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You Don't Have to Re-invent the Wheel to Implement Technology Activities in Early Childhood Education

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Abstract
This study on technology education in preschool aims to explore how technology activities in preschool are enacted and what knowledge, related to the five dimensions of the nature of technology, is made possible for the children to learn when intersubjectivity is established in the interaction between the participants. The empirical data encompass three video-documented technology activities, involving five children and one preschool teacher. Drawing on the five dimensions of the nature of technology by DiGironimo, the participants' interactions were analysed using interaction analysis. The results showed that the teacher, through well-defined and sensitive orchestration, enacted goal-oriented activities by allowing a play-oriented approach, and that intersubjectivity on technology was established related to four of the five dimensions of technology. The lack of knowledge related to the historical dimension of technology suggests further scrutiny and is discussed as essential in ECE technology education for contemporary children, growing up in high-tech societies.

Keywords Technology education · Mechanical technology education · Sociocultural perspectives · Intersubjectivity · Preschool

Introduction

> The wheel is only one of many simple machine examples that can become the focus of a science exploration. There will be ample opportunities for such investigations throughout the school year. The children should have them occasionally and should be encouraged to take advantage of any when they occur spontaneously. (McIntyre, 1975, p. 26)

Considering that the quote above was first published nearly 50 years ago, it is evident that technology has a long history in early childhood education (ECE). In contemporary high-tech society, using artefacts in explorative activities and play to spark children's interest and curiosity for science and technology is even more recognised as an important part of preschool activities (Öqvist & Högström, 2018). Allowing children to develop an understanding of and knowledge about the nature of technology is crucial for their ability to meet future needs in a world of rapidly changing technology, which is expressed repeatedly in the research literature as well as in curricula for ECE (Boström et al., 2021; de Vries, 2016; Siu & Lam, 2005). While technology today often is conceived as digital technology, it is essential that the subject of technology education also comprises knowledge about mechanical technology and how technology has been part of and developed through the entire history of mankind as intertwined in technological and societal developments, and not as something that was invented through computer science in the last century (Mitcham, 1994). In this study, this is addressed by exploring technology education activities that involve mechanical technology in preschool activities with the youngest children with a particular focus on the artefact of the wheel, as is also mentioned in the quote above.

Technology education is, despite its increasingly emphasised focus in preschool curricula, rarely clearly defined but instead conceptualised as a broad curriculum content

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area (Boström et al., 2021; Turja et al., 2009). Technology curricula in ECE also vary with regard to the targeted age range and to how content is specified, as well as to the pedagogical aims and approaches (Siu & Lam, 2005). Unsurprisingly, the literature also implies that teachers' knowledge of the characteristics that constitute technology education is vague, and the details of how technology knowledge could and should be taught in ECE remain uncertain (e.g. Fleer 2000; Öqvist & Högström, 2018; Sundqvist & Nilsson, 2018). Although research on technology education in ECE is a growing field, it is largely built on preschool teachers' perceptions of the subject or on the results of design-based studies (Eliasson et al., 2022). Less is therefore known about the specific aspects of technology that are made possible for the children to learn by exploring in situ activities.

The research presented here is intended to contribute to the field by focusing on situated technology learning activities in a preschool setting with children aged 2–3 years, where the classic topic of the 'wheel' was selected to stimulate their interest in technology. Drawing on sociocultural perspectives (e.g., Säljö, 2009; Vygotsky 1934), the aim of this study is to explore technology education as it unfolds in the interactions between a teacher and children in technology activities in preschool. In light of sociocultural theoretical perspectives, the units of analysis consist of the interaction between the participants. We used interaction analysis (Derry et al., 2010; Jordan & Henderson, 1995) to scrutinise *if* and, if so, *how* intersubjectivity (Linell, 2014; Rommetveit, 1974) in terms of whether mutual, temporary, and sufficient understandings of technology were established by the participants in the technology activities. To identify the nature of technology in our analysis, we draw on DiGironimo's (2011) five-dimensional model (see Fig. 1).

The following research questions guided our study:

1. How is technology education enacted in the interaction between a teacher and children in technology activities in preschool?
2. What knowledge related to the five dimensions of the nature of technology is made possible for the children to learn, when intersubjectivity is established in the interaction between the participants?

