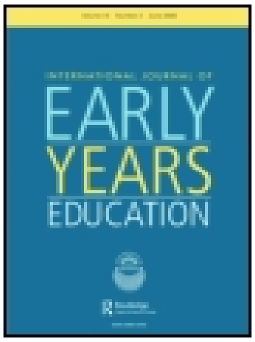

International Journal of Early Years Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ciey20

Teachers' and children's use of words during early childhood STEM teaching supported by robotics

Marie Fridberg & Andreas Redfors

To cite this article: Marie Fridberg & Andreas Redfors (2021): Teachers' and children's use of words during early childhood STEM teaching supported by robotics, International Journal of Early Years Education, DOI: 10.1080/09669760.2021.1892599

To link to this article: https://doi.org/10.1080/09669760.2021.1892599

Published online: 25 Feb 2021.

INTERNATIONAL JOURNAL OF EARLY YEARS EDUCATION
https://doi.org/10.1080/09669760.2021.1892599

Teachers' and children's use of words during early childhood STEM teaching supported by robotics

Marie Fridberg and Andreas Redfors

Faculty of Education, Kristianstad University, Kristianstad, Sweden

ABSTRACT

With science and digitalisation emphasised further in the new Swedish preschool curriculum, there is a need to clarify teachers' role in educating children in and about these areas. With research pointing out the importance of a conscious language use in STEM teaching, we here focus on words used by teachers and children during inquiry-based STEM activities in five different preschools. Bers' powerful ideas about early childhood computational thinking (Bers 2018. *Coding as a Playground*. New York: Routledge.) were used for analysis and results highlight how digital programming and use of robots can promote a more versatile use of robotic words, compared to analogue, 'unplugged', programming without robots. Furthermore, it is also found that use of precise decontextualised language by the teacher seems to stimulate children's use of words related to STEM and the object of learning. The findings add to the discussion about how teachers can scaffold children's learning by inquiry teaching of STEM supported by robotics.

ARTICLE HISTORY
Received 14 May 2020
Accepted 17 December 2020

KEYWORDS
Early childhood education; STEM; robotics; communication; preschool teachers

Introduction

Swedish preschool is part of the national educational system as a voluntary school form for children aged one to five years. During the years, the pedagogical task for Swedish preschool has been gradually reinforced and from 2010, science defined as 'simple chemical processes and physical phenomena' is included (Swedish National Agency for Education ([1998] 2010)). In 2019, a new national preschool curriculum was implemented and this time with a strengthened focus on digitalisation (Swedish National Agency for Education 2018). According to the Swedish National Agency for Education (2018), children should be given the opportunity to develop 'adequate digital skills', defined as being able to understand the impact digitalisation has on society and the individual, being able to use and understand digital tools and media, having a critical approach to digital technology and being able to solve problems in a creative way by use of digital technology. The new emphasis on digitalisation in the preschool curriculum has resulted in questions being raised about different didactic aspects such as what content and what

CONTACT Marie Fridberg marie.fridberg@hkr.se Faculty of Education, Kristianstad University, LISMA, SE-291 88, Kristianstad, Sweden

methods should be used, for both science and digital technology. In a recent survey on how preschool teachers in Sweden describe programming activities in their teaching practice by Otterborn, Schönborn, and Hultén (2020) an increased use of programming is reported, also in connection to specific content. However, further studies into actual teaching and learning are advocated, and therefore, we here report on an analysis of words used by teachers and children during STEM teaching supported by robotics.

Traditional school teaching has treated science, mathematics, engineering, and technology as separate disciplines. The acronym STEM has long been used to label any practice involving one or more of these disciplines, whether integrated or not (Ortiz-Revilla, Adúriz-Bravo, and Greca 2020). To emphasise the intention of integrating the disciplines in various ways in teaching, aiming to solve real-world problems, the concept of 'integrated STEM' emerged. This advocates for the introduction of these integrated disciplines from early age (Honey, Pearson and Schweingruber 2014; MacDonald et al. 2020). This fits well with Swedish preschool where interdisciplinary teaching is a long-standing tradition. An effective STEM education must consider children's interest and experience and promote rich and exciting experiences related to two or more of the four letters of the acronym (Toma and Greca 2018). Also, teachers need knowledge of subject specific content and skills on how to generate contextual teaching and learning situations (Fleer and Pramling 2015; Thulin and Redfors 2017). Fleer states that the challenge goes beyond content knowledge and include teacher beliefs about how children learn science and teaching practices (Fleer 2009). Teachers' views of the science content are important and Fleer, Gomes and March (2014) have shown that teachers have unique possibilities by implementing a 'sciencing attitude', which fits well with integrated STEM and also robotics. In addition to STEM, robots are finding their way into classrooms and preschools, and educational robotics is discussed as a transformational tool for learning computational thinking, coding, and engineering. A literature review by Jung and Won (2018) in robotics education using robotics kits for young children showed however that research agendas in the field need to be broadened. Many of the analysed studies had examined the technological properties of educational robots rather than the teaching activities and the learners. In addition, the advantages of educational robots had been generalised with no consideration taken to the different types of robots used (Jung and Won 2018). This calls for more detailed investigations of how children actually engage in activities that focus on robotics education, a demand this study aims at meeting. Also, according to our experience, many preschool teachers start their teaching of programming with analogue, sometimes called 'unplugged', activities. The idea is to let the children familiarise themselves with arrows on the floor and programming each other, before moving into 'real' programming with robots, referred to as 'digital' programming here. What is interesting with this approach is that to our knowledge, no research has evidenced this teaching strategy to be more fruitful than starting the other way around, with robots and then continue with unplugged activities. Our observations led to an interest to further explore the communication during 'plugged' and 'unplugged' robotics activities. More specifically, the research question guiding this study was

- What characterises teachers' and children's use of words during STEM teaching supported by robotics, with and without robots?

