainable and challenging, and arranged them in increasing complexity. The students were informed that the last three courses would be dedicated to the development of three open-ended design-thinking projects from the fields of science and mathematics.

The ScratchJr programming environment

Several graphical programming interfaces have been developed that allow novices to more easily engage in authentic programming and Computational Thinking activities (Dwyer *et al*, 2013). Drag-and-drop environments have become very popular for teaching programming to young children and novice programmers, as they do not require knowledge of programming syntax but provide an environment where compile-time errors are non-existent (Duncan *et al*, 2014). *ScratchJr* is an introductory programming environment that allows young children (5–7 years) to 'discover' the basic programming concepts by creating projects in the form of interactive stories and games. *ScratchJr* takes advantage of the popularity of mobile devices, since it is available both for smart phone devices with iOS or Android operating systems and screen sizes up to 7 inches (Papadakis, Kalogiannakis & Zaranis, 2016).

Instruments

For data collection, participants were asked demographic questions, open-ended questions, and Likert-type questions, on a 5-point Likert scale, which ranged from 'strongly disagree' to 'strongly agree'. To evaluate the first research question, we adapted a simple survey instrument – Teachers' Self-Efficacy in Computational Thinking (TSECT) from Bean *et al* (2015).

This instrument is intended to capture a sense of the student's self-efficacy in utilising programming and CT within their future endeavours in teaching science education. The scale had good reliability, as the Chronbach's Alpha was 0.95. This survey was given as a pre- and post-test before and after the intervention. Also, to investigate to what extent pre-service teachers accept the usage of *ScratchJr* for learning and teaching CT and science education, in terms of perceived ease of use and perceived usefulness, we followed the research approach of Saltan and Kara (2016). We used a questionnaire adapted from Davis' Technology Acceptance Model (TAM) (1989) (perceived usefulness and perceived ease of use). The second instrument was given after the end of the intervention.

Results

For the first research question, a t-test of the pre- and post-survey scale revealed a statistically significant increase in pre-service teachers' self-efficacy in CT from pre- (M =12.80, SD = 9.22) to post- (M = 30.59, SD = 4.77), $t(121)$ =11.48, $p <$ .0001. Cohen's effect size (d = 1.42) indicated a large positive effect. For the second research question, the participants were asked to respond to 14 items, with answers ranging from 1 to 5 on a Likert-type scale, which evaluated two factors of the TAM model: namely 'Perceived usefulness' and 'Perceived ease of use'. Overall, the 'Perceived usefulness' factor had a mean score of 4.12 (SD=.87), and the 'Perceived ease of use' had a mean score of 3.99 (SD=.51). The mean scores of the items show that participants mainly have positive and similar acceptance ratings for the items and the factors in the scale. For the third research question, the results from independent samples' t-tests showed that there was no significant difference between the 'perceived ease of use' and the 'perceived usefulness' mean scores of the participants regarding their direction at school, as well as their experience from IT-based university courses (Table 1).

Discussion and conclusions

ScratchJr seems to positively contribute to the development of pre-service kindergarten teachers' self-efficacy in utilising programming and CT within their future endeavours in teaching science. From the consideration of research data, it also seems that *ScratchJr* is useful for helping pre-service teachers to use computational constructs, engage in programming processes, acquire programming skills and motivation, and develop positive attitudes toward programming and usage in teaching science education. Also, the study's results revealed that pre-service teachers mainly have positive and similar acceptance of *ScratchJr* in terms of usefulness and ease of use, regardless of the school direction or their experience in IT university courses. Based on these findings, we believe that *ScratchJr* is appropriate to function as an introduction to basic programming concepts and CT, as well as the development of educational applications from kindergarten teachers.

References

Bean, N., Weese, J., Feldhausen, R. & Bell, R.S. (2015) 'Starting from scratch: Developing a pre-service teacher training program in computational thinking'. In *Frontiers in Education Conference (FIE)*, IEEE (pps. 1-8), IEEE

Davis, F.D. (1989) 'Perceived usefulness, perceived ease of use, and user acceptance of information technology', *MIS Quarterly*, **13,** (3), 319–340

Duncan, C., Bell, T. & Tanimoto, S. (2014) 'Should your 8-year-old learn coding?' In *Proceedings of the 9th Workshop in Primary and Secondary Computing Education* (pps. 60-69), ACM

Dwyer, H., Boe, B., Hill, C., Franklin, D. & Harlow, D. (2013) 'Computational Thinking for Physics: Programming Models of Physics Phenomenon in Elementary School', *Physics Education Research Conference*, 133–136. Portland

Fesakis, G. & Serafeim, K. (2009) 'Influence of the familiarization with scratch on future teachers' opinions and attitudes about programming and ICT in education', *ACM SIGCSE Bulletin*, **41,** (3), 258–262

	Humanities direction	Science–Technology direction	Independent samples t-test	Experience in IT university courses	Non-experience in IT university courses	Independent samples t-test
Perceived usefulness	(M=4.01, SD=.91)	(M=4.31, SD=.82)	t(120)=.95, p>.05	(M=4.12, SD=.53)	(M=3.98, SD=.55)	t(120)=.83, p>.05
Perceived ease of use	(M=3.74, SD=.54)	(M=4.20, SD=.39)	t(120)=.98, p>.05	(M=4.0, SD=.39)	(M=3.90, SD=.44)	t(120)=.89, p>.05

Table 1: Mean, standard deviation and independent samples t-test.

Papadakis, S., Kalogiannakis, M. & Zaranis, N. (2016) 'Developing fundamental programming concepts and computational thinking with *ScratchJr* in preschool education: a case study', *Int. J. Mobile Learning and Organisation*, **10,** (3), 187–202

Saltan, F. & Kara, M. (2016) 'ICT Teachers' Acceptance of "Scratch" as Algorithm Visualization Software', *Higher Education Studies*, **6,** (4), 146

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EUROPEAN SCIENCE EDUCATION RESEARCH ASSOCIATION ESERA

Exploring some simple machines and their applications

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Abstract

Open-ended investigations, supported by class discussion, can lead to a deep exploration of a topic. Here we discuss this idea using a set of wooden models or machines. Each model has the same elements: a handle that can be turned but with a different effect on turning for each model. Working with Year 2 and Year 6 (ages 7 and 11) classes illustrates the different manual and oral capabilities between younger and older age groups. The younger age group showed that they are still able to articulate quite sophisticated concepts using these models. The models can also be used in a range of activities and, in particular, in cross-disciplinary studies.

