Res Sci Educ (2019) 49:1569–1593
DOI 10.1007/s11165-017-9667-6

Young Children's Development of Scientific Knowledge Through the Combination of Teacher-Guided Play and Child-Guided Play

Marija Sliogeris[1] · **Sylvia Christine Almeida**[1]

Published online: 20 September 2017
© Springer Science+Business Media B.V. 2017

Abstract Play-based approaches to science learning allow children to meaningfully draw on their everyday experiences and activities as they explore science concepts in context. Acknowledging the crucial role of the teacher in facilitating science learning through play, the purpose of this qualitative study was to examine how teacher-guided play, in conjunction with child-guided play, supports children's development of science concepts. While previous research on play-based science learning has mainly focused on preschool settings, this study explores the possibilities of play-based approaches to science in primary school contexts. Using a qualitative methodology grounded in the cultural-historical theoretical perspective, children's learning was examined during a science learning sequence that combined teacher-guided and child-guided play. This study revealed that the teacher-guided play explicitly introduced science concepts which children then used and explored in subsequent child-guided play. However, intentional teaching during the child-guided play continued to be important. Play-based approaches to science allowed children to make sense of the science concepts using familiar, everyday knowledge and activities. It became evident that the expectations and values communicated through classroom practices influenced children's learning through play.

Keywords Science education · Cultural-historical theory · Play · Elementary education · Early childhood education

✉ Sylvia Christine Almeida
sylvia.almeida@monash.edu

Marija Sliogeris
marija.sliogeris@monash.edu

[1] Education, Monash University-Peninsula Campus, A 3.12 Peninsula Campus, Frankston, Melbourne 3199, Australia

Introduction

A growing amount of research has demonstrated play as a meaningful context for young children to engage in rich science learning (e.g. Fleer 2009; Fleer et al. 2014; Larsson 2013; Siry 2013). The use of a cultural-historical theoretical perspective has uncovered the important role of the teacher in enabling science learning during play (Fleer 2009). Teacher-guided play is one form of teacher involvement that can be used support children's science learning through play (Blake and Howitt 2012). The combination of teacher-guided play and child-guided play has been shown to result in richer learning of concepts (Edwards and Cutter-Mackenzie 2011). In this paper, we aim to provide further insight into how the combination of teacher-guided play and child-guided play supports children's development of science understandings. In so doing, we present a qualitative study that examined children's learning during a play-based science learning sequence that combined both types of play in a formal learning setting.

Previous research on science learning through play has predominately focused on children's experiences in prior-to-school early learning settings, and less is known about play-based science learning in school settings. From a cultural-historical perspective, each setting has a unique impact on children's learning since different institutions have differing practices, goals and values (Hedegaard 2008). Previous research has enabled useful insight into children's science learning during play, however since this has been carried out mainly in early learning settings less is known about how the school context may influence children's science learning through play. Therefore, our study examines play-based science learning in an Australian primary school thereby offering rich understandings of play-based learning extending beyond the studies focused on early learning settings. This study is thus significant for researchers and educators interested in play as an approach to science pedagogy, and its potential in enhancing the science learning of children in the early years of school.

Literature Review

Research into young children's science learning has increasingly drawn on a cultural-historical theoretical perspective (Vygostky 1987) with the recognition that foregrounding cultural and contextual factors enabled insight into the processes by which children develop their science understandings (Fleer and Pramling 2015; Robbins 2005). Robbins (2005) illustrated that by eliciting and interpreting children's thinking within their social and cultural context, it was evident that children's science thinking was inextricably connected to their interactions and their participation in home and community practices, and the cultural and historical context in which these occur. As Fleer (2009) demonstrated, children experience science phenomena in their daily playful experiences and these experiences give meaning to the abstract concepts of science. For many children, play is an everyday activity through which they explore their world.

The cultural-historical perspective of play positions it as occurring within, and influenced by, a child's social and cultural context (Fleer 2011). This differs from perspectives that view play as an internally motivated activity based on the child's level of development. Instead Fleer (2010, 2011) contends that children's prior experiences, and the context and interactions in which the play occurs, place the possibilities and limitations on children's play activities. This is the understanding of play used within our study, and in the studies reviewed below.

While play allows children to engage in activities that draw on familiar, everyday experiences, play can also provide opportunities for children to develop understandings of concepts that transcend their everyday knowledge and experiences, such as science concepts (Siraj-Blatchford 2009). The teacher is crucial in enabling this to occur, as Fleer (2009) demonstrated by contrasting the science play in two different preschools. In the preschool where the teacher chose to implement science play by providing children with materials *without* any intentional, direct teaching of the science concepts, the children only engaged in activity that was meaningful in an everyday way but did not result in learning of science concepts. However, the teacher in the second preschool intentionally orientated play activities towards the learning of specific science concepts and thus enabled the children to use their everyday knowledge to develop understanding of the science concepts. In both preschools, children's play meaningfully connected to their everyday lives, but only the play in the second setting included science learning, and this was due to the teacher's "conceptually orientating" the children's play by planning for, and mediating the learning during the play (Fleer 2009, p. 295).

Fleer et al. (2014) similarly found that the everyday play activities supported by a child-care environment provided many opportunities for science learning. However, the teacher needed to recognise and make use of these in order for children to make the connections between science concepts and the everyday knowledge evident in their play. Larsson (2013) illustrated the lost chances for science learning when the teacher does *not* recognise science learning opportunities in children's play. She found that the teacher requires not only awareness of potential science learning, but also the child's 'perspective' (the motives and interests guiding the child's activity) in order to capitalise on these science learning opportunities. Siry (2013) identified that this calls for a collaborative approach in which the teacher takes time to observe and learn about the children's thoughts and approaches to the science play activity, and then use this information to work alongside the children to support and extend their investigations. The importance of intentional, collaborative involvement from the teacher has emerged as a significant theme in the studies presented above. One form of involvement is through the combination of teacher-guided play or activity, and child-guided play.

Teacher-guided science play can include guided discussion and investigation, modelling of science activity and explicit introduction of science concepts (Blake and Howitt 2012; Edwards and Cutter-Mackenzie 2011). This way children are introduced to unfamiliar materials and science concepts and skills. However, Blake and Howitt (2012) emphasised that this teacher-guided activity should not be an isolated event but be followed by opportunities for children to explore and extend this learning, particularly through child-guided *free play*. Similarly, Edwards and Cutter-Mackenzie (2011) highlighted that teacher-guided and child-guided play *together* result in richer learning as children explore the same concepts and activity in different ways while each experiences builds on the other. Segal and Cosgrove (1994) also presented the relationship between the learning in structured teacher-led activities and freer, child-guided play. They found that the spontaneous play that occurred outside of the formal learning activities actually related to the learning of a science unit. This was evident as children engaged in a 'pretend' scientific inquiry using their learning in meaningful ways as they were able to "reflect upon, re-examine and extend their classroom experiences" (p. 310). Together, these studies identified the potential of using teacher-guided activity (such as teacher-guided play) in combination with child-guided play, to support children's learning. In our study, we aim to explore in detail the impact the combination these two approaches can have on children's science learning, particularly within a context that has received less attention in this area of research: the primary school setting.

All but one of the studies mentioned above (Segal and Cosgrove 1994) were carried out in prior-to-school learning environments, such as preschool or child-care settings. While play is a predominant activity in many Western early childhood settings (Blake and Howitt 2012), play-learning is also valuable in school, where it can engage and motivate children, support learning of vital academic and personal skills, and provide opportunities for linking academic learning with real-world experiences (Briggs and Hansen 2012). Recently, there has been increased implementation of play-based learning approaches designed for the early primary school level, such as the Australian *Walker Learning Approach* (Walker 2011).