Theoretical framework

The study originates from botSTEM, *Robotics and STEM education for children and primary schools*, and the EU programme ERASMUS+ KA201, with partners in Spain, Sweden, Italy, and Cyprus. One aim of botSTEM is to develop a research- and evidence-based on-line 'toolkit' encompassing a didactical framework and tested teaching practices. The activities aim to introduce integrated STEM teaching scaffolded by robotics to four to eight-year-old children supported by the botSTEM didactical framework that links inquiry and engineering design principles. According to the botSTEM experience, integrated STEM teaching in early years is especially viable with one teacher teaching most subjects to the same class in primary school, and with preschool teachers often working with a holistic view on the teaching of different content areas (Greca Dufranc et al. 2020). Also, as stated above, teachers' attitude to the content area is important and according to Fleer, Gomes and March (2014), teachers have great possibilities in fostering a 'sciencing attitude' in children. This scientific attitude fits well with the integrated STEM approach (Ortiz-Revilla, Adúriz-Bravo, and Greca 2020) underpinning the botSTEM project. Furthermore, the botSTEM didatical framework builds on a view that observations and experiments are embedded in theory, i.e. 'Theory laden' (Hanson 1958), and that empirical and theoretical work is connected in an interactive process of discussions, experiments and observations in the science community (Adúriz-Bravo 2012; Giere 1988; Koponen 2007). Hence, botSTEM activities focus on versatile theoretical models for talking about science phenomena. In addition, the activities are selected to be connected to the Big Ideas (Harlen 2015), and to the everyday lives of young children (Greca Dufranc et al. 2020).

The above described ideas shaping the botSTEM framework (Greca Dufranc et al. 2020) are central in the teaching activities developed in the botSTEM project, and the teaching activities make use of inquiry teaching and engineering-design teaching methodologies. Working with inquiry teaching and engineering design involves formulating questions, but it is difficult for children to ask questions about something they have neither seen, nor touched, nor experienced. It is very important for young children first to engage, notice, wonder and question (Bers 2018; Chalufour and Worth 2004). However, many of the emergent questions may not be investigated, therefore the role of the teacher is to focus on children's observation, clarify questions and guide problem solving to assist children in finding answers to their questions. The botSTEM teaching model consists of three phases, each designed to encompass more than one STEM discipline. First selection of a real-world problem in a playful manner, next guided inquiry focusing on science and/or technology (Martin-Hansen 2002; NRC 2012) followed by the final phase, i.e. the problem resolution requiring the design or implementation of a technological solution. Figure 1 describes the botSTEM didactical model.

The steps of the inquiry and engineering design methodologies are similar, but the latter includes a 'compare and compete' step, since a relevant aspect of the engineering design methodology is to compare the different solutions obtained. In addition, the botSTEM framework is influenced by the definition of robotics and coding as the action of putting together sequences of instructions and debugging, or problem solving. Coding is often described as the new language of the digital society, needed to