Keywords: Argumentation, machines, pushes and pulls, open investigations

Introduction

The PSTT founded its College of outstanding primary school science teachers (Shallcross *et al*, 2015) with a challenge to its new Fellows: have a box of wooden models and explore how they can be used in a primary school setting. The set of models developed are described in detail by Sophie Franklin (Franklin, 2013) and some will be briefly described in this paper. There are a myriad of machines that convert circular motion into other forms of movement. An example of this is the so-called double slider gear system (see Figure 1). Here, rotating the handle causes wheel A to rotate and, with it, coupler block B. As block B rotates, it is coupled to wheel C, which is offset from wheel A, and can now rotate at the same speed as wheel A.

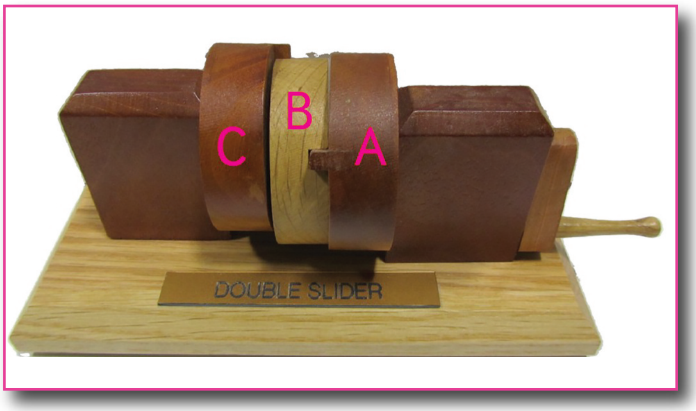
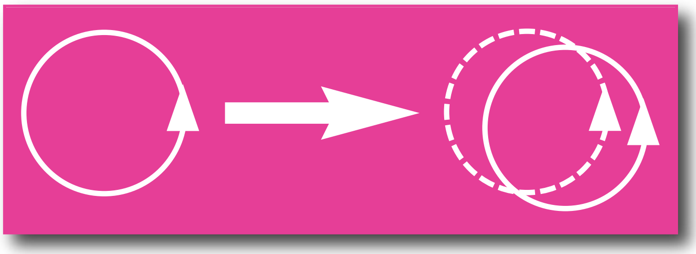


Figure 1: Double slider model system.

Figure 2: A pictorial version of the operation of the double slider mechanism: rotating wheel A causes wheel C (dashed wheel), which is offset, to rotate in the same direction and at the same speed.



In pictorial form, the motion can be summarised as in Figure 2. It is a simple machine to operate and it is also simple to understand what it is doing. John Oldham designed this system to solve a problem with a paddle steamer design, but it also now has several modern-day applications.

The Geneva wheel is another example of a rotating system, where the complete continuous rotation of wheel A causes partial or intermittent rotation of wheel B. For wheel B to undergo a complete rotation, several complete rotations of wheel A are required (see Figures 3 and 4).

The Scotch Yoke (Figure 5) transfers rotation into vertical (up-and-down movement – see Figure 6).

Peter Sainsbury (Sainsbury, 2011) has reported the first use of these models, adopting an approach similar to Mitra and Rana's 'hole-in-the-wall' project (Mitra & Rana, 2001; Mitra, 2003). Mitra and Rana set up a computer interface through a hole-in-the-wall of their centre in India and, without instructions, observed how children interacted with the computer. These workers observed remarkable

Figure 3: Geneva wheel model system.

progress made by the self-taught children. In a similar approach, Sainsbury left the models in an accessible place and observed primary school children of all ages playing with, exploring and observing the models. Their discussions about the models, how they worked and what they did were noted. Sainsbury wanted to add a challenge to the children's exploration. This was provided by some Year 4 students (8-9 years old) who wanted to know where these models could be used in real life examples. The school displaying the models is in close proximity to an army barracks and some of the children's inquiries yielded real life examples from their family members serving in Afghanistan. A very diverse list of uses was compiled by these children.

The full set of models is described in detail by Franklin (2013), but the 12 models used were: the double slider, the Geneva wheel, the fast return actuator, the eccentric, the cam and follower, the self-conjugate cam, the scotch yoke, the intermittent drive, the double universal joint, the roller gearing, the loose link coupling and the positive action cam. Based on these preliminary explorations, we surveyed how these models were used by Fellows (teachers) of the PSTT College and also trialled them in local primary schools as part of an undergraduate final year project. In addition,