Theoretical Framework

To explore how technology education is enacted and what is made possible for children to learn related to the five dimensions of the nature of technology, we theoretically draw on sociocultural–historical perspectives (Linell, 2014; Rommetveit, 1974; Säljö, 2009; Vygotsky, 1934). This implies that we understand learning as situated in a cultural practice and intertwined with the use of cultural tools, which mediate aggregated human knowledge (Vygotsky, 1934). In this study, this implies that in the situated activity the participating children and teachers actively contribute to establishing, negotiating, and re-establishing knowledge through their interaction and orientation in the context of technology activities (see also Säljö, 2009). Crucially for this study, the notion of interaction is not restricted to verbal speech, but also includes non-verbal communication, such as gestures, movement, and gaze (Linell, 2014; Vygotsky, 1934). Hence, this study differs from many previous design-based studies that focused on organising technology education. Instead, the analytical interest in this study rests on the interactional level by focusing on instances when intersubjectivity (Linell, 2014; Rommetveit, 1974) is established. Intersubjectivity is understood as a temporary and sufficient understanding established between participants, enabling activities to

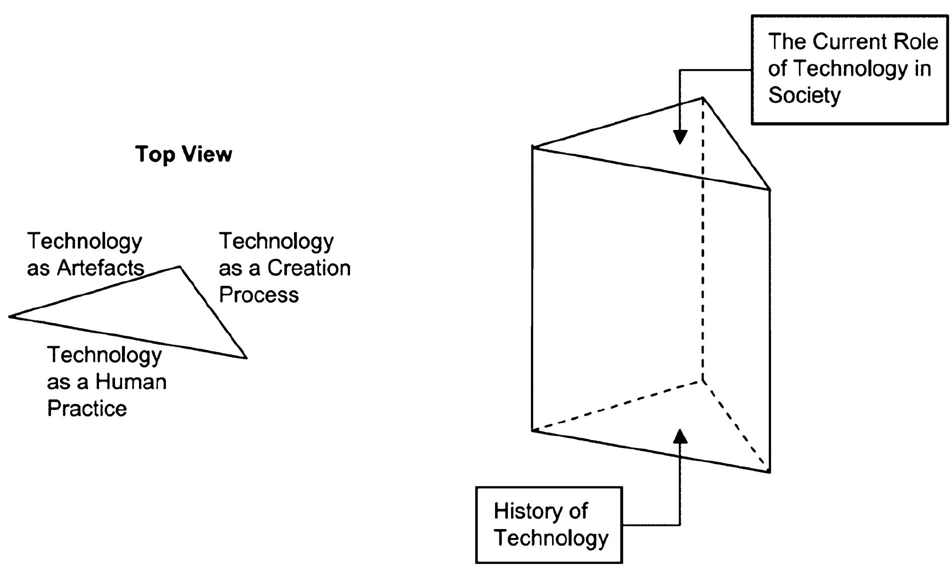

Fig. 1 Dimensions of the nature of technology. Top and side views of the dimensions of the nature of technology (DiGironimo, 2011, p. 1341. The figure is used with permission by Nicole DiGironimo, personal communication 04-10-21)

unfold. This implies that intersubjectivity is a joint activity and cannot be imposed individually and that it also involves alterity, an awareness that 'the other is necessarily different from one's self' (Linell, 2014, p. 189), which spurs negotiable responsive interactions to re-establish intersubjectivity between participants. Alterity is thus understood as the potential for negotiating and establishing intersubjectivity.

Children, Teachers and In Situ Technology Activities in Preschool

Recent research examining technology activities in preschool has suggested making a distinction between teacher-planned activities and activities initiated by children during free play (Eliasson et al., 2022; Öqvist & Högström, 2018). This might reflect a common distinction between play- or goal-oriented approaches to teaching in ECE today. Traditionally, play-oriented approaches have been emphasised in several curricula for preschools, as well as in an overview of technology education in a study conducted by Turja and colleagues (2009). However, in recent decades, other studies have highlighted that more goal-oriented approaches have played an increasing role (Sundqvist, 2020).