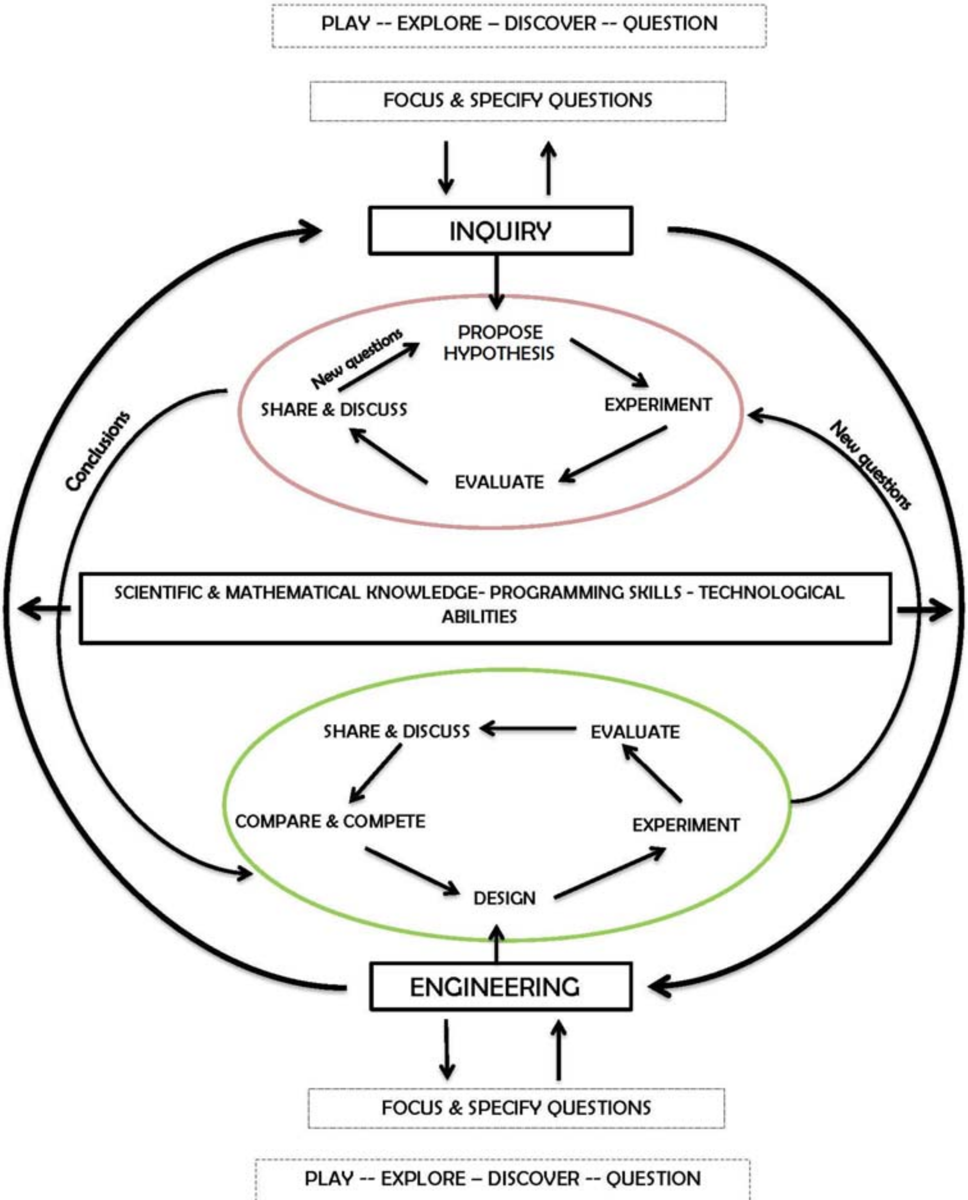

Figure 1. botSTEM didactical model for integrated STEM education in early years (Greca Dufranc et al. 2020).

be understood by everyone in order to be able to interact in a culture and society heavily influenced by computer systems. Coding with robots shows children what they can create with technology, engaging children as producers and not merely consumers of technology (Bers 2018).

The ability to interact with someone and to share attention to a content in focus can be seen as a fundamental aspect of teaching (Pramling Samuelsson & Asplund

Carlsson 2008) but research has found that shared attention is not enough for learning. The participants also have to establish a kind of agreement of a shared perspective in an activity. This shared perspective can theoretically be named intersubjectivity (Rommetveit 1974), a concept adding to the framework for integrated STEM and the botSTEM framework. We have previously reported on illusory and sufficient intersubjectivity in science activities in preschool (Ivarsson 2003; Fridberg et al. 2019). Illusory intersubjectivity arise when the teacher and children seemingly talk about and focus on the same aspect of a science phenomenon, such was the case with a water purification activity. When all participants directed their attention towards a water purification system, the teacher talked about how pure the water in it was while the children instead focused on how pure the purification filter was. It took a short while for the teacher to realise that the small word 'pure' had different meaning to her and the children, causing some confusion before it could be sorted out. Of great importance to maintain intersubjectivity around a scientific content is the teacher's ability to 'walk on a bridge', meaning that s/he at the same time considers children's perspectives and the science learning aimed for. Also, a more de-contextualised (generative and sometimes scientific) language, with more precise wording, supports intersubjectivity, as compared to a contextualised language (local and everyday) (Fridberg et al. 2019, 2020). In this view, it is therefore better during practical work with science to point and formulate a sentence 'Look at the water in the cup' than simply 'Look there'. Use of de-contextualised and contextualised language is looked for also in the present study.

Method

Design

As part of the botSTEM project, 2017–2020, in-service preschool teachers implement and evaluate activities from the toolkit, which were video recorded by researchers. In Sweden, three researchers and five preschools, located in mid-sized towns, are involved in this process. The participating preschool teachers had previously been involved in different professional development courses led by the researchers on the topic of science teaching in preschool. During these courses, the botSTEM project was introduced and preschool teachers were asked to contact the researchers if they were interested in participating. Five preschool teachers from five different preschools joined the project and they were during the fall of 2018 each asked to choose, try out and evaluate an optional botSTEM activity. Interestingly, despite that they all had previous experience with science teaching focusing on different science phenomena, they all chose either of two activities, as described in Table 1. The children involved in the study are four-five years old and consist in all cases of a small subset of 2–6 children, in total 16 children.

The Blue-Bot® is popular in Swedish preschools for work with programming and digitalisation. The transparent, beetle-like robot has a bluetooth function, but the Blue-Bot® can also be programmed physically through a set of buttons on its back. It can be programmed to take steps forward, backward, make 90 degree turns, and sequences can be repeated.