Play-based learning is considered particularly appropriate for science because it allows children to embody the roles and processes of science (Briggs and Hansen 2012). Scientists identify the 'playfulness' of their work, and claim that early play experiences inspired their curiosity and enjoyment in science (Wolfe et al. 2015). Yet school remains an under-researched setting in studies using a cultural-historical framework to investigate science learning through play. The possibilities of play was an unanticipated finding of Segal and Cosgrove's (1994) study of science in early primary school, and the researchers identified the need for further research on play in this context, particularly in investigating the role of the teacher. Yet this area remained under-researched, as Andrée and Lager-Nyqvist (2013) identified when child-initiated play again unexpectedly emerged as a way that older (sixth grade) children meaningfully enacted the roles, practices and ways of thinking of science. Both these studies focused on imaginary role-play, without examining the possibilities of broader approach to play as used in the preschool settings examined in the reviewed studies. It is this need that we aim to address in our study.

Theoretical Framework

Learning as Occurring Within Institutions

The studies reviewed above illustrate how children's development of science knowledge is inevitably connected to their prior knowledge and experiences, as well as their interactions and activities within a particular context. The cultural-historical theory of learning emphasises the relationship between learning and the practices of everyday life—the ways of doing things, forms of interaction, types of activities and the aims and beliefs that guide these (Hedegaard 2008; Vygostky 1987). Within a society, different institutions have different practices: the practices of school are different from home, while the practices of preschools and early years learning centres are different from those in primary school (Fleer 2010; Hedegaard 2008).

Therefore, a change in a child's predominant institution (such as from preschool to school) has a major influence on their development, as this change introduces them to new practices and expectations (Fleer 2010; Hedegaard 1999). While children's activity is usually aimed at "successfully participating in the practice traditions of particular institutions", their activities and motives also can differ from the institution's practices and expectations (Hedegaard and Fleer 2008, p. 15). An example is when a child is taking part in a classroom practice (e.g. story time) but creates a game in which he/she challenges the classroom expectations (e.g. by rolling about rather than sitting still) (Hedegaard and Fleer 2008). Hedegaard and Fleer (2008) distinguish between the two by describing them as the institution's perspective and the individual's perspective. It is by recognising the two, and the relationship between them, that insight is gained into children's development.

It follows that the institution's perspective surrounding play in a prior-to-school learning environment would differ from those in a school setting. This is significant in our study, since we are examining children's play and learning in the primary school: a different setting from prior-to-school learning settings, which has been the predominate setting of previous research. Thus we aim to gain insight into how the practices and expectations of this setting influence children's learning of science through play.

Everyday and Scientific Knowledge

Everyday and scientific concepts are examples of the different types of knowledge that result from the different approaches various institutions use for learning (Hedegaard and Chaiklin 2005). Everyday concepts are developed as children engage in everyday family life, and learn the skills and knowledge they need to be able to participate in daily activities (Hedegaard 2008). Often children are not conscious of this knowledge, as it is embedded in their daily practices. Fleer (2009) gives the example of a child who, through everyday activity, knows to wear a jumper on a cold day. However, since this this everyday knowledge does not include the scientific concept of insulation, the child may not know that a wetsuit could also be used to conserve body heat when surfing.

Conversely, scientific knowledge involves an abstract understanding that can be consciously applied to different situations. Vygostky (1987) associated scientific knowledge with the academic concepts learnt in school. Children actively build scientific knowledge as they explore the relationships between concepts both at a specific level and a general level. For example, a child who is connecting the relationships between a specific insect, its particular food source and habitat is also developing the 'core concept' which is the general relationship between an animal, food source and habitat (Fleer 2010).

While everyday and scientific concepts are so different, they are fundamentally connected since children use their everyday knowledge and experience to understand scientific concepts, while everyday knowledge evolves as children use their new scientific knowledge in daily life (Fleer 2010). A child who has spent time exploring their home garden (everyday knowledge) will meaningfully recognise different types of insects and habitats when she learns about them in school. As the child makes the connections between an insect, its food sources and habitat (scientific knowledge), she/he might then go home to plant flowers in the garden in order to create a habitat that provides the food source of her/his favourite insect—butterflies.

Therefore, meaningful learning experiences need to connect these two types of concepts. Hedegaard and Chaiklin (2005) refer to this as the *double move* of teaching. In this dualistic approach, the teacher devises learning experiences that support development of the conceptual system of scientific thinking, but also connect this with the everyday lives of the students. When this approach is applied to play-based learning, Fleer (2010) describes this as *conceptually orientating* the play so that activities intentionally support the learning of scientific concepts while the teacher actively connects everyday and scientific knowledge.

The development of scientific knowledge is a lengthy, gradual process as children build concepts into a complex conceptual system (Fleer 2010). To study this would require a longitudinal approach, which was outside the scope of our research given that this study had to be carried out over a short learning sequence (in the findings we call for a need for such a longitudinal study for future research). Instead, here we aim to see how the science play experiences supported the *initial* development of a scientific understanding of science concepts. As Fleer (2010) explains, young children start to develop scientific thinking through basic abstract thinking (such as learning labels and making a representation of the reality, i.e. through drawing) and by beginning to make mental and physical models of the relationships between the concepts they are learning. In our study, we examine how the combination of teacher-guided and child-guided play support children in developing scientific knowledge that is linked to their everyday knowledge.

Method

Research Questions

This study examined young children's learning during a science learning sequence that combined both teacher-guided and child-guided play. The research questions were:

1. What science learning occurs during play-based science experiences in the primary school context?
2. How do these play-based experiences support children's science learning?
3. What influence does teacher involvement, in the form of a teacher-guided play experience prior to the child-guided play, have on children's science learning during such play-based learning experiences?

Study Design

By using a cultural-historical theoretical perspective, this study positions children's learning as inseparable from their cultural and historical context. Therefore, the study design aimed to recognise this interconnection between the child, their activity and interactions, and the institution in which these occurred (Hedegaard and Fleer 2008). Hedegaard and Fleer (2008) describe this as a dialectical-interactive approach since it incorporates the three, inter-related and interactive perspectives of researcher, institution, and child. The purpose of our qualitative study was to understand how the combination of teacher-guided and child-guided play can support the development of young children's science knowledge in the primary school context. Within this aim, the researcher's perspective was concerned with children's use and development of everyday and scientific knowledge during play, while the institution's perspective concentrated on the influence of school practices, values and expectations on the children's learning. Finally, the child's perspective addresses children's motives and activities during play.

A combined *educational experiment* and case study methodology was used. An educational experiment is a qualitative research methodology developed through cultural-historical research that involves planning and implementing a "pedagogical intervention" and examining the influence of this intervention on children's activities and learning (Hedegaard and Fleer 2008, p. 185). Acknowledging the relationship between institutional practice and children's activity and learning, the educational experiment examines the influence of an intervention into practice. The intervention is planned teaching guided by the findings of previous research, with the aim of developing further understandings of previously developed theories and concepts, and their incorporation into practice (Hedegaard and Fleer 2008). Therefore, in this study, the pedagogical intervention was the entire play-based science learning sequence implemented in the class. One of the researchers and the classroom teacher collaborated to design and implement this learning sequence that drew on prior research's recommendations for children's science learning through play, to enable further insight into these and how they can be incorporated into practice.

An educational experiment requires that children's learning be examined to discover the influence of the pedagogical intervention (Hedegaard and Fleer 2008). A case study approach was used as it provides a contextual, holistic understanding of a situation while using a variety of data generation methods (Bassey 1999). This allowed the different perspectives (researcher, institution and child) to be revealed. The play-based science learning sequence examined in this project provided the spatial and temporal boundaries of the case.

Context of the Research

Participants and Setting

One Foundation Level class (first year of school—typical age 5–6 years old) and their female teacher participated in this study. The school, a small primary school campus of a non-government school, was located on a large, rural property located 70 km from a capital city in south-eastern Australia. The lower primary levels of this school implemented a play-based pedagogy that combined explicit teaching with child-guided, hands-on experiences. Four mornings per week were dedicated to a structured play-based learning time of 1.5 to 2 h in length, during which the classroom was arranged with many different play areas based on current learning intentions (including science) and connected to children's current interests and needs. Children, with guidance from the teacher, would select the area in which they will work, while the teacher supported their learning. This learning was then extended throughout the rest of the day during sessions that focus on specific learning intentions, e.g. literacy, numeracy or science. The science learning sequence was designed to fit into this program.