While some studies suggest play-oriented activities (Thorshag & Holmqvist, 2019; Yliverronen et al., 2018), others stress that a clear structure and organisation of activities is of significance for enabling subject-focused communication on technology (e.g., Johansson 2020; Kilbrink et al., 2014; Looijenga et al., 2015; Simoncini & Lasen, 2018). One example of the latter is an intervention study in the Netherlands by Looijenga et al., (2015), which examined both teacher-led activities and more free activities. The findings from this study showed that in teacher-led activities, the focus was directed towards a shared language about technological aspects, while in the activities characterised by free choice and play, the learning process was rather undefined. A case study conducted by Mawson (2013) concerning 3–4-year-old children's technological experiences in early childhood settings in New Zealand indicated that children developed a higher level of understanding of the technological process in an activity when the activities were planned and organised by the teacher. Some recent studies from Sweden (Sundqvist, 2020, 2021; Thorshag & Holmqvist, 2019) emphasise that in play-based collaborative learning activities, the teacher's role is crucial, since *how* technological knowledge is mediated by teachers in such activities is imperative for the kind of technological knowledge that is made available for the children to develop. On the same note, the findings of an observational study by Johansson (2020) involving a Swedish preschool class indicate the importance of directing the children's focus to the companion meanings (described as value judgements on what knowledge is and what kind of knowledge is worth knowing) as means for teachers to organise technology education. In this way, the children can critically reflect on technology and develop an understanding of the wider relation between technology and humans, society, and nature.

To summarise, previous research identified the significance of creating collaborative technology activities and emphasised the importance of including contextual aspects and teachers' roles in mediating knowledge related to the dimensions of the subject technology. Findings regarding how to frame technology activities differ as follows: as teacher-led activities or as free-choice, play-oriented activities. This implies a need for research to further explore the teacher's role and the implications of how technology education is organised within ECE settings.

The Nature of Technology as Specific Content Knowledge in Preschool

Many studies within the field of technology didactics lean on scholars within the philosophical field, such as Mitcham's (1994) four basic conceptual distinctions of technology, as (i) objects, (ii) knowledge, (iii) activities, and (iv) part of human society and culture. Drawing on these distinctions, deVries (2016, 2017) focused on three meaningful aspects of technology when teaching young children about technology: the participants, everyday objects, and meaningful facets. Building on Mitcham (1994) and de Vries (2016, 2017), we address in situ technology education from philosophical, historical and educational perspectives. We draw on DiGironimo's (2011) framework since it was developed to analyse technology education in empirical studies. The framework consists of five dimensions of the nature of technology and is illustrated by the shape of a prism with a triangular base (see Fig. 1), where the three sides represent technology as (1) artefacts, both as products of technological innovation and as technological processes; (2) a creation process or system of processes and what is needed, both physically (such as technological objects) and mentally (specific content knowledge) to engage in these processes; and (3) human practices, which concern political, cultural, gender, economic and environmental aspects and ethical involvement. One side/dimension cannot exist without the other two, and they comprise what DiGironimo (2011) defines as 'the shape and structure of technology' (p. 1341). In a preschool context these three dimensions of the nature of technology could be approached as (1) exploring technological artefacts and how they work; (2) creative activities and learning about what materials and techniques to apply; and (3) learning about simple technological systems and their impact on humans, animals and the environment. The base and the top of the prism represent the fourth and fifth dimensions, respectively. The base represents (4) the history of technology as accumulated human knowledge, and in a preschool context this dimension could concern aspects such as when and why technological objects such as for example cutlery were created and reflecting on what was used before the fork or the knife was invented (see Sundqvist & Nilsson 2018). The upper end of the prism represents (5) the current role of technology in society and addresses the constant changes of technology in society and how individuals experience and understand technology over time. In a preschool context, this could entail meta-communication about how technological artefacts are perceived as needed or not. The standing prism (Fig. 1) implies 'that the enterprise of technology, like any human enterprise, grows out of its past' (p. 1341). The ever-changing and progressing process of human technological creation is thus represented through five distinct yet concurrent and merging dimensions (DiGironimo, 2011).

Method, Participants and Setting

The present study draws on video documentation of technology education activities in preschools. A strategic choice (e.g., Cohen et al., 2011; Derry et al., 2010) was made to include preschools with a pronounced technology focus on the assumption that this would increase the opportunities for observing organised technology activities.