Table 1. Description of the science phenomena, botSTEM activities, and total time spent on the teaching activities, in the different preschools.

Teacher/ Children	Science	botSTEM activity	Description	Dig /Ana	Time (min)
Preschool teacher 1 2 children	Weather	Children programming each other as Blue-Bots	A grid is placed on the floor and three children and two teachers program each other to walk to a picture of a house, placed in a square. In some other squares on the way are obstacles, e.g trees. The child or teacher representing a Blue-bot has arrows placed on his or her back, similar to the arrows on the Blue-bot, and another child programs by pressing the back.	Ana	9
		Using the Blue-Bot as a link between different aspects of a natural science phenomenon	The Blue-bot is placed on a grid on a table and in some of the squares there are pictures of clothes. Two children program the Blue-bot to walk to suitable clothes for dressing on a cold, warm or rainy day.	Dig	10
Preschool teacher 2 4 children	Minerals	Using the Blue-Bot as a link between different aspects of a natural science phenomenon	One teacher and four children sit on the floor around a carpet with a grid. The carpet represents a small town, with shops, roads, etc. One child places a 'treasure stone' in a square and another child programs the Blue-bot to find it, and the children take turns. The activity continues with the children building their own paths where they program their Blue-bots.	Dig	30
Preschool teacher 3 6 children	-	Children programming each other as Blue-Bots	The teacher focuses her teaching on the arrows in the activity and skips the part where children program each. The six children walk a winding path of arrows with instructions placed among them. After the activity, the children construct their own paths by placing arrows on the floor.	Ana	29
Preschool teacher 4 2 children	Animals	Using the Blue-Bot as a link between different aspects of a natural science phenomenon	The teacher and two children sit on the floor around a grid. On some of the squares are pictures of animals. The children use the teacher's cell phone to scan a QR-code and get to hear information about a certain animal. They thereafter program a Blue-bot to go between pictures related to the same animal.	Dig	10
Preschool teacher 5 2 children	Animals	Using the Blue-Bot as a link between different aspects of a natural science phenomenon	In a grid on the floor are baby animals pictured in some of the squares. One teacher and two children pick cards picturing adult animals and the children take turns to program the Blue-bot to go to the corresponding baby animal.	Dig	22

Analysis

The video sequences varied in duration as described in Table 1, and they were either filmed by a researcher or by the preschool teachers themselves. First, the video sequences were transcribed with transcripts including descriptions of gestures that were deemed to contribute to the communication. Second, a content-based analysis was performed

(Denscombe 2017), where the full transcripts were analysed for statements relating to powerful ideas defined by Bers (2018). The robotics part of the botSTEM framework presented by Greca Dufranc et al. (2020), and the present study builds on the framework described by Bers for early childhood computational thinking, where seven powerful ideas are central (Bers 2018), namely

- Algorithms – a series of ordered steps in a sequence to solve a problem, such as dressing to go out. Understanding abstraction is central to understanding algorithms and identifying what constitutes a step in the sequence is a matter of abstraction.
- Modularity – breaking down tasks or procedures into simpler units, engaging in decomposition. This can be practiced without computers, for instance when analysing the task of having a birthday party. What different tasks are involved?
- Control structures – the order in which instructions are executed. In early childhood the key issue is familiarising with patterns and realising the relationship between cause and effect, e.g. pressing a button and the robot executes the instruction.
- Representation – sort and manipulate data and values in different ways. Concepts can be represented by symbols, e.g. numbers represent quantities. To code, children need to understand that programming languages use symbols to represent actions.
- Robotics – computing systems need hardware and software to operate, where the software provides instructions to the hardware. Hardware is programmed to perform a task and many devices can be programmed, not just computers. These five powerful ideas have their origin in computer science and are all strongly linked to foundational concepts in early childhood education.

Bers (2018) also put forward two additional powerful ideas concerning processes and habits of mind, design and debugging process:

- Design process – an iterative process used to develop programs and tangible artefacts. Bers (2018) suggests a series of steps defining a cyclic design process adapted for children, with steps; ask, imagine, plan, create, test, improve, share.
- Debugging – fixing of programs using testing, logical thinking and problem solving. Debugging initiates troubleshooting strategies that can be used on a variety of systems. Things do not work the first time; many iterations are usually necessary to get it right.

Both researchers analysed the transcripts with a high level of agreement and discussed variations in the categorisation to reach consensus. The identification of relevant statements was followed by a quantitative analysis of number and percent of statements belonging to the different Bers' ideas. 'Design process' and 'Debugging' proved to be difficult to separate in the analysis, and they have therefore been combined to a single category, capturing statements from iterative processes involving both design, testing and finetuning. In addition to the powerful ideas (Bers 2018), words connected to the four content areas of STEM were analysed, with T and E combined due to the strong interconnectivity of the two.

- Scientific (S) words and concepts – e.g. when preschool teacher 2 emphasise 'black tonalite' about a mineral.

- Engineering and technological (TE) words – e.g. the word 'obstacle course', 'constructing bridge'. (Excluding words related to robotics, design and debugging).
- Mathematics (M) words – e.g. counting 'one, two, three', by children and teachers in all activities.