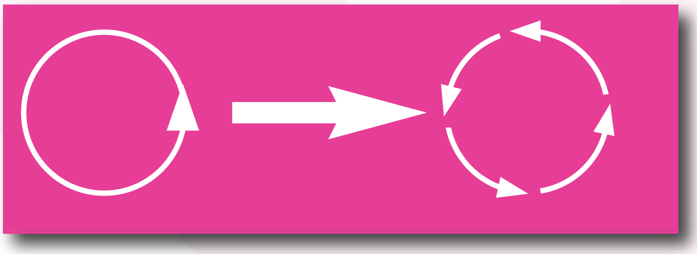
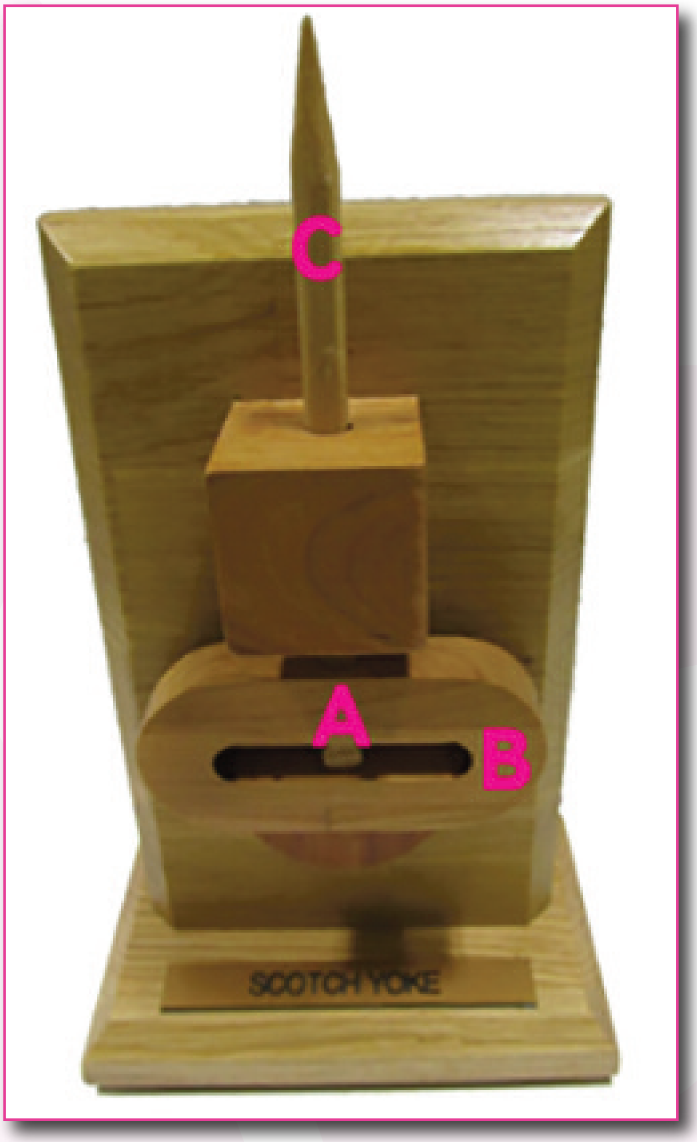


Figure 4: A pictorial version of the operation of the Geneva wheel mechanism. Rotating wheel A for one complete revolution causes wheel B (dashed wheel) to move around a fixed amount and stop. In order for wheel B to complete a full rotation, several full rotations of wheel A are required.

Figure 5: Scotch Yoke wheel model system.



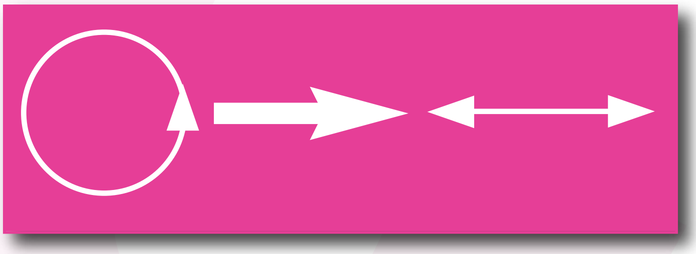


Figure 6: A pictorial version of the operation of the Scotch Yoke mechanism. Rotating wheel A one complete revolution causes the oval-shaped wheel B to move up and down and, being connected to the pointer C, this moves up and down.

in this paper we focus on how they were used in different ways for a Key Stage 1 year group (aged approximately 6-7 years) and a Key Stage 2 year group (aged approximately 10-11 years).

Key Stage 1 group

Each session with a new class began in the same way. Given that there were 12 different models and that more than one set was available (not always the case for teachers), all pairs of children had a model to explore all of the time. One of the problems with open explorations of this kind is the availability of the resource and this can itself hamper exploration. For the first 15 minutes or so, the children were asked to explore the models and share them between the groups on their table. In this way, children could explore 2-3 models each. At the end of this time, they were asked to describe the models and their actions to each other. For many models, the children could not only describe the action of the model, but could also describe whether the resulting motion was faster or slower than the rate of their handle-turning to operate the model. The children rotated around the tables so that they had time to explore all the models.

They were then asked to group the models and justify their reasons. If rules for class discussion are established (e.g. Mercer *et al*, 2003), this can be a very fruitful exercise, even with young learners. There are in fact myriad ways that these models could be grouped and a wide range of groupings were suggested by the children, showing that they had grasped the cause and effect nature of most of the models.

Other discussions included how many times one would have to rotate wheel A in the Geneva wheel to make wheel B rotate once, the different types of wood that were used to make the models, and whether other materials could be used to construct them. The children were asked whether they had seen these machines in real life or whether they could imagine where they were used. The two models described were often mentioned by the children; in the case of the Geneva wheel, there were various suggestions such as a shutter system, opening and closing something or a timing device (which is one of the uses). They were then given a set of pictures and asked to match them to the models, with an example set shown in Figure 7.

Some of the children were unfamiliar with several of the objects in the picture, but a few were able to identify the correct model.

Key Stage 2 group

Understandably, the pace of the lesson was quicker for the older age group, in that they explored and described the models in a shorter time span than the Key Stage 1 groups. In addition, when they were asked to group the models, they were much more assertive in their decisions and were seeking the answer about which was the 'correct' grouping from the leader. The leader stated that, provided the grouping could be explained and justified, it was 'correct' and that there were many groupings.

When presented with the pictures of real life objects, the older pupils were able to identify most of the objects and could, overall, pair the models with pictures. A final challenge set was for the children to build one of the models using a Lego modelling kit available at the school. Although the

Figure 7: Illustrative objects that could use some of the models in the set: a toy merry-go-round, a watch, a steam engine and a washing machine.

children took a while to decide on which model to reproduce and needed to figure out how to use the Lego modelling kit, most groups managed to complete a good representation of the wooden model. Such an exercise illustrated several aspects: firstly, it demonstrated that the children possessed a range of fine motor skills; secondly, the students demonstrated that they understood what the wooden model was doing and could reproduce it using a new model system; and they also demonstrated collaborative skills and a variety of argumentation and reasoning skills.

The teachers commented that they had never used the Lego kits before and that the children had achieved a great deal in the workshop and had been on task for the majority of the time. When asked whether they enjoyed the workshop and whether they learned something new, there was strong agreement. Having access to such a set of models, or even multiple sets, is a problem for most schools, but several of these models can be made simply and cheaply using everyday materials.