The Science Learning Sequence

The science learning sequence was implemented in the final term of the school year. *Small invertebrates* were chosen as a relevant topic as it was the season of spring and children were noticing the increase in insects and similar animals. The learning objective was for children to understand the *core concept*, that is, the relationship between animals, their needs and habitat (Fleer 2010) with the aim for children to begin to develop this scientific understanding by developing awareness of this conceptual model as it applied to particular small invertebrate (e.g. worms).

The learning sequence consisted of an introduction session, child-guided play sessions, one teacher-guided play session, and a reflection session. For the child-guided play, a *Bug Research Lab* was arranged in the classroom, which supported various open-ended activities including the construction of mini worm farms, observation of small invertebrates in the school grounds, non-fiction texts and work-sheets, and materials for children to create their own texts. The teacher-guided play session included discussions, a whole-class construction of a mini worm farm and guided small group planting experiments. These activities were designed to allow children to develop a model of the conceptual system: both physically (e.g. by creating a worm farm that physically represents the relationships between the concepts of worm, habitat and food source) and mentally (developed through discussion and writing or drawing). The learning goals and activities were inspired by those described in Edwards and Cutter-Mackenzie (2011) and Fleer (2010).

Data Collection Methods

The science learning sequence (including sessions with the teacher for planning and informal interview) occurred over 6 weeks in the final term of the school year. Various means of data gathering were used throughout the sequence, as is summarised in Table 1.

Observation—the Researcher's Perspective

Observation captures the contexts, interactions and actions that make up a *case* (Gray 2003), and in this study was aided by field notes, audio-recordings of conversations, and collections of artefacts in the form of copies/photographs of children's work. These sources of data were combined in typed transcripts in preparation for analysis. The researcher took the role of *observer as participant* (Gray 2003) while participating in the class as the co-teacher of the science activities, and also openly collecting data. Therefore it was important to distinguish between the researcher's own perspective (based on the research purpose and guiding theories), and the purpose and activities of the participants (Hedegaard and Fleer 2008). Consequently, other methods of data collection were also used to uncover these multiple perspectives.

Document Collection—the Institution's Perspective

School documents, such as policy, curriculum and planning documents, were collected from the teacher to enable insight into the aims, values, expectations and practices which provide both opportunities and limitations for children's activity (Hedegaard and Fleer 2008). To enable these to be interpreted in context, they were supplemented with observations and informal discussion with the teacher.

Participatory Research Practices—the Child's Perspective

This study used the idea of *pockets of participation*: allowing children to contribute their knowledge and skills in a certain aspect or *pocket*, of research, in this case, data collection (Franks 2011). The research aims and methodology were explained to the children using a picture book created for this project, and children were invited to be *co-researchers* by sharing information on their learning. Children could do this through photography, writing or drawing, and informal interviews. These means were chosen because they were familiar cultural tools in this school context (Robbins 2005).

Role of the Researcher

The first author was the active researcher in the field for this study. Her previous employment with the school helped identify it as appropriate setting for play-based pedagogical experiences. To avoid risk of coercion caused by the researcher's colleague relationship with the teachers, a formal approach was used to recruit the teacher participant. An explanatory statement and consent form was email by the Head of Campus to all relevant primary teachers (with the lowest class level selected). The children in the class were not familiar with the researcher as a teacher, but nonetheless care was taken to ensure they understood the role of the researcher and their rights within the study. For this purpose, a picture book was created and

Table 1 Overview of data collection

Elements of data collection	Data collection sequence						
Learning sequence	Meeting with teacher	Introduction session	Child-guided play	Teacher-guided play	Child-guided play	Reflection session	Meeting with teacher
Number of sessions	1	1	2	1	3	1	1
Temporal sequence	Week 1	Week 2	Weeks 2–3	Week 3	Weeks 3–4	Week 5	Week 6
Participants involved	Teacher	Whole class[a]	Selected children[b]	Whole class[a]	Selected children[b]	Whole class[a]	Teacher
Data collection methods	• Informal interview • Document collection	• Artefacts: children's work • Informal interview	• Field notes • Audio-recording • Informal interviews • Artefacts: children's work	• Field notes	• Field notes • Audio recording • Informal interviews • Artefacts: children's work	• Artefacts: children's work • Informal interview	• Informal interview • Document collection

[a] Whole class: all assenting children present for this session

[b] Children selected based on their decision to play in the 'science area' during the class's play-based learning time. A total of $n = 7$ children were observed during the child-guided play sessions, with one child observed twice (both before and after the teacher-guided session)

read to the class, using images and narrative to detail each step of the research process, including the concept of assent. After this, the children completed individual assent forms to supplement their parents' consent forms.

The researcher was actively participating in the setting as a co-teacher of the science learning sequence (mostly taking the main teaching role at the preference of the classroom teacher).

Data Analysis

In keeping with the cultural-historical framework of this study, the analysis method aimed to capture the connectedness between children's learning and the context in which it occurs, and drew on the three levels of interpretation as presented in Hedegaard and Fleer (2008). The first level of analysis consisted of interpreting and labelling specific instances in the data that exemplified the key theoretical concepts of everyday knowledge, scientific knowledge or institutional practices. Through this process, common themes were identified across the data (such as specific forms of everyday knowledge, or institutional practice) and these were the focus of the second level of analysis. This involved creating a commentary that summarised, compared and compiled specific examples with the aim of holistically considering children's learning as integrated with the interactions, motives and conflicts evident in the situation. The final stage of analysis examined how this evidence of children's learning related to the research aim, that is, how the play learning experiences influenced children's development of scientific concepts connected to everyday concepts, within the practices of the school setting. Representative examples in the form of case studies were selected, described and interpreted in detail in order to demonstrate the findings in context. These are presented in the following sections.

Trustworthiness

Robbins (2005, p. 153) demonstrates that when children's thinking is elicited and interpreted within the children's "context, relationships, culture and activities…and the tools and artefacts [used by the children]", then richer, more detailed—and thus more accurate—insight can be gained into their thinking and learning. The research process then becomes an interaction between the researcher and participants (Hedegaard and Fleer 2008), and this development of familiarity and trust over time assists in the production of credible findings (Lincoln and Guba 1985). This was a focus of the study design, where age appropriate means were designed to ensure the children were comfortable with the research aim and project (as described previously). The prolonged involvement of the researcher in the classroom over the several weeks the learning sequence was implemented (coupled with her former familiarity with the school) also enhanced her understanding of the setting, and relationships with the participants.

With the aim of developing a holistic understanding, the different sources of data were compiled and examined as a whole to construct the *world* of the case. For example, observation notes and transcriptions of audio recordings were viewed in combination with any artefacts (i.e. photographs, drawings) constructed by the child at the time. These were also considered within the context of any previous or subsequent data related to the children, and all this was placed within the larger context of the values and practices within the classroom as constructed through analysis of school pedagogical documents, observation and informal interview with the teacher. While the variety of forms of research method and data allowed the identification of similarities across data, the purpose was not simply a triangulation of data, but rather an uncovering of the “different aspects of a child’s everyday life” to create a holistic understanding of children’s learning (Hedegaard and Fleer 2008, p. 55).

Uncovering the different perspectives of researcher, child and institution (foregrounded in both the research and analysis methods as described in previous sections), enables trustworthiness by recognising the researcher and research methods as inevitably influencing, and influenced by, the researched situation (Hedegaard and Fleer 2008). The different perspectives were clarified by member checking integrated throughout the data collection (Lincoln and Guba 1985). Recognising the children’s thinking needs to be elicited in context (Robbins 2005), informal questioning during data collection was used to clarify and expand children’s thinking. The teacher was also questioned both at the time, and in the organised informal interview sessions, to clarify the researcher’s understanding of classroom practices and expectations. This was particularly important, since the researcher’s active role, and familiarity with the setting, placed her at risk of overlooking and/or not critically examining certain aspects (Gray 2003).