Hence, the final set of word categories numbers nine. Adding to this is the tenth category 'Local' that have been used to identify words and phrases of contextualised language where a de-contextual wording would have included words from the other categories, i.e. when concepts and de-contextualised words could have been used, but instead everyday wording or pronouns like it, they, this etc. This is following up on previous studies (Fridberg et al. 2019, 2020) where use of everyday language and decontextualised scientific wording in connection to practical work has been found fruitful for the teaching and learning process.

In the process of categorisation, utterances in the dialogue of children and teacher have been treated as consisting of one or several statements, where a single statement can be coded for more than one category. For example, when Anton, a boy participating in the activity of Preschool teacher 2, states 'There's one and two and three … ', at the same time showing with his hand stepwise in a grid how the Blue-Bot® should be programmed, the statement categories are considered to be both Algorithm and Mathematics. The analysed activities varied in length between 10 and 30 min and in order to be able to compare the number of coded statements between them, the frequencies of statements have been normalised to 10 min. Hence, number of statements per 10 min are depicted in Table 2. The category-based coding of the video transcripts has been done with a double-blind initial coding by the two authors, followed by a discussion leading to a shared view and consensus. The coding was finalised by use of the NVivo™ software rendering frequencies of the categorised statements.

Ethics

Ethical considerations are guided by the Swedish Research Council (2016). Trust, virtue and confidentiality have been keywords and written and verbal informed consent from

Table 2. Normalised number of categorised utterances per 10 min for children (C) and teacher (T) for the five preschool teachers P1-P5 in their analogue (ana) and digital (dig) activities.

	P1 (ana) 2 children		**P1 (dig)** 2 children		**P2 (dig)** 4 children		**P3 (ana)** 6 children		**P4 (dig)** 2 children		**P5 (dig)** 2 children	
	C	T	C	T	C	T	C	T	C	T	C	T
Algorithms	1	0	2	3	3	1	0	0	0	2	1	0
Modularity	1	1	8	7	2	4	0	0	7	18	0	0
Control structure	22	2	19	15	4	2	1	1	12	21	0	0
Representation	2	1	10	17	4	6	2	2	5	18	1	0
Robotics	3	21	3	10	7	18	4	9	1	42	1	5
S words	0	0	0	14	2	4	0	1	10	40	6	10
TE words	0	1	0	0	6	6	1	1	0	0	0	0
M words	0	0	0	0	4	2	2	2	0	3	1	0
Design-Debug	0	2	2	10	14	11	0	1	1	6	0	1
Total	**30**	**29**	**44**	**76**	**46**	**53**	**12**	**17**	**35**	**150**	**10**	**16**
Total (%)	51%	49%	37%	63%	46%	54%	41%	59%	19%	81%	40%	62%
Local wording	1	7	0	14	0	4	0	1	0	16	2	6

teachers and caregivers was collected. Of great importance was also a sensitive approach to children and teachers during video observations and children were asked for verbal consent prior to filming. The children were happy to show their robotic skills to, and interact with, the researchers. In one case a child started crying when hurting a leg while s/he jumped, whereby the researcher switched off the camera until all children were happy and focused on the robots again. To ensure the participants' anonymity, all names in the excerpts are pseudonyms.

Results

When the data material was analysed, interesting features emerged in the communication between the teachers and children, as depicted in Table 2.

These features included how teachers displayed a different use of language connected to STEM and Bers' powerful ideas for computational thinking compared to children, and how the language varied depending on whether the activity included digital or analogue programming. The results also highlight the use of a contextualised (local) and decontextualised language by teachers in the teaching situation.

Teachers' and children's varied use of Bers' programming ideas and STEM language

Overall, in the six analysed activities, the teachers use more words connected to Bers' powerful ideas and STEM than the children do, as evident from Table 2. This seems reasonable, given that teachers are leading the activities and give instructions. Two of the more noteworthy categories where the teachers dominate are 'robotics' and 'science'. The teachers encourage the children to program by pushing the buttons on the Blue-Bot®, to consider arrows or to reset the Blue-Bot® before programming again, at the same time keeping in mind the science concepts they want the children to learn about. For example, preschool teacher 2 and her group of children had been working with different minerals and their characteristics for months prior to the botSTEM activity. The following example shows how the teacher combined the science phenomenon and the Blue-Bot®:

> And now you can choose a nice stone that you place and that the Blue-Bot® should find. [The preschool teacher takes out the box with stones and places it next to Stella] (Preschool teacher 2)

In contrast, the use of words connected to TE and M in STEM are more evenly distributed among teachers and children. Also, children's use of 'Control structure' are equal to the teachers or higher, in five of six activities. In their talk about programming, children largely focus on the order of steps the Blue-Bot® or themselves should take to reach the goal. They count, measure, and often use their own bodies and hand gestures to highlight and understand the sequence they are programming. Or as in the following example, where Alice explains how her family's robotic lawn mower works:

> Uhm, when we programme how it should go, where it should cut, then you press buttons [she shows with her hands om the floor]. *One step forward or turn*. Then it drives out when we are going to sleep or in the middle of the morning. (Alice, 5 years)

'Representation' is another Bers-idea where the children's level of word use is prominent. In the following example, Preschool teacher 1 has marked a pretend door on the grid. The door is for the Blue-Bot® to exit through after having been programmed to the right outdoor clothes first. In the play it symbolises that the Blue-Bot® has reached its goal and can go out and play. In this example, the robot makes a wrong turn just before exiting and this is commented by Ali who understands the representation of the door on the grid. To Nour, however, his talk about going outside appears to be confusing:

Ali: No! It was almost out but it didn't run out. [smiles and points outside the grid]
Nour: Are we going out?
Teacher: Not us, only the robot should go out. Do you want to play more with it?