However, the point this illustrates is that, given an appropriate stimulus, children at primary school can carry out very sophisticated investigations largely unaided. Children need time to explore and investigate and they do need a teacher/leader who can provide support through questions to stimulate investigations. Extension activities worked well with both age groups and both girls and boys were engaged in these activities. Just as Mitra and Rana (2001) discovered, children can work things out for themselves if they are given enough time.

Fellows' feedback

In a primary school in Glasgow, the models were used to foster curiosity about engineering in a Scottish primary 7 (11-12 years) science club. The models were set out as the pupils entered the room and they worked in small groups to discuss each model in turn. There was no intervention from the teacher, who simply observed them working and listened to their discussions and questions. Initial discussions focused around trying to describe the movement of each of the models, e.g. *'This one could make something go up and down when you turn the handle'* (Scotch Yoke) and *'This one moves the movement across'* (Loose Link Coupling). Pupils were then directed to draw diagrams of the models and use arrows to show the operators' actions and how the machine changed the input motion into the output motion. During this activity, pupils were asked to suggest possible uses for the machines. Although they were able to accurately describe the motion, they found it very difficult to suggest possible uses due to a lack of background knowledge. They were then asked to choose two of the machines to research further at home and see what applications they could find.

The following week pupils shared their research with their groups and the discussions centred round real life applications of each machine. Many of the examples were accompanied by short video clips or gifs that showed the machines in action. Being able to see the machines in action helped pupils to visualise where each machine's motion could be applied.

The final task was for groups to use the knowledge and understanding they had gained to design a new application for some of the machines.

Feedback from the science club pupils was overwhelmingly positive and they all reported that having models of the machines that they could manipulate and observe had helped them to understand how they worked and could be used.

It was clear from observing the pupils and listening to their discussions and questions that the models had challenged their thinking and made them curious about how the machines were used and how they were developed.

Other uses

Fellows (teachers) reported a wide range of activities that were prompted by these models. Here are some very specific examples that they mentioned:

'We've been using them mainly in Year 5 as we were making cams in our space unit and the children have loved them.'

'The children explored the different models and mechanisms, drew detailed diagrams of how they worked, including direction arrows. They then began to think about how the various mechanisms could be incorporated into a design of their own fairground

ride. They had to decide which model was most suitable to incorporate into their design and why.'

They also mentioned more cross-disciplinary uses, as shown by the quotes below:

'The models were used as part of a lesson on Victorian technology and the industrial revolution.'

'Our teachers have used them in art work, looking at textures, shapes and colours of the wood.'

Some children researched the model mechanisms and not only identified where they were used, but also their history.

Summary

Machines are a challenging subject at primary school level. This study suggests that, given an appropriate resource and the opportunity, children of a wide range of ages can make significant advances in their understanding of some quite complex machine mechanisms. They can compare different machines and group them in a wide range of ways using obvious and less obvious, but no less valid, sorting criteria. Progression of the investigation can take a number of forms, but challenging them to think about and match the machines with real life machines produces lively and progressive discussions. Having the confidence to support open-ended learning is a challenge but, in this study, the progress registered by the children illustrates that it can be a significant benefit to learning.

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References

Franklin, S.D. (2013) *How things move.* PSTT booklet, available from www.pstt.org.uk

Mercer, N., Dawes, L., Wegerif, R. & Sams, C. (2004) 'Reasoning as a scientist: ways of helping children to use language to learn science', *British Ed. Res. J.*, **30**, 359–377

Mitra, S. & Rana, V. (2001) 'Children and the Internet: experiments with minimally invasive education in India', *British Journal of Educational Technology*, **32**, 221–232

Mitra, S. (2003) 'Minimally invasive education: a progress report on the "hole-in-the wall" experiments', *British Journal of Educational Technology*, **34**, 367–371

Sainsbury, P. (2001) 'Let the creative cogs turn – give science to the children', *Primary Science*, (120)

Shallcross, D.E., Schofield, K.G. & Franklin, S.D. (2015) 'The Primary Science Teaching Trust', *J. Emergent Science*, (9), 8–9

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why & how?
PRIMARY SCIENCE
TEACHING TRUST

The benefits of outdoor learning on science teaching

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● Naomi K.R. Shallcross. ● Sophie D. Franklin ● Dudley E. Shallcross

Abstract

A short review of the literature concerning outdoor learning relevant to primary school is provided, followed by some short case studies of work generated by primary school teachers. The aim of this article is to start to marry practice-based work in schools with the wider research base. Here, we look at the impact of outdoor learning on children where English is their second language (EAL); the impact on the curriculum, teachers and children; and how a science trail can support multi-sensory learning.

Introduction

In this new style of paper for the *Journal of Emergent Science*, we are seeking to take teachers' experiences in school, through case studies, action research, etc. and set them in the context of the wider research literature. There is no attempt to make the teachers' contributions definitive (i.e. these are teachers' reflections), but to link themes that emerge from their experiences with known research in the field. In this article, we will focus on the use of the outdoor classroom. There are many benefits of using the outdoor classroom, especially for science lessons, and these have been shown in a range of studies.