As a qualitative study, the aim of this study was transferability rather than generalizability (Lincoln and Guba 1985). By presenting the findings of this study through richly described case studies, they can be assessed in their applicability to other contexts.

The Findings: Case Studies and Interpretations

We present the findings of our study through four case studies and a detailed interpretation of each. Drawing on the theoretical framework of the study, these case studies and interpretation provide insight into the children’s development of scientific knowledge that is connected to their everyday knowledge, within the context of the school institution. Each case study and interpretation responds to the research questions in a holistic, integrated way by demonstrating the relationship between the children’s learning and the activities of the science learning sequence within the school context. The first two case studies focus on how the combination of teacher-guided and child-guided play supported children’s science learning by orientating play and transforming everyday knowledge. The second two case studies focus on how the school setting influenced children’s science learning, particularly through imaginative play and the use of science texts. For clarity and to maintain confidentiality pseudonyms are used for the children.

Case Study 1: Orientating Play Towards Science

When making mini worm farms during child-guided play, the children evidently enjoyed the creative aspect of placing various materials (soil, leaves, stones etc.) into the small plastic containers used for their worm farms. In the child-guided play sessions before the teacher-guided play session, the children’s predominant motive appeared to be the creative activity itself. After the teacher-guided session, their creativity was more orientated towards the science focus (the relationship between a worm’s characteristics, needs and habitat). This is illustrated in the following example, which follows one child, Neil, through the learning sequence, as he constructs mini worm farms both before and after the teacher-guided play session.

The first time Neil constructs a worm farm (prior to the teacher-guided play), Neil and his classmate Owen spend an extended amount of time on the construction and engage in detailed discussion about the amount and placement of various materials. It appears that their predominant motive is the physical, creative engagement with the materials rather than the science aspect of creating a habitat that suits the characteristics and needs of a worm, as is evident in the following exchange:

> **Researcher:**…why are you putting these things on?**Neil:**Ah because they ah might want to eat them?
> *(a little later)***Researcher:**So tell me more, why are you putting the grass in?**Neil:**So they can hide.
> **Researcher:***(a little later)*So tell me, why are you putting sticks in?**Owen:**Ahh, they might like to climb on them?**Neil:**There. Most of the bags are done. (referring to the several bags of materials, i.e. stones, leaves)
> *(a little later, Neil and Owen work together to design the top of the worm farm, concentrating on making a 'path' for the worm)*

The boys' replies (saying "ah" and using a questioning tone) suggest that selecting materials according to their appropriateness for a worm's habitat was not uppermost in their minds, particularly when combined with Neil's comment *Most of the bags are done*. Rather, they were evidently engaged in using all the materials in their creative design. The worm-farm construction materials were presented in a similar way to the craft play area in the classroom (materials placed out for children to use), and the boys had simply engaged in the everyday activity of creating rather than developing their science knowledge because the play had not been framed according to the science concepts. This was also evident in the observations of other children engaging in making a worm farm prior to the teacher-guided play. This is similar to Fleer's (2009) finding that an open-ended, materials-based play approach to science learning only resulted in children developing their everyday knowledge, and not scientific knowledge, since there was no involvement from the teacher to explicitly orientate the children to the science concepts.

During the teacher-guided play session held a few days later, Neil and the class were engaged in a discussion about a worm's characteristics and the habitat that met these needs, which was then linked to the construction of a whole class mini worm farm. When, a few days after this, Neil again makes a worm-farm, his activity is now more orientated towards thinking about making an appropriate habitat for the worm:

> *Neil is placing the materials into the container for his worm farm.***Researcher:**When you are making a worm farm, what kind of things do you need to think about?**Neil:**What the worm would like.
> …
> *(a little later, Neil takes the spray bottle and moistens his worm farm)***Researcher:**Do you think the worm would be happy here? Why?**Neil**Because it is moist.

Neil is using the knowledge he encountered during the teacher-guided play session about worms, their need's and habitat, to guide his creation of his mini worm farm. This orientation to the science concepts was also evident in observations of other child-guided play held after the teacher-guided play, with children talking about making a natural habitat and ensuring that soil was moist for worms. This evidence suggests that the teacher-guided play experience played an influential role in "conceptually framing" (Fleer 2010, p. 95) the subsequent child-guided play experiences so that the children's play activity was orientated to the science concepts and relationships between them, instead of just everyday creative activity.

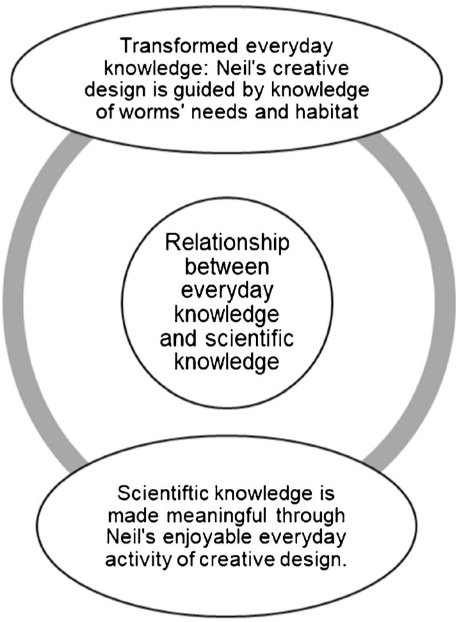
However, the creative, and sensory aspects of using the materials was still important to Neil, as well as to other children observed. Neil still displayed evident enjoyment in the creative design making comments such as *I am decorating*, while also enjoying the sensory experience of the various materials, such as running them through his fingers. Fleer (2009) explains that in her study "the playful context supported the interlacing of everyday concept formation and scientific concept formations. The everyday thinking provided a meaningful way for children to explore the science concepts" (Fleer 2009, p. 299). Similarly here, the relationship between everyday and scientific knowledge is evident in Neil's activity (see Fig. 1).

Now that Neil's activity was orientated towards the science concepts, it created an opportunity for the teacher (in this case the researcher) to assess and extend his science knowledge. When constructing his second worm farm, Neil was following the process used during the teacher-guided play: layering stones, soil and sand to allow drainage thus ensuring the soil remained moist but not waterlogged. This was explained to the children during the teacher-guided play, however Neil's understanding was confused as illustrated in the following exchange:

Neil places stones in his worm farm
Researcher: Why are you putting the stones?
Neil: To make it watery.
later on, when Neil was spraying his worm farm with water
Neil:…need the water so the stones, the worm don't die
Researcher: The stones?
Neil: Sometimes the stones can cause the worm to die. So need water so the worm don't die.
Neil places his hands on his side, as if to indicate how a stone could harm a worm.

Neil is certainly considering the needs of the worm, and has an idea that there is a connection between the stones and moisture. However, he has not understood the concept of drainage and instead tries to make sense of the stones using his everyday knowledge that stones are hard and therefore can harm the worm. Similarly, other children showed uncertainty

Fig. 1 The relationship between Neil's everyday and scientific knowledge



about particular concepts and this provided opportunities for the researcher to reiterate the concepts discussed during the teacher-guided play, thus enabling the children to extend their understanding.

As illustrated in this case study, the teacher-guided play supported in orientating Neil's play activity so that he engaged with the science concepts. This allowed him to adapt his meaningful, everyday activity of creative design to include his new concept knowledge, while also highlighting opportunities for the teacher to extend his understanding during the subsequent child-guided play. The relationship between everyday and scientific knowledge, and the role of the teacher in mediating children's learning is extended in the followingcase study.