The above is one example of how representations are used in terms of pictures on the grids in the activities. At the same time, it highlights how confusing the use of abstractions can be to young children. We have elaborated on this in earlier work (Fridberg et al. 2019, 2020) where we conclude that teachers need to, at the same time, be aware of both the intended object of learning and the child's perspective. In order to help Nour with her understanding of the situation, the teacher needs to consider her prior understanding of outdoor play and explain that we now play that the robot is going outside through a pretend-door.

In the activity conducted by Preschool teacher 2, the children display an even higher level of the category 'Design-Debug' than the teacher does. The children talk to each other and to the preschool teacher about trying and re-trying, making errors and what should be corrected in the programming to make the Blue-Bot® reach its goal.

The use of Bers' programming ideas and a STEM language in digital versus analogue activities

An interesting finding from Table 2 is how the total number of statements, teachers and children combined, are more frequent in the digital activities as compared to the analogue activities, except for in the activity by Preschool teacher 5. Preschool teacher 1 is especially interesting here, since the same teacher conducts both a digital and an analogue programming activity. With the same teacher performing the teaching, the use of Bers' programming ideas is elevated for both teacher and children when the Blue-Bot® is involved in the arrangement. This increase is noted for the categories Algorithm, Modularity, Control structure, Representation and Design-Debug in the digital activity. Preschool teacher 2 and 3 have previously been analysed for the teaching strategies used by the two teachers and the result showed a similar arrangement, for the digital and analogue activity (Fridberg and Redfors 2019). The teaching strategies included e.g. promoting the children's co-operation and making use of their own ideas, but interestingly, the result here indicates a more frequent and varied use of Bers' programming ideas in the digital activity. Altogether, this points to the Blue-Bot® as an important factor for a varied use of programming language in preschool. Worth noting is also how the use of science words is increased in the digital activities as compared to the analogue, in Table 2. This could partly be explained by the fact that no science aim was described by Preschool teacher 3, whose activity instead shows a higher level of words connected to 'Technology' and 'Mathematics'. But for Preschool teacher 1, science in terms of weather are present in both the digital and analogue activity, with the digital displaying more science words than the analogue version. The reasons for this can only be speculated on. Whether children are programming each other or a Blue-Bot®, both activities demand that children focus on turns, arrows, sequences etc. Still, in our data, science is more discussed when the Blue-Bot® is involved. Do children need to concentrate harder on their performance, i.e. turns, sequences etc. when they program with their bodies?

The role of decontextualised language in preschool programming

In analysing the use of contextualised language, i.e. occurrences when a decontextualised alternative seems possible and realistic, a pattern emerges. The teachers have in all cases a relatively more extensive use of contextualised (local) language compared to the children, see Table 2. Examples of contextualised (local) language with possible alternative expressions are demonstrated here.

Teacher:	How are you going to get to the food? Which way should you go?
Alternative:	How are you going to programme the Blue-Bot® to get to the food?
Teacher:	Do you press that?
Alternative:	Do you programme the Blue-Bot® like that?

In the cases, where the teacher uses contextualised (local) language to a large extent, the number of categorised statements for the children are relatively lower. For instance, even though Preschool teacher 4 displays many categorised statements, the number of categorised statements for the children is relatively low, less than 20% of that for the teacher. This could correlate with the use of local language in this case. This in turn could be said to indicate that a more precise and decontextualised STEM-oriented use of language stimulates the children and could be thought of as important in STEM-teaching.

Discussion

We have previously reported on a project (Fridberg, Redfors and Thulin 2018) that combined digital tools and scientific inquiry to synthesise the two knowledge domains in science, described by Eshach (2006): domain-specific knowledge and domain-general knowledge. While the former refers to theoretical models of real world objects and events (e.g. knowledge of atoms and forces), the latter refers to the scientific work process and skills such as observing, reasoning and designing experiments (Keys 1994; Schauble et al. 1995; Zimmerman 2000). Our results showed how preschool children's investigations of water phases resulted in enhanced and focused scientific reasoning when the performed experiments were later recreated by the children in short movies by use of computer tablets (Fridberg, Redfors and Thulin 2018). The arrangement of the botSTEM activities in the present study are also synthesising the two domains, as they combine children's investigations and inquiry with the aim to make them develop knowledge of weather, minerals or animals. The activities hence combine robotics and STEM and this study provide novel knowledge of how teachers with a sciencing attitude (Fleer, Gomes and March 2014) and children talk to each other during activities including digital or analogue programming.