Some benefits of outdoor learning that are of importance in the primary school setting include:

1. Making learning a multi-sensory experience (e.g. Gray & Birrell, 2015; Mann & Taylor, 1973; Phillips, 2015);
2. Lending itself to inter-disciplinary studies (e.g. Dillon *et al*, 2005);
3. Recognising and celebrating differing learning styles (e.g. Gardner, 1993);
4. Engaging boys: *'Some boys who are at risk of becoming disaffected at a very young age have shown significant improvements if their learning takes place outside'* (Bilton, 2005);
5. Connecting the school to the neighbourhood and the world at large, e.g. citizenship (e.g. Dillon *et al*, 2005);
6. Blurring the boundaries between academic learning and creative play (e.g. Phillips, 2015);
7. The outdoor classroom fosters active, hands-on, inquiry-based learning in a real world setting. Through group problem-solving activities, students embrace the learning *process* as well as seeking final outcomes (e.g. Morgan *et al*, 2016; DeWitt & Hohenstein, 2010);
8. Connections are made experientially with the real world outside the classroom, helping to develop skills, knowledge and understanding in a meaningful context (e.g. Phillips, 2015; Morgan *et al*, 2017);
9. Outdoor environments and surroundings act as a rich stimulus for creative thinking and learning. This affords opportunities for challenge, inquiry, critical thinking and reflection (e.g. Gray & Burrell, 2015);
10. Children and young people are able to understand the relevance of a subject taught in school to everyday life (e.g. Gehris *et al*, 2015);
11. Children and young people can sometimes behave differently outdoors. Quiet pupils may speak more, others become calmer and more focused when outside, especially in a natural space (e.g. Smith, 2015);
12. The multi-sensory experience outdoors helps children and young people to retain knowledge more effectively. There are opportunities for pupils to learn with their whole bodies on a large scale (e.g. Malone & Tranter, 2010);
13. Learning in a less structured environment can provide a different learning experience from that of the classroom (e.g. Dillon *et al*, 2005); &

14. Opportunities to play outside are often particularly beneficial, as most children tend to be less inhibited in their language use in an outdoor environment. Practitioner observations have shown that children commonly make at least five times as many utterances outdoors as they do inside. This has clear implications for ensuring that the potential for outdoor spaces as learning environments is maximised (Dowdell *et al,* 2011).

Case studies

Three Fellows of the PSTT College (Shallcross *et al*, 2015) were asked to reflect on their experiences using the outdoor classroom.

Case Study 1: Reflections on the impact of outdoor learning on EAL students

Our community school has around 420 children on roll and 95% of these have English as an additional language, with the majority being from an Asian background. 11.5% are SEND (Special Educational Needs and Disabilities) children. Few children have access to gardens or a green space outside of school. There are high levels of social deprivation and a rising number of individuals and families with mental health issues. Our pupils generally have limited life experiences and rarely experience nature and the outdoor world.

When our school roll dropped and we moved from being a 3-form entry to 2, the decision was made to demolish the infant building and build a sports hall. This would provide income for the school, as it could be hired by groups in the community. After its construction, we were left with an L-shaped piece of land approximately 8 feet wide and 100 feet long.

I applied for a grant from Awards for All to construct a wildlife garden. The bid was successful (see Figure 1), and a local Environmental Action Group, including some young offenders, began

Figure 1: Case study 1: part of the outdoor space.

work. The children and staff were consulted about what features the garden should have and submitted drawings and plans. A competition was held for the whole school and wider community and we incorporated some of the features into the completed garden (this approach is noted by Wake, 2015).

Developing spoken language was an area for which I believed the garden would be highly beneficial. Many parents and grandparents spoke little English and so many children entering the school did not have high English language skills.

One of the main aims of the garden was to encourage more parents, particularly mums, to become more involved in school life. Part of the garden included a community herb garden where people could come and pick herbs for cooking. We concentrated on plants that are particularly used in Asian recipes. This helped to create a dialogue between parents (usually mums) and staff and also between parent and child.

The garden has: compost bins, a pond, bird viewing area, bug hotels, a willow dome with seating, and raised beds. Different functional parts of the garden were developed. One part was dedicated to plants that could be used as dyes, such as onion, rhubarb, St John's Wort and camomile. One area focused on bio-mimicry, e.g. burrs (which provided inspiration for Velcro). Slugs were encouraged here, so we could look at the properties of slug slime and compare it with commercial glue. Another area was a medicinal garden, with a range of plants and herbs used historically to treat illness. We grew a range of vegetables and fruit and these were used by the cooking club. We planned for crops that would come to fruition before the end of term.

The garden provided the opportunity to deal with wider issues faced by the school. Children who were experiencing mental health problems found the garden a place where they could be peaceful. This worked too for pupils with behaviour issues, where, for example, digging was a useful task for alleviating frustration. Just being outdoors has an amazing effect on the body. We held a soup competition in January. We first made a batch of soup with children from all year groups using in-season vegetables. Then the recipe was sent home with the challenge to adapt it any way they liked, but the additions had to be grown in this country (apart from spices). This was a way of introducing economic education to children and their families and also an introduction to monitoring our carbon footprint. We also held a cake competition later in the year. The cakes had to have a vegetable ingredient included in the recipe.

We made a book of the recipes and asked the dental health service to give a talk to parents about reducing sugar. We have one of the highest incidences of tooth decay and childhood diabetes in the country and showing that cakes could be made with reduced sugar was a small step in trying to address these problems.

We ran an after-school gardening club, which was staffed by behaviour support workers and we also held Saturday morning gardening sessions (an hour before the football team met for training, so they could come and 'warm up'!). Parents and ex-pupils also attended these sessions.

Every year in the summer we have a science week. This has had various themes over the years, but we always have a celebration day where parents are invited into school to see what their children have been learning. We always run 'Garden Tours' as part of this day. The pupils who attend gardening club take groups of parents on guided tours explaining about the different areas and plants.

The written work that evolved from this activity was, for the majority of children, of a much higher standard than that previously produced. Children who found speaking in class difficult discovered their voices outdoors. Natural links between subjects were spontaneous and child-led. We ended up having a bird and plant identification session as well as the planned lesson. Wherever possible, we would make sure that my class had some time outdoors each day. Even a 10-minute break in the middle of winter would invigorate the class and staff. Despite many barriers and difficulties, we have seen real progress in children's learning (especially in science) and a greater connection with the community.

Case Study 2: Reflections on the impact on the school curriculum, children and teachers

The development of a 'Secret Garden' (see Figure 2) has been fundamental in the development of an exciting and innovative curriculum throughout the school. In Figure 2, a before-and-after picture of part of the space is shown. We use the 'Cornerstones' curriculum, developed by the Learning Partnership in Wales. The learning is through 'Contexts for Learning' and many of the projects require the use of an outdoor space, which of course the secret garden provides. For example, the nursery class does 'Wellie Wednesday' every week; whatever the weather, they are in the garden exploring, looking at minibeasts, digging, planting, etc.