Case Study 2: Transforming Everyday Knowledge into Scientific Knowledge

Throughout the learning sequence children demonstrated everyday knowledge both in the form of prior experiences (e.g. gardening at home) and as everyday activity during their play (e.g. brushing sandy soil out of their eyes). They also used anthropomorphism when talking about or drawing small invertebrates, and this reflected their everyday lives: children spoke about animated television shows and picture books that presented insects with human characteristics, while the teacher and researcher often unconsciously used anthropomorphical language when speaking to the children. It became evident that children used this everyday thinking to understand the science concepts, as demonstrated in the following example which again follows Neil has he builds his understanding of the relationship between a worm's characteristics, needs and habitat.

During their first play session (before the teacher-guided session), Neil and Owen searched for a worm in the school grounds, prompting Neil to share his everyday knowledge: he describes his father's vegetable garden saying *I've got this patch. My dad digs there. Plants these leafy things - I don't know, I've got this patch, my dad plants these little stalks - I don't know. Anyway, there's THOUSANDS of worms there*. At this precise point, Neil was passing by a school vegetable/herb garden yet he made no suggestion that this might be a suitable place to look for a worm. His knowledge of worms and their habitat was everyday knowledge: a knowledge embedded in a concrete situation and learnt through participating in everyday activity (Vygostky 1987). Neil only had the concrete knowledge developed from his everyday experience that worms live in his father's garden. Neil was not able to use this knowledge in a more abstract way to consider that since his father's garden had worms, another garden might also be a suitable place to find a worm.

The boys decide to dig in the extremely dry and sandy soil of the playground. As he digs, Neil flicks some sandy soil onto his face and eyes. Immediately he covers his faces with his arms, as he tries to remove the soil. This everyday experience enables Neil to begin to understand the relationship between a worm and its' habitat, as evident in the following exchange:

Researcher:…What's this soil like?
Neil: It's like grey soil. Worms wouldn't live here.
Researcher: Why don't you think?
Neil: It's very dusty.
Researcher: It's very dusty
Neil:I think [inaudible] where there's no dust coming up. Cause get in their eyes.
Owen: They got no eyes, they are blind.

Neil: Yeah, they can be blind ‘cause -**Owen:** *Interrupting* They can’t see.
Neil is still pre-occupied with removing dust from his face and talking to the researcher, and does not appear to be paying attention to Owen
Neil: If they get dust in their eyes. If they had hands they could do it, but they don’t have any hands, so they could be blind if like stuff stuck on them. They won’t live there.
Owen: Neil, Neil, worms don’t even have any eyes.**Neil:**I know but they could be blind. See they shake it off.
The boys cease the conversation and continue searching for a place to dig for worms.

Neil is starting to make the important connection between the characteristics and needs of worms, and their habitat. In building these connections and relationships between concepts (albeit using everyday, anthropomorphical thinking), he is developing his scientific knowledge of the science topic. Pivotal to stimulating Neil’s thought process is the researcher’s question *Why don’t you think [worms would live there]?* This question conceptually framed (Fleer 2010) Neil’s play experience so that he was focused not only on the everyday experience of having sand on his face, but also on building the connection between a worm’s needs and its habitat. Neil was now consciously thinking about these concepts: an important step in developing a conceptual system (Fleer 2011). The role of such open-ended questioning in supporting children’s development of science concepts was a key finding evident throughout the observations.

This episode demonstrates the importance of the ‘double move’ in pedagogical framing: that is, the introduction of scientific concepts *combined* with everyday knowledge (Fleer 2010, p. 93; Hedegaard and Chaiklin 2005). Owen (taking a *teaching* role) contradicts Neil’s everyday, anthropomorphical explanation that *worms…get dust in their eyes*, and Owen shares his conceptual knowledge *that worms don’t have eyes*. Yet this has no impact on Neil’s thinking, as he is absorbed in his experience of getting sand on his face. Instead, Neil’s focus on his everyday experience needs to be acknowledged, and then linked with the concept (worms do not have eyes) in order to gain his attention and support his understanding. An example of this double move would be examining a worm’s characteristics and needs, and discussing how different soils do or do not meet these needs, just as the human characteristic of eyes that need to be kept clean do not go well with sandy, dusty environments!

The above incidents happened during a child-guided play session that occurred before the teacher-guided play. The teacher-guided play included a whole-class discussion about the characteristics and needs of worms, and the habitat that meets these needs. This included the definition of terms such as ‘moist’ and ‘natural habitat’, and identification of the types of gardens that are inhabited by worms. Learning this terminology proved to be important in enabling Neil to begin to think consciously about the relationship between a worm and its habitat, when he again elected to make another mini worm farm. When he went outdoors to find a worm, it was obviously damp outside due to a rainstorm the previous night and this prompted the following exchange:

*(Neil and the researcher go outdoors)***Neil:**This won’t take long. Look how moist it is today. The worms are happy because the dry soil is wet soil. Then the worms can play!
*Neil goes directly over to the herb garden and starts digging.***Researcher:**Why do you think the worm might live here?**Neil:**Because it’s moist. Actually, it is moist.

In contrast to Neil’s first search, he now displays a definite understanding about the kind of habitat to find a worm, and has made a connection between the two science concepts (moist soil and worm) thereby indicating this growing scientific knowledge. His use of a label, *moist*, indicates emerging abstract thinking as a label can be applied to many examples, not just one concrete situation (Fleer 2010). Neil is still using everyday, anthropomorphical thinking, such as *The worms are happy…the worms can play*, but his everyday thinking has adapted to his new scientific knowledge, exemplifying the relationship between the two types of knowledge. Similarly with other children, the use of labels was very evident in their talk during child-guided play following the teacher-guided play session, indicating that the introduction and discussion of terminology during the teacher-guided session was important in supporting children's development of scientific knowledge.

Case Study 3: Learning Science Through Imaginative Play

Imagination is an important aspect of play and of learning (Fleer 2011), and this was evident in the previous case studies in the imaginative design of a 'home' for a worm, and in imaginative, anthropomorphical thinking. Imaginative play with toy small invertebrates was an activity that occurred repeatedly throughout the observed child-guided play (see Fig. 2). This was unexpected by both the researcher and classroom teacher, as the teacher explained that the toys were provided simply to attract children's interest in that area. Yet, it became evident that the children meaningfully explored and extended their knowledge of science concepts through this play, which included role play, talking about, and examination of, the toys. This is was evident in Ellie and Ned's play.

Ellie and Ned had completed making a worm farm, when the researcher briefly left them to assist another child. When the researcher returned, Ellie and Ned were engaging in a dramatic play with the plastic toy spider, butterfly and bull ant:

Ellie: This [*spider*] is the guard, the evil guard and this is the king [*butterfly*]. [*Puts on character voice for spider*] I'm going to kill you..Ahhh. Ok, Ok. Grrrrr. I killed it I killed…
Ned:I'm the bull ant. [*puts on character voice*] Grr
Ellie:[*using normal voice*] This is the spider and it's got fangs
Ned:[*using normal voice*] Did you know that bull ants are friends with spiders?
Ellie:[*using normal voice*] Yeah, he's the guard. *[character voice]* Kill them kill the… [*the dramatic play continues*]
Ned: Is this a bull ant? [*holding up toy bull ant*]
Researcher: How can we find out?

Fleer (2011) illustrates the close link between imagination and concept formation, and her ideas will be used in the following analysis. In Ellie and Ned's play, imagination and reality are

Fig. 2 Toy 'small invertebrates' provided for the children

dialectically linked: the reality of the plastic, inanimate toys is changed through imagination into the characters of a *good king* and an *evil guard*, yet the reality (characteristics of real butterflies and spiders) influences the imaginary roles (as predators, the spider and bull ant are appropriate for *evil* roles). However, their imagination is not limited by reality: the children are not simply imitating reality but rather are thinking about "the system of relations between roles" (predator–prey relationships), and the "possibilities" for imaginary play that this provides (Fleer 2011, p. 228). Ellie and Ned are consciously thinking about these ideas as is evident when Ellie explains the roles of the spider and butterfly and when Ned asks *Did you know that bull ants are friends with spiders?* thereby identifying spiders and bull ants in the same category of 'predators'.