During the implementation phase of the botSTEM project where teachers were trying out, evaluating and modifying the botSTEM activities, we have mostly experienced how teachers chose to start with analogue/unplugged versions of the activities, where the children 'program' each other. However, we have found (Fridberg and Redfors 2019) that the robots can be strong motivators for the children's joint inquiry, and as this study points out, they also promote a more versatile use of language in relation to Bers' programming ideas and STEM content. Interestingly, Preschool teacher 1 performs both a digital and an analogue activity, with the digital programming showing more varied robotics discussions. In addition, Preschool teacher 2, who otherwise makes use of the same teaching strategies as Preschool teacher 3 (for example including the children's own ideas in the arrangement), displays a richer language use in terms of the Bers' powerful ideas. Interestingly, Preschool teacher 1, 3 and 5 use few statements relating to Debugging and Heikkilä and Mannila (2018) points to a possible explanation when they describe how focus on debugging is an uncommon aspect in Swedish preschool. To point out children's errors or mistakes contradicts the norm that builds on meeting children with patience and encouraging them to try and retry as a means of learning. As Heikkilä and Mannila (2018) put it,

> Focusing on debugging brings up quite uncommon aspects in Swedish preschools. There is a tradition in Swedish educare not to focus on children's mistakes or what is right and wrong according to certain norms. Swedish preschools are very child centred and children are encouraged to try and retry as a means of learning and developing. (Heikkilä and Mannila 2018, 17)

However, the verbal interaction can, as in the case of Preschool teacher 2, be turned around and focus on possible improvements, without reference to possible shortcomings of a first version.

Further studies are needed before it is potentially possible to make generic recommendations about whether it is more fruitful to introduce programming to preschoolers in a digital or analogue manner. Interestingly, Heikkilä and Mannila (2018) suggest that debugging unfolds differently in analogue and digital programming, where in their study the former opened for several different 'right' ways to program and the latter was more of a negotiation of how the situation should be handled socially. So far, we conclude, from this study, that digital programming supported a more varied use of programming words. One of the limitations in this study is that the Blue-Bot® is the only kind of robot being used for digital programming. What result would emerge if other kinds of robots would be involved? Future studies aim at analysing use of language and teaching strategies around an extended pool of robots.

An interesting finding is how use of contextualised language by the teachers influence the overall communication in the different teaching situations. When the teachers use a richer, more decontextualised language, this seems to stimulate the children to express more statements in the different Bers' and STEM categories. This points to the importance of raising teachers' awareness about the relevance of putting words to, and naming, materials and actions involved in preschool teaching of STEM (Fridberg et al. 2020) and robotics.

Conclusion

In summary, the present study highlights how digital and analogue programming and the use of a decontextualised language may influence teachers' and children's communication about robotics and STEM in preschool. The coding of the recorded communication in these five cases also has highlighted the occurrences and possible pitfalls of use of representations related to abstractions, representing something other than programming issues. The role of abstractions in early years teaching as discussed here, is an interest that has been heightened by this work, but further research along this line including also the related issues of analogies and metaphors is needed and planned.

Acknowledgements

We acknowledge support from ERASMUS+ 2017-1-ES01-KA201-038204.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

We acknowledge support from the ERASMUS+ [grant number 2017-1-ES01-KA201-038204].

ORCID

Marie Fridberg http://orcid.org/0000-0003-0513-1221
Andreas Redfors http://orcid.org/0000-0003-4792-8749

References

Adúriz-Bravo, A. 2012. "A 'Semantic' View of Scientific Models for Science Education." *Science and Education* 22 (7): 1593–1611. http://doi.org/10.1007/s11191-011-9431-7

Bers, M. 2018. *Coding as a Playground*. New York: Routledge.

Chalufour, I., and K. Worth. 2004. *Building Structures with Young Children*. Redleaf Press: St. Paul.

Denscombe, M. 2017. *The Good Research Guide: For Small-Scale Social Research Projects* (6th ed). Open University Press.

Eshach, H. 2006. *Science Literacy in Primary Schools and pre-Schools*. Dordrecht: Springer.

Fleer, M. 2009. "Supporting Scientific Conceptual Consciousness or Learning in 'a Roundabout Way' in Play-Based Contexts." *International Journal of Science Education* 31 (8): 1069–1089. doi:10.1080/09500690801953161.

Fleer, M., J. Gomes, and S. March. 2014. "Science Learning Affordances in Preschool Environments." *Australian Journal of Early Childhood* 39 (1): 38–48. doi:10.1177/183693911403900106.

Fleer, M., and N. Pramling. 2015. *A Cultural-Historical Study of Children Learning Science*. Dordrecht: Springer.

Fridberg, M., A. Jonsson, A. Redfors, and S. Thulin. 2019. "Teaching Chemistry and Physics in Preschool – a Matter of Establishing Intersubjectivity." *International Journal of Science Education* 41 (17): 2542–2556. doi:10.1080/09500693.2019.1689585.

Fridberg, M., A. Jonsson, A. Redfors, and S. Thulin. 2020. "The Role of Intermediary Objects of Learning in Early and Years Chemistry Physics." *Early Childhood Education Journal* 48 (5): 585–595. doi:10.1007/s10643-020-01016-w.