The older children have been using the garden to study life cycles and minibeasts, using identification keys and collecting data to take back to the classroom to be able to construct pictograms and bar graphs. The insect habitats have proven very exciting to watch, and we have had a range of birds nesting in our bird box. We have also used the gardening equipment to plant fruit trees and develop the planting area.

Figure 2: Part of the 'Secret Garden' in Case study 2 – before and after.

The pond dipping station allows the children to investigate what is in the pond and they have been able to use the pond camera to see what lies beneath. The children in Years 3 and 4 (ages 8 and 9) have been engaged in a project called 'The Big Dip', which concentrates on comparing and contrasting freshwater ponds and rock pool habitats. It has been so exciting for the children to be able to pond dip in our own school grounds and the creatures that they have found have been extremely interesting and diverse. Apart from any impact on science, there is an impact on language skills; children express ideas outdoors that they do not in the indoor environment, stimulated by what they observe. The change in seasons, and week-to-week changes, are noted and remembered by the children, some of whom have seen dramatic changes as the garden has developed since they started in reception class. Multi-disciplinary studies are natural to plan; we use data gathered to support numeracy, derive inspiration for elements of literacy, and both geography and design and technology projects have used the 'Secret Garden'. For children with special educational needs, this space is most welcome, allowing them to explore the world around them in a relatively safe environment, and both children and teachers look forward to their sessions in the garden. The only element of the 14 benefits listed above that is missing is no. 5, but greater engagement by parents, relatives and friends in the upkeep of the 'Secret Garden' has developed a greater connection with the neighbourhood.

Case study 3: Reflections on a sound trail and its impact on sensory learning

The idea behind science trails has been discussed in a previous article in the *Journal of Emergent Science* (Morgan *et al*, 2017) and will only be briefly recapped here. Teachers develop (with children where possible) a trail either within the school grounds or in the local environment, which may be urban as well as green spaces, with a particular theme. This case study reports on a sound trail outside the school grounds. The trail takes the children on a circular route through an urban area, through a park, over a bridge and back to the school. In the park, children close their eyes and identify sounds; they may record the loudness of these using a decibel meter, or record the sound to play back at school. They record where the sounds were heard on the walk and if it was specific to a location. They have taken musical instruments out to test them in these environments: how far away can you be and still hear the instrument?

For children where English is the second language (EAL), the use of picture cards and/or cards with words both in English and their first language, with a variety of sources of sound, was helpful. Cards showing various animals, vehicle types and elements such as the wind engage these children well. We challenge children with questions like *'Can it ever be absolutely quiet?', 'Why is the sound being made?', 'How is the sound being made?'* In this environment, it is easier to differentiate learning. Back in the classroom, the children have made a sound drama, using the sounds they have heard as stimulus for a story. They discuss where the sounds were heard and whether that was a unique location and why. They have played back the sounds weeks, and even months, later to see whether they still recognise them and where they heard them, and they are able to do so. Younger children may make a story stick sequence for the sound journey using different materials to generate the different sounds. Some common comments include:

'We found closing our eyes really helped us to concentrate.'

'We never realised how many animals we can hear when we listen quietly.'

'We knew it was going to be noisy by the railway bridge so we waited for a train, it was noisy and we could use our sound meters to see how noisy it was.'

'When we spotted some sounds, like the dog, we pointed our log boxes at them and noticed that the numbers were changing lots and the numbers were much higher.'

Sounds heard in the urban environment include: traffic, people talking, traffic lights, buses, ambulance, banging on glass, (it is very noisy). Sounds heard in the park include: water flowing, birds, people talking, cars, someone playing tennis, train, splashing fountain, street cleaning, motorbike, wind, grass swaying, footsteps on leaves, laughing, hoot from a truck.

These outdoor experiences are memorable for the children and they do retain science concepts over a long period of time because of this. Here, all 14 potential benefits listed above have been realised.

Summary

In this paper, we have highlighted some of the benefits of outdoor learning, as evidenced through research. We have then asked three teachers to reflect on their experiences of outdoor learning and see that the majority of benefits are observed in each case. Although these are reflections and no attempt has been made to obtain quantitative data, this supports the use of the outdoor classroom.

We would welcome your comments on this paper. If you are a primary school teacher and have outdoor classroom experiences that you would like to share, we plan to write a follow-up paper in a future edition, which collates these reflections and comments. If you disagree with elements of the paper, we would also like to hear from you. Please e-mail PSTT at info@pstt.org.uk

References

Bilton, H. (2005) *Learning outdoors: improving the quality of young children's play outdoors.* London: David Fulton Publishers (p.144). ISBN 1843123509

DeWitt, J. & Hohenstein, J. (2010) 'School trips and classroom lessons: An investigation into teacher-students talk in two settings', *J. Res. Sci. Teaching*, (47), 454-473

Dillon, J., Morris, M., O'Donnell, L., Reid, A., Rikinson, M. & Scott, W. (2005) *Engaging and Learning with the Outdoors: The Final Report of the Outdoor Classroom in a Rural Context Action Research Project.* Slough: National Foundation For Educational Research

Dowdell, K., Gray, T. & Malone, K. (2011) 'Nature and its influence on children's outdoor play', *Australian Journal of Outdoor education*, **15,** (2), 24–35

Gardner, H. (1993) *Frames of mind: the theory of multiple intelligences* (18th edition). New York, NY: BasicBooks

Gehris, J.S., Gooze, R.A. & Whitaker, R.C. (2015) 'Teachers' perceptions about children's movement and learning in early childhood education programmes', *Child Care Health and Development*, (41), 122–131

Gray, T. & Birrell, C. (2015) '"Touched by the Earth": a place-based outdoor learning programme incorporating the Arts', *Journal of Adventure Education and Outdoor Learning*, **15,** (4), 330–349

Malone, K. & Tranter, P.J. (2003) 'School grounds as sites for learning: Making the most of environmental opportunities', *Environmental Education Research*, **9,** (3), 283–303