This consciousness of thinking is important, since through conscious thinking ideas are no longer embedded in the concrete situation but can be adapted and used in other ways (Fleer 2011): a defining feature of scientific knowledge. Through conscious thinking of the characteristics of, and relationships between, insects and spiders, Ellie and Ned are demonstrating their emerging scientific knowledge of these animals, and adapting it to their dramatic play. Thinking consciously about "roles, rules and directions of play" also develops children's ability to think "consciously about concepts" (Fleer 2011, p. 231), and this is particularly demonstrated when Ned steps out of the imaginary play situation to ask *Is this a bull ant?* His imaginary character has an *evil* role, therefore it is important to him that the toy represents an animal that is a predator in reality. Ned is consciously thinking about the rules of the play, but also consciously thinking about the science concept of different species of ants.

Ned's question initiated a different kind of imaginary role play, that of 'being a scientist':

Ned: Is this a bull ant? [*holding up toy bull ant*]
Researcher: How can we find out?
[*Both children take the magnifying glasses and examine the toy*]
Ned: It's got fangs
Ellie: What are those?
Ned: It looks like a beard?
Ellie: You mean a moustache?
Ned: Moustache??
Ellie: The bull ant has a moustache?**Researcher:**Why don't you look in the book to see if it helps you find out if this is a bull ant?
[*The children search for information about ants in the non-fiction book. As he looks at the book, Ned talks about it using his 'evil spider' character voice*]

By using the magnifying glasses (not necessary for observation, considering the 5-6 cm size of the toys), the children take on the imaginary roles of scientists, copying what they know of the reality of a scientist's role and procedures (as described in Fleer 2011). Davydov (Davydov 1999; Fleer 2010, 2011) argues that knowledge of a concept develops through the same process by which the concept was originally discovered. Ellie and Ned use the science skills of inquiry and observation in order to *discover* the characteristics of the bull ant so that they can categorise it as either a bull ant or a common black ant: similar processes by which species were first identified and categorised. As the children read the book, they use the scientific process of learning from previously established information, and this would provide an opportunity to extend their current everyday knowledge so that they can correctly identify the ant's mandibles (rather than their everyday terms of *fangs* and *moustache*). Interestingly, Ned’s use of his *character voice* as he uses the book illustrates the still important link between the initial dramatic toy play and the science concepts.

The researcher’s questioning in the above episode both initiated and extended the children’s play so that they used these scientific processes. If the researcher had simply provided the answer, these learning opportunities would have been lost. This is supported by Siry’s (2013) study of young children’s science development through participatory pedagogies, which found that open-ended questioning from the teacher during child-initiated investigations allowed children to engage with authentic science practices while building complex understandings.

Ellie and Ned did not return to their dramatic play with the toys, but instead remembered and returned to their worm farm activity. Similarly, other children’s play with the toys was brief and occurred when the children were either distracted, or paused for some reason in their main activity of building a worm farm or finding and observing small invertebrates. This conflicts with the children’s obvious enjoyment of the toys (observed by both the researcher and classroom teacher), and the fact that play with toys was an acceptable activity during the class’ play-based learning time. An explanation for this is perhaps the institutional practices related to the arrangement of imaginary role-play areas. In another area of the classroom, an imaginary play area was arranged with a sand ‘horse racing track’, toy stables, horses and other items. Conversely, the toys in the science area were simply placed on the table with no ‘setting’. Children’s activity often adapts towards conforming to Institutional practices (Hedegaard and Fleer 2008), and this classroom’s practices for arranging learning areas likely influenced the children’s perception about what activity was acceptable in the science area.

Institutional practices reflect values and beliefs (Hedegaard and Fleer 2008), and, when preparing the science area, neither the classroom teacher nor researcher had consciously planned for (and therefore valued) dramatic play with the toys as part of the science learning experiences. While the classroom teacher and the pedagogical approach supported science learning through various experiences occurring during child-guided play (e.g. constructing models of insects at the craft area), in the class planning documents for play-based learning “science” or “exploratory play” was listed as a separate type of play experience from “dramatic play.” This perhaps reflects a broader societal belief that associates science with work, rather than play, particularly in the school context. This is mirrored in research: while a few studies (Andrée and Lager-Nyqvist 2013; Segal and Cosgrove 1994) have highlighted the useful role of child-initiated role play in school science learning, in these studies this play occurred spontaneously rather than being planned for and supported by the teacher.

Yet, as the representative example illustrates, this kind of play provides opportunities for children to explore their understandings of science concepts, practices and roles. In this particular case, dramatic play potentially could have provided a meaningful way for the children to construct a physical model of core concept (relationship between animals, food source and habitat) by having children plant seedlings to create a *live* ecosystem to use during dramatic play. Different plants could represent different habitats for the various small invertebrates.

Imaginary play presents a context for meaningful science learning, but institutional practices can influence children’s engagement in this play. Similarly, institutional practices and their influence on children’s science play activity are highlighted in the following case study.

Case Study 4: Using Science Texts During Play

A particular way that the children’s motives and activity reflected the practices and values of the institution (the school) was evident in the children’s eagerness to create a *product of* *learning*, particularly a written text. A popular example was the Bug Observation Form which the classroom teacher had retrieved from the internet. This worksheet prompted children to document the appearance of an observed small invertebrate by listing the number of legs and wings, and writing and drawing the colour and appearance. By focusing solely on the visible characteristics of a *bug*, this worksheet missed an opportunity to draw children's attention to the core concept of the relationships between small invertebrate, their needs and habitat. However, the worksheet still took an important role in supporting children's science learning, as demonstrated in Marcus' play.

Marcus told the researcher that he wanted to find and observe a bug and then complete a *Bug Observation Form*. After finding a beetle outside and bringing it carefully back to the classroom inside an 'observation container' he spent some time closely observing it before beginning to complete the form. He focused on doing it correctly: asking for feedback and making corrections. The following exchange illustrates Marcus' pride in his work:

> *The researcher reminds Marcus to write his name in the section labelled 'Scientist's name'. After he has done this he shows it to the researcher again.*
> **Marcus:**This is really cool.
> **Researcher:**What is cool?
> **Marcus:**Doing the bug form.
> *Later, at the end of the session, and after Marcus has found out more about the beetle by reading a book with assistance from the researcher:*
> **Marcus:** I've gone all the way down *[to the end of the form]*
> **Researcher:**Well done, Marcus.
> **Marcus:**Other people. It takes for other people a really long time.
> **Researcher:**Yeah? Does it take a long time for other people to fill the form?
> **Marcus:**Yeah. But today I did it waaay shorter. *[emphasis on 'waaay']*

Marcus' motive and activity was to complete the form quickly and correctly, and this reflects the institution's (the school's) values and practices regarding creating texts. The creation of texts was encouraged and valued during play and children were expected to fully complete and correct their work (as Marcus reflects when he points out *I've gone all the way down*, and corrects his spelling). Children's work was shared through show-and-tell, in wall displays, and in assessment portfolios, providing a context for the obvious pride and value Marcus, and other children, placed on their work.

The provision of worksheets such as the Bug Observation Form also embodied the institution's high pedagogical value of literacy and numeracy learning: the teacher explained that incorporating this learning into the child-guided play areas was an important part of their play approach. This in turn reflects the importance placed by Western society on literacy and numeracy learning. Development occurs when a child's motives and activity adapt to the values and practices of the institution (which in turn are influenced by the society's values and traditions) (Hedegaard and Fleer 2008). Through Marcus' motive to succeed within the school's practices surrounding creating texts, he is not only developing his literacy and numeracy abilities but also developing the skill of creating a scientific text: an important part of Western Science practice. The process of creating this text also allows Marcus to extend his scientific understanding of the science concepts, as is discussed in the following.