Fridberg, M., and A. Redfors. 2019. "Preschool Teachers' Role in Establishing Joint Action During Children's Free Inquiry in STEM." *Journal of Research in STEM Education* 5 (2): 151–169. doi:10.51355/jstem.2019.48.

Fridberg, M., A. Redfors, and S. Thulin. 2018. "Preschool Children's Communication During Collaborative Learning of Water Phases Scaffolded by Tablets." *Research in Science Education* 48 (5): 1007–1026. doi:10.1007/s11165-016-9596-9.

Giere, R. N. 1988. *Explaining science: A cognitive approach*. University of Minnesota Press.

Greca Dufranc, I. M., E. M. García Terceño, B. Cronquist, M. Fridberg, and A. Redfors. 2020. "Robotics and Early-Years STEM Education – The botSTEM Framework and Activities." *European Journal of STEM Education* 5 (1): 1–13. doi:10.20897/ejsteme/7948.

Hanson, N. R. 1958. *Patterns of discovery*. Cambridge University Press.

Harlen, W. 2015. *Working with big ideas of science education. Trieste (Italia): Science Education Programme of IAP*.

Heikkilä, M., and L. Mannila. 2018. "Debugging in Programming as a Multimodal Practice in Early Childhood Education Settings." *Multimodal Technology and Interactions* 2 (3): 42. doi:10.3390/mti2030042.

Honey, M., G. Pearson, and H. Schweingruber, eds. 2014. *STEM Integration in K–12 Education: Status, Prospects, and an Agenda for Research*. Washington, DC: National Academies Press.

Ivarsson, J. 2003. "Kids in Zen: Computer-Supported Learning Environments and Illusory Intersubjectivity." *Communication and Information* 3 (3): 383–402. https://doi.org/10.1080/1463631032000149692

Jung, S. E., and E. S. Won. 2018. "Systematic Review of Research Trends in Robotics Education for Young Children." *Sustainability* 10 (4): 905. doi:10.3390/su10040905.

Keys, C. W. 1994. "The Development of Scientific Reasoning Skills in Conjunction with Collaborative Writing Assignments: An Interpretive Study of six Ninth-Grade Students." *Journal of Research in Science Teaching* 31: 1003–1022. doi:10.1002/tea.3660310912.

Koponen, I. T. 2007. "Models and Modelling in Physics Education: A Critical Re-Analysis of Philosophical Underpinnings and Suggestions for Revisions." *Science and Education* 16 (7–8): 751–773. https://doi.org/10.1007/s11191-006-9000-7

MacDonald, A., C. Huser, S. Sikder, and L. Danaia. 2020. "Effective Early Childhood STEM Education: Findings from the Little Scientists Evaluation." *Early Childhood Education Journal* 48 (3): 353–363. doi:10.1007/s10643-019-01004-9.

Martin-Hansen, L. 2002. "Defining Inquiry." *The Science Teacher* 69 (2): 34–37.

National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.

Ortiz-Revilla, J., A. Adúriz-Bravo, and I. Greca Dufranc. 2020. "A Framework for Epistemological Discussion on Integrated STEM Education." *Science & Education* 29: 857–880. doi:10.1007/s11191-020-00131-9.

Otterborn, A., K. J. Schönborn, and M. Hultén. 2020. "Investigating Preschool Educators' Implementation of Computer Programming in Their Teaching Practice." *Early Childhood Education Journal* 48 (3): 253–262. doi:10.1007/s10643-019-00976-y.

Pramling Samuelsson, I., and M. Asplund Carlsson. 2008. "The Playing Learning Child - Towards a Pedagogy of Early Childhood." *Scandinavian Journal of Educational Research*. 52 (6): 623–641. doi:10.1080/00313830802497265

Rommetveit, R. 1974. *On Message Structure: A Framework for the Study of Language and Communication*. London: Wiley.

Swedish Research Council. 2016. *Good Research Practice*. Stockholm: Swedish Research Council.

Schauble, L., R. Glaser, R. A. Duschl, S. Schulze, and J. John. 1995. "Students' Understanding of the Objectives and Procedures of Experimentation in the Science Classroom." *Journal of the Learning Sciences* 4: 131–166. doi:0.1207/s15327809jls0402_1.

Swedish National Agency for Education. 2010. *Curriculum for the Preschool Lpfö 98 Revised 2010*. Stockholm: Skolverket.

Swedish National Agency for Education. 2018. *Curriculum for the Preschool Lpfö 2018*. Stockholm: Skolverket.

Thulin, S., and A. Redfors. 2017. "Student Preschool Teachers' Experiences of Science and its Role in Preschool." *Early Childhood Education Journal* 45 (4): 509–520. doi:10.1007/s10643-016-0783-0.

Toma, R., and I. M. Greca Dufranc. 2018. "The Effect of Integrative STEM Instruction on Elementary Students' Attitudes Toward Science." *EURASIA Journal of Mathematics, Science and Technology Education* 14 (4): 1383–1395. doi:10.29333/ejmste/83676.

Zimmerman, C. 2000. "The Development of Scientific Reasoning Skills." *Developmental Review* 20: 99–149. doi:10.1006/drev.1999.0497.