Mann, M. & Taylor, A. (1973) 'The effects of multi-sensory learning systems on the concept formation of young children', *Journal of Research & Development in Education*, **6,** (3), 35–43

Morgan, J., Franklin, S.D. & Shallcross, D.E. (2017) 'Science trails', *J. Emergent Science*, (13), 31–35

Phillips, R. (2015) 'Playful and multi-sensory fieldwork; seeing, hearing and touching New York', *Journal of Geography in Higher Education*, **39,** (4), 617–629

Shallcross, D.E., Schofield, K.G. & Franklin, S.D. (2015) 'The Primary Science Teaching Trust', *J. Emergent Science*, (9), 8–9

Smith, D. (2015) 'The outdoor environment, enriching or not? The quest to find out: A brief review of the literature', *He Kupu*, **4,** (1), 15–17

Wake, S.J. (2015) *Bringing schools to life through a co-design learning approach with children. Living and Learning: Research for a better-built environment.* Eds. Crawford, R.H. and Stephan, A. Proceedings of the 49th International Conference of the Architectural Science Association: Living and Learning: Research for a Better Built Environment (pps.859-868)

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why & how?
PRIMARY SCIENCE TEACHING TRUST

A science ‘show and do’: Teacher and technician training – down under

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Abstract

Science demonstrations and experiments play an important role in the teaching and learning process. This creates a challenge for some teachers whose own training may not have involved the skills and confidence to deliver some of these activities. University science departments, in liaison with local primary and secondary school teachers, can provide meaningful practical science professional development in this area. The opportunity for teachers and technicians to spend several hours engaged in hands-on practical work alongside academics and, as importantly, their peers, has been welcomed in Western Australia (WA) for several years. After initial courses in chemistry practical work, the sessions have, by request, expanded into the other sciences, including Aboriginal science.

Keywords: University-school liaison, teacher workshops, professional development

Intruduction

The School of Science at Edith Cowan University (ECU) in Perth, Western Australia, has been working with Bristol ChemLabS Outreach (School of Chemistry, University of Bristol, UK) to deliver professional development (PD) to local educators since 2010, over a week-long period each year. Several half-day teacher and technician sessions were created and delivered. The half-day workshops have been well received. Subsequent national initiatives make such events even more in demand.

The rationale behind the professional development project

Chemical demonstrations and experiments play an important role in the teaching process, delivering a visual representation of difficult concepts and attraction to the fun of chemistry. (Bodner, 2001; Lister, 1996). There is evidence to suggest that students recall the visual imageries of a demonstration and/or experiment long after the words have been forgotten (Bodner, 2001; Garcia-Martinez & Serrano-Torregrosa, 2015). Both offer a foundation by which learning can be built upon and thus facilitate the retention of such knowledge (Bodner, 2001; Garcia-Martinez & Serrano-Torregrosa, 2015).

Student participation in STEM subjects in primary and secondary schools has become a key focus of the Australian Government (Department of Education and Training, 2015). Stimulating students to study STEM subjects and exposing them to scientific careers will likewise help to secure Australia’s future (Department of Education and Training, 2015; The Australian Industry Group, 2015). Beginning interest in the school sector will increase the number of individuals taking on STEM subjects in tertiary education and in their careers (The Australian Industry Group, 2015). This echoes a Europe-wide concern about school students, the future of Europe and STEM (Rocard, 2007).

A focus for primary school science was announced in August 2017 by the Premier of Western Australia, Mark McGowan, so that primary schools can help to prepare students for future employment opportunities in STEM (McGowan, 2017).
The McGowan Government committed AU$12 million to turn classrooms into laboratories, providing teachers with the appropriate facilities, glassware and equipment to operate chemistry experiments. The project evolution is summarised in Figure 1 overleaf.

Contents of the PD workshop

The initial focus of the project in 2010 was chemistry. The content of the chemistry workshop remains relatively unchanged. It consists of two

Figure 1: Evolution of the workshops.

Project Evolution

2010 – pilot workshops solely for laboratory technicians (chemistry focus)

2014 and 2015 – extended invitation to high school chemistry teachers

2016 – content from other sciences added

2017 – sessions now open to all primary (using some resources from the Primary Science Teaching Trust; Shallcross *et al*, 2015) and high school science teachers and science technicians

main areas: the first is a series of practicals that are a little unusual to many science teachers, such as the use of thermochromic paints, 'polymorph' thermoplastic, burning methane bubbles off a hand and producing iron on the head of a match. Many of these can be found in the Royal Society of Chemistry's (RSC) resource *Classic Chemistry Demonstrations* (Lister, 1996). The second area includes the types of experiments that cannot usually be done in a school, such as those with liquid nitrogen and dry ice. Such experiments are always useful for science teachers to be able to tell their students that they have done, or even to record the experiments on their mobile devices as they do them to add into their resources. Other areas include rocketry, Aboriginal science and microbiology.

The 'show and do' (or show and play) workshop consists of a presenter going through each activity, explaining the science behind it and how to demonstrate this most effectively. In practice, the group is split into two, visit one set of presenters, then have a go themselves before moving to the second group of presenters. Participants observe presenters' demonstrations for about 1-1.5 hours and then get time to 'play', 'discover' and 'network' for 1.5-2 hours. A combined lunch is provided between the morning and afternoon slots to allow participants from both sessions to network.

Feedback from previous workshops

Feedback is vital for the ongoing development of the workshop. Each year participants complete a questionnaire and feedback is implemented in subsequent workshops where considered practicable or desirable. The relative novelty of a 'show and do/play' workshop has been obvious from observations during the sessions and from comments received (a sample of typical comments is provided in Figure 2):

Meeting expectations is a tricky thing to plan for a large group of delegates coming from a range of school types, job roles and those who re-attend these courses. We know that, for those who said no, it didn't mean that the main reasons were that they did not receive lesson plans; this was something we worked with teachers on developing using these experiments, but did not provide them ready-made because we wanted to support the teacher's development. One way of gauging the success of a workshop is the intent to revisit or to suggest to colleagues that they should attend.

Feedback from 2017 workshop

This year there were 37 participants from both primary and high schools in the two workshops.