Similarly to Ellie and Ned in the previous case study, Marcus also takes the role of *scientist* by using the *Bug Observation Form*: labelling himself as the scientist and using *scientific tools* (such as the insect observation container and a clipboard for writing). The form draws his attention to aspects of his bug that are important for classification in Western Science (i.e. the amount of legs). Thus Marcus is discovering the beetle using processes (observation, textual and visual documentation, classification) similar to those which were historically used in the discovery of different species. Marcus is not only developing science skills, but also developing awareness of the characteristics of the beetle, which is then furthered by reading a non-fiction text.

Reading a non-fiction book on *mini-beasts* supports Marcus' emerging scientific knowledge: With prompting from the researcher, Marcus found information about his beetle and was fascinated to discover that it was a Dung beetle which "likes to be around animal droppings." The researcher then referred back to the *Bug Observation Form*, asking *Do you think you want to put some extra information here? Instead of just saying beetle, you could say…* and Marcus quickly responded by changing the bugs name from beetle to *Dung Beetle*. This change in label is significant: Marcus is no longer focused on the concrete, that is, the tangible beetle in front of him. Instead, he now sees it has an example of a category of beetle (Dung beetle) that has a distinctive habitat and food source (animal droppings). His mental model of the relationship between this type of beetle, its habitat and food source is evident in in his informative text written during the reflection session concluding the science sequence (see Fig. 3).

Marcus' model is still focused on the 'particular' (Dung beetles) rather than the abstract understanding of the general relationship between animal and habitat. However, he is starting to form the base from which this abstract understanding will emerge (Fleer 2011).

Discussion

The aim of this study was to understand how a play-based science learning sequence, combining both teacher-guided and child-guided play, can support the development of children's science knowledge. We examined this in the primary school setting in order to explore science learning through play in this context which has received less attention in previous research. The following subsections address the three main aspects of this aim: firstly, supporting the development of science knowledge; secondly, combining teacher-guided and child-guided play; and finally, learning science through play in the primary school context.

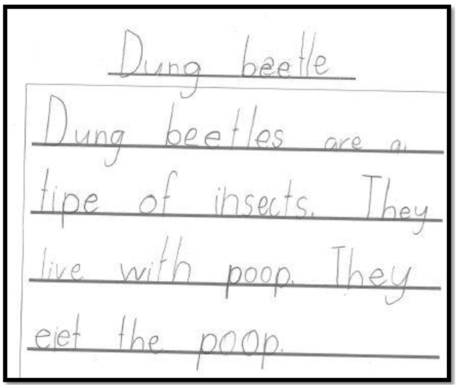


Fig. 3 Marcus' informative text about Dung beetles

Supporting the Development of Science Knowledge

In this study, the play-based learning experiences allowed children to engage with science using activities and ways of thinking that were meaningful to them. For Neil, everyday, anthropomorphic ways of thinking supported him in making sense of the connections between a worm and its habitat, as was evident when he explained that a worm is 'happy' in moist soil. Also, the everyday activity of creative design and construction was a key element in Neil's worm farm creation, even when his activity was orientated towards the science concepts (a worm's needs and habitat). Similarly, Ellie and Ned used the familiar activity of playing with toys to explore and extend their understanding of the characteristics of, and relationships between spiders and insects. These children's everyday knowledge (creativity, anthropomorphism, imaginary play with toys) adapted to include their new science knowledge. At the same time, the science knowledge was made meaningful and engaging because the children were exploring it through familiar, everyday means.

This relationship between everyday knowledge and scientific knowledge within play-based science learning has been established in prior research (e.g. Fleer 2009). This finding is significant within this current study because these kinds of everyday activities (creative design, play with toys, role-play) are often not typical science activities within a primary school context. In this study, however, they took an important role in the children's science learning, therefore supporting Siry's (2013) argument for a reconsideration of what is considered 'science learning activity' in school. As Segal and Cosgrove (1994) argue "some [primary school] teachers may overlook the potential of this natural, sophisticated way [play], by which children can consolidate their learning in science" (p. 311). While these authors were referring specifically to imaginary role-play, the current study presents the possibilities for supporting children's science development through a broader range of play activities.

Combining Teacher-Guided and Child-Guided Play

In the science learning sequence examined in this study, the teacher-guided play assisted in "conceptually orientating" (Fleer 2009, p. 295) the subsequent child-guided play. Fleer (2009) explains that when children's science activity is conceptually orientated, it is focused on explicit science concepts. During the teacher-guided play, the researcher (in the role of teacher) explicitly presented a conceptual model representing the relationships between particular small invertebrates, their needs and characteristics, and their habitat. This was represented both as a mental model (developed through discussion) and a physical model (the guided construction of 'mini-ecosystems' in worm and ant farms). After the teacher-guided play, the child-guided play activities indicated that the children were now using this model in their play. An example was Neil's worm farm construction: when constructing the worm farm after the teacher-guided play he was consciously using the materials to make a habitat that met a worm's needs. This was in contrast to his first construction (before the teacher-guided play) where his focus was on using the materials creatively, rather than conceptually. Neil also illustrated his emerging conceptual understanding through his use of terminology introduced during the teacher-guided play: understanding and using the label 'moist' allowed Neil to think more consciously about a worm's habitat and identify areas where he might be likely to find a worm.

Previous studies have indicated that teacher-guided activity is useful for explicitly introducing children to concepts which can then be explored during child-guided play (Blake and Howitt 2012; Edwards and Cutter-Mackenzie 2011; Segal and Cosgrove 1994). Our study supports this by demonstrating that the teacher-guided play took an important role in introducing conceptual models and related terminology subsequently used in child-guided play. This provides insight into how these two types of play activity relate, illustrating that the teacher-guided play influences children's orientation towards the child-guided play activities, so that it focuses on the science concepts.

However, teacher involvement *during* the child-guided play was also important in supporting the children's learning. This became evident when the researcher's (in the role of the teacher) open-ended, conceptually framed questions guided children in consciously connecting their play activity with the science concepts, and the relationships between these. For example, the questions *Why don't you think [worms would live in sandy soil]?* and *Do you think the worm would be happy here [in your worm farm]?* enabled Neil to think consciously about the relationships between worm and habitat as he engaged in his play activities. Open-ended questioning was also important in supporting children's inquiries, such as when Ned's inquiry *Is this a bull ant?* was extended by the researcher's question *How can we find out?*

The researcher's (as teacher) involvement during child-guided play provided opportunities to assess, and subsequently extend, children's thinking. For example, the researcher's interaction (in role of teacher) with Neil during his second worm-farm construction exposed Neil's incomplete thinking about using stones for drainage to create moist soil. Similarly, inquiries made by Ellie and Ned, and Marcus, about particular insects were recognised by the researcher during their play, and subsequently supported.

So while teacher-guided play took a useful role in supporting children's science learning through play, teacher involvement during the child-guided play was also important. This could pose a challenge for the teachers seeking to implement play-based approaches similar to the one described in this study, since the teachers and assistants must share their time with students working in other areas. How children can be supported in being more independent during child-guided science play would be a useful topic for further research. Further studies could suggest directions for this: Segal and Cosgrove (1994) demonstrate that children can independently incorporate their knowledge of the scientific inquiry process into their child-guided play, while Edwards and Cutter-Mackenzie (2011) illustrate the potential of peer teaching.

Learning Science Through Play in the Primary School Context

The class in which the study took place had particular values, expectations and practices regarding play-based learning, and this institutional perspective influenced the science learning that occurred. The school's structured, intentional approach to play-based pedagogy created a context in which learning through play was supported and accepted, with an emphasis on play for learning, rather than entertainment. This gave the children in the study the freedom and confidence to play in a primary school learning context. Institutional practices, such as the expectation that children 'work' in a single play area for the entire play session, allowed the learning opportunities described in the representative episodes.