Overall Comments:

'Fantastic! Informative, entertaining and very useful for my teaching.... which PD usually isn't'

'This was a fantastic PD and I really appreciated the opportunity to attend'

'I would highly recommend it to other teachers'

'Seeing the experiments and having a chance to also "play"'

'An absolutely brilliant workshop, I was really inspired'

	Yes	No
Attended similar before	31%	69%
Met your expectations	90%	10%
Interested in attending again	100%	0%
Would your school have funding for you to attend again?	85%	15%

Figure 2: Feedback examples from the 2017 workshops.

We know that, in a few instances, people wanted to return because there was not enough time to work through all that is available. We do not expect people to work through everything, as we are catering for such a wide range of educators. However, all the attendees wanted to either attend again and/or recommend the workshop to a colleague.

The PD events delivered since 2010 have been free of charge to course participants. An important factor for future planning is whether future courses will be 'pay-to-play'. Charging for events such as these is a tricky internal matter for schools and colleges.

Suggestions for improvement

Where possible, suggestions received have been implemented. However, as with all such events, some suggestions cannot be acted upon for a host of reasons (see Table 2) that are not considered by participants.

Suggested improvement	Comment by organisers
Longer sessions	Initially the sessions were 2 hours long and each year we have added another 0.5 hour. Last year, the workshop ran for 3 hours. Since two workshops are run in one day, there is a maximum limit of 3 hours per workshop.
Link each activity to the curriculum	The resource booklet has partly done this – but it is sad that a narrow curriculum view is present. That said, the booklet is being re-written, with each experiment and demo being linked to the WA curriculum. The booklet will be ready by the end of 2018 and it is hoped that it will be adopted by WA schools to be used as a teaching tool in chemistry topics.
More structure	The structure of a 'show and do/play' event does not lend itself to a highly structured event. Some educators may not be comfortable with this.
More safety and disposal information	The resource booklet addresses this but cannot supersede local rules.
More technician input	The resource booklet addresses this, and several technicians, including a university technician, were on hand for comment and help.
More equipment sets to allow more repeats of each activity	Two teaching laboratories were set up. It is always a compromise to have a large number of experiments rather than a smaller number with more kits for repeats.

Table 2: Suggested improvements and limitations considered by organisers.

Requests for additional topics included: plastics, forensics, fuel cells and sensors. These are under consideration. There is a demonstrated appetite for training courses for educators in the Greater Perth area. Suggestions were also given for other courses, which delegates hoped that ECU could provide in the future:

- Understanding the underlying chemistry
- Chemical handling and disposal
- Science communication
- Analytical chemistry instruments
- Extension activities
- Science week visits
- Trainee teachers and technicians
- Safety courses
- ICT training

An initial request for resources has resulted in the activities booklet (Wajrak & Harrison, 2014) being written and distributed at these and other PD events.

Summary

The professional development (PD) workshop organised by ECU with Bristol ChemLabS (Shallcross *et al*, 2013) input has now been attended by over 300 primary and high school lab technicians and teachers and is now a permanent fixture in the ECU Outreach Science programme, and in technician and teacher organisations' timetables. The workshop is so popular that bookings are made in June for the annual November workshops. Recent Australian government announcements as to the importance of STEM in primary and secondary schools suggest that these PD sessions will be required for many more years.

Anyone who wishes to obtain a copy of the resource booklet can do so by contacting Dr. Magda Wajrak at: m.wajrak@ecu.edu.au

References

Bodner, G.M. (2001) 'Why lecture demonstrations are "exocharmic" for both students and their instructors', *University Chemistry Education*, **5,** (1), 31–35

Department of Education and Training (2015) *Restoring the focus on STEM in schools initiative.* ACT, Australia: Australian Government

Garcia-Martinez, J. & Serrano-Torregrosa, E. (2015) *Chemistry Education – Best Practices, Opportunities and Trends.* Weinheim, Germany: Wiley-VCH

Lister, T. (1996) *Classic Chemistry Demonstrations.* Cambridge, UK: The Royal Society of Chemistry

McGowan, M. (2017) *McGowan Government delivers science in schools election commitment.* Perth, Australia: Government of Western Australia

Rocard, M. (2007) *Science Education NOW: A renewed Pedagogy for the Future of Europe*. Brussels: European Commission. Retrieved from: http://ec.europa.eu/research/science-society/ document_library/pdf_06/report-rocard-onscience- education_en.pdf

Shallcross, D.E., Harrison, T.G., Obey, T.M., Croker, S.J. & Norman, N.C. (2013) 'Outreach within the Bristol ChemLabS CETL (Centre for Excellence in Teaching and Learning)', *Higher Education Studies*, **3,** (1), 39–49

Shallcross, D.E., Schofield, K.G. & Franklin, S.D. (2015) 'The Primary Science Teaching Trust', *J. Emergent Science*, (9), 8–9

Wajrak, M. & Harrison, T. (2014) 'Chemical Demonstrations Booklet', produced by, as part of SCC1123 *Chemistry for the Life Sciences Textbook*, Melvin Joesten & John Hogg, 1st Edition. Melbourne, Australia: Cengage Learning

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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.

Guidelines on written style

Contributions should be written in a clear, straightforward style, accessible to professionals and avoiding acronyms and technical jargon wherever possible and with no footnotes.
The contributions should be presented as a word document (not a pdf) 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

Reviewing process

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

Books for review

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

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ASE's flagship primary publication, *Primary Science*, is produced five times a year for teachers of the 3–11 age range. It contains a wealth of news items, articles on topical matters, opinions, interviews with scientists and resource tests and reviews.

Endorsed by the PSC, It is the 'face' of the ASE's primary developments and is particularly focused on impact in the classroom and improving practice for all phases. *Primary Science* is the easiest way to find out more about current developments in primary science, from Early Years Foundation Stage (EYFS) to the end of the primary phase, and is delivered free to ASE members. In the past, the Committee and Editorial Board have worked closely with the Early Years Emergent Science Network to include good practice generated in EYFS across the primary phase. Examples of articles can be found at: www.ase.org.uk/journals/primaryscience/2012

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