The children's play activity was orientated towards "successfully participating" (Hedegaard and Fleer 2008, p. 15) in these institutional practices by meeting the expectations that were communicated through these practices. This was evident in Marcus' motivation to correctly complete his 'Bug Observation Form', exemplifying how the school's values and expectations surrounding the creation of texts supported Marcus' activity. Contrastingly, the institutional practice perhaps also restricted other types of play activity: Ellie and Ned did not engage in extended imaginary play with the toys, possibly because the practices surrounding the arrangement of play areas suggested that imaginary play was not the expected main activity within the science area.

Certain institutional practices also restricted potential opportunities for children to explore connections between science concepts (the basic aim of teaching for scientific understanding [Fleer 2010]). Concurrent to the 'small invertebrate' learning sequence presented in this study, 'planting' was another activity presented during the class' play learning time. Yet these two strongly connected science foci were not linked since the two areas and activities were physically separate. Similarly, the provision of a worksheet was an institutional practice used to support literacy development. However, the provided Bug Research Form focused predominately on the observable characteristics of small invertebrates, rather than maximising this opportunity for scientific learning by drawing children's attention to habitat and food sources. While the science learning objective for the learning sequence emphasised the relationships between concepts, and these featured in the teacher-guided play, some institutional practices unconsciously restricted potential opportunities for exploring these connections in the child-guided play.

This study illustrated that institutional practices and expectations are influential in supporting or limiting children's play activities, and subsequently, the learning that occurs. Fleer (2009, 2011) highlighted the importance of the teacher's conscious and intentional support in developing children's scientific knowledge through play. This study emphasises that this needs to include conscious, critical analysis of the institutional perspective and its influence. Connections between concepts need to be foregrounded in every aspect of planning, including the arrangement of areas and creation of worksheets. However, this study demonstrates that the institutional influence can be subtle, and that teaching for scientific understanding is not a simple task for teachers. Further research exploring ways of supporting teachers in implementing this would be worthwhile. It can be hypothesised that schools that do not typically utilise play-based pedagogies may find particular challenges when implementing this approach to science, since the children may be concerned that by 'playing' they are not meeting the learning expectations of the institution. This is another issue that could be addressed by further research. There is also need for a longitudinal study that would follow children as they move through to higher grades and considers the role of play pedagogy in supporting the development of scientific knowledge.

Implications of the Study

Play has received less consideration as a means of science pedagogy in the school context. However, this study demonstrates that play continues to be meaningful way for exploring science concepts, even once children have entered school. The play activities of the children in this study (such as creative and imaginary play) are not typically considered as science activities in school, suggesting the need for a more flexible approach to science learning that acknowledge children's unique ways of making meaning of their world. This study confirms the necessary role of the teacher in supporting science learning through play, and presents teacher-guided play as a useful pedagogical strategy for orientating and introducing children to conceptual frameworks which can then be further developed during child-guided play. Play has the potential to enhance children's science learning, and thus merits time and space in the school science curriculum.

References

Andrée, M., & Lager-Nyqvist, L. (2013). Spontaneous play and imagination in everyday science classroom practice. *Research in Science Education, 43*, 1735–1750. https://doi.org/10.1007/s11165-012-9333-y.

Bassey, M. (1999). *Case study research in educational settings*. Buckingham: Open University Press.

Blake, E., & Howitt, C. (2012). Science in early learning centres: satisfying curiosity, guided play or lost opportunities? In K. Tan & M. Kim (Eds.), *Issues and challenges in science education research: moving forward* (pp. 281–299). Dordrecht: Springer. https://doi.org/10.1007/978-94-007-3980-2.

Briggs, M., & Hansen, A. (2012). *Play-based learning in the primary school*. London: SAGE. https://doi.org/10.4135/9781446254493.

Davydov, V. V. (1999). What is real learning activity? In M. Hedegaard & J. Lompscher (Eds.), *Learning activity and development* (pp. 123–138). Aarhus: Aarhus University Press.

Edwards, S., & Cutter-Mackenzie, A. (2011). Environmentalising early childhood education curriculum through pedagogies of play. *Australasian Journal of Early Childhood, 36*(1), 51–59. Retrieved from http://www.earlychildhoodaustralia.org.au/our-publications/australasian-journal-early-childhood/.

Fleer, M. (2009). Understanding the dialectical relationship between everyday concepts and scientific concepts within play-based programs. *Research in Science Education, 39*, 281–306. https://doi.org/10.1007/s11165-008-9085-x.

Fleer, M. (2010). *Early learning and development cultural-historical concepts in play*. Melbourne: Cambridge University Press.

Fleer, M. (2011). 'Conceptual play': foregrounding imagination and cognition during concept formation in early years education. *Contemporary Issues in Early Childhood, 12*(3), 224–240. https://doi.org/10.2304/ciec.2011.12.3.224.

Fleer, M., & Pramling, N. (2015). *A cultural-historical study of children learning science: foregrounding affective imagination in play-based settings*. Dordrecht: Springer. https://doi.org/10.1007/978-94-017-9370-4.

Fleer, M., Gomes, J., & March, S. (2014). Science learning affordances in preschool environments. *Australasian Journal of Early Childhood, 39*(1), 38–48. Retrieved from http://www.earlychildhoodaustralia.org.au/our-publications/australasian-journal-early-childhood/.

Franks, M. (2011). Pockets of participation: revisiting child-centred participation research. *Children & Society, 25*, 15–25. https://doi.org/10.1111/j.1099-0860.2009.00258.x.

Gray, A. (2003). *Research practice for cultural studies: ethnographic methods and lived cultures*. London: Sage.

Hedegaard, M. (1999). The influence of societal knowledge traditions on children's thinking and conceptual development. In M. Hedegaard & J. Lompscher (Eds.), *Learning activity and development* (pp. 22–50). Aarhus: Aarhus University Press.

Hedegaard, M. (2008). Children's learning through participation in institutional practice. In B. van Oers, W. Wardekker, & R. van der Veer (Eds.), *The transformation of learning* (pp. 294–318). New York: Cambridge University Press.

Hedegaard, M., & Chaiklin, S. (2005). *Radical-local teaching and learning a cultural-historical approach*. Aarhus: Aarhus University Press.

Hedegaard, M., & Fleer, M. (2008). *Studying children: a cultural-historical approach*. Melbourne: Open University Press.

Larsson, J. (2013). Children's encounters with friction as understood as a phenomenon of emerging science and as "opportunities for learning". *Journal of Research in Childhood Education, 27*, 377–392. https://doi.org/10.1080/02568543.2013.796335.

Lincoln, E. G., & Guba, Y. S. (1985). *Naturalistic inquiry*. Beverly Hills: SAGE Publications.

Robbins, J. (2005). Brown paper packages'? A sociocultural perspective on young children's ideas in science. *Research in Science Education, 35*, 151–172. https://doi.org/10.1007/s11165-005-0092-x.

Segal, G., & Cosgrove, M. (1994). "I want to find out how the sun works!" Children's sociodramatic play and its potential role in the early learning of physical science. *Research in Science Education, 24*, 304–312. https://doi.org/10.1007/BF02356357.

Siraj-Blatchford, I. (2009). Conceptualising progression in the pedagogy of play and sustained shared thinking in early childhood education: a Vygotskian perspective. *Education and Child Psychology, 26*(2), 77–89.

Siry, C. (2013). Exploring the complexities of children's inquiries in science: knowledge production through participatory practices. *Research in Science Education, 42*, 2407–2430. https://doi.org/10.1007/s11165-013-9364-z.

Vygostky, L. S. (1987). *Volume 1: Problems of general psychology.* (R. W. Rieber, A. S. Carton, Eds., & N. Minick, Trans.) New York, NY: Plenum Press.
Walker, K. (2011). *Play matters: investigative learning for preschool to grade 2* (2nd ed.). Camberwell: ACER Press.
Wolfe, C. R., Cummins, R. H., Myers, C. A., & Cedillos, E. M. (2015). Scientific inquiry and exploratory representational play. In D. P. Fromberg & D. Bergen (Eds.), *Play from birth to twelve: contexts, perspectives and meanings* (3rd ed., pp. 207–215). New York: Routledge.