Empirical data were generated by means of video documentation, which was conducted by the first author during a period of five weeks, consisting of ten technology activities with 11 children (aged 2–5 years) and four preschool teachers from three Swedish preschool groups. The technology content in the activities include, for instance, knowledge about the wheel, trains and train stations, design and creation activities. The activities were planned and organized by the teachers within the everyday curriculum of each preschool group, which entailed activities in smaller groups (2–4 children). The teachers were sensitive to the children's engagement during the activities and therefore there was a recurring flexibility allowing spontaneous directions within the framework of the planned technology activities. For example, the teacher Fiona once moved the activity outside to look for wheels, which was not planned beforehand. The empirical data encompassed a total of 234 min of video recordings. The video data were organised by categories, including participants, activities, non-verbal and verbal actions and artefacts. To illustrate how knowledge related to the different dimensions of the nature of technology emerged in the interactions, some excerpts were systematically selected from the transcribed empirical data. The two criteria were (i) sequences where intersubjectivity was analysed as being established between participants, and (ii) instances where the interaction involved knowledge that could be related to any of the dimensions of the nature of technology. This iterative selection process produced three excerpts from two separate activities from one of the preschool groups to be further elaborated on for analysis. In these activities, selected for this study, one preschool teacher and five children (aged 2–3 years) interact.

Video Documentation and Analysis

Video documentation was chosen for generating data, since it enables studies of both verbal and non-verbal communication, as well as the participants' local and deictic language, the denoted meaning of which varies depending on time and/or place (Derry et al., 2010; Jordan & Henderson, 1995). Video recordings enabled collective analysis processes, which further ensured that enhanced aspects of multimodal interaction were discerned, thus enriching the interpretation and analysis processes (Derry et al., 2010; Jordan & Henderson, 1995).

During the initial research process, a broad and explorative approach guided the researchers' efforts to explore the kinds of technology that could be included in ECE. This laid the foundation for the analytical process conducted collaboratively by the researchers and gave the interaction between participants a direct focus. The transcriptions and an initial analysis were further discussed within our broader research group *Play, teaching and learning in preschool for social and cultural sustainability*.

Since much interaction between children this age (2–3 year olds) consists of non-verbal actions, we present the transcripts in tables where the non-verbal interaction is placed first, followed by the verbal utterances. The first analytical aspects and ideas emerged during the process of transcribing the empirical data (see also Derry et al., 2010). A first reading of the transcribed empirical data was followed by an iterative analysis process that alternated between the video and the transcripts. The transcriptions were subjected to interaction analysis (Jordan & Henderson, 1995) to identify units of interaction in which intersubjectivity between the participants was or was not established, by scrutinising the participants' actions and responses. By depending on DiGironimo's (2011) framework of the nature of technology, the analyses explored what kind of knowledge that could be related to the dimensions emerging in the interaction between participants in the technology activities. The knowledge related to the dimensions of the shape and structure of the nature of technology are visualised in the model as not existing on their own but merging with each other. To identify and analytically support our results, we separated the dimensions, which is fundamental when conducting analyses. It is important, though, to keep in mind that a single action can involve knowledge related to several dimensions of a technological nature.

During the ongoing phase of the project, the first author continuously discussed the implications of technology activities with the teachers and children, which served as a basis for the interpretive validity. To meet the ecological validity criteria (see also Cohen et al., 2011), the teachers implemented technology activities in their in situ, everyday teaching activities. The study was thus conducted within a familiar setting for both the teachers and the children.

Ethical Considerations

Ethical aspects were treated according to the current ethical considerations of the Swedish Research Council (2017). Information about the aim and design of the study was given, and parental approval was obtained by written consent. The participating children were verbally informed by both their teachers and the researcher about the study and their right to terminate their participation at any time. To visually clarify the researcher's documentary role, the researcher wore a signal vest when filming, thus increasing the children's possibilities to choose to contribute to or decline to partake in the data production (Larsson et al., 2019). Ethical considerations were approached continuously by reflexive means during the entire research process, and any signs of unwillingness to participate on the children's part were monitored throughout the study (Quennerstedt et al., 2014). Within the framework of this study, no children showed any signs of reluctance to be filmed. Participants and settings were given pseudonyms when reporting findings.

Results

The empirical findings of the study are presented in the following three excerpts, framed in terms of how technology education was enacted in technology activities and what knowledge related to the five dimensions of the nature of technology was made possible for the children to learn when intersubjectivity was established in the interaction between the participants.

What Are Those Sticks?—Introducing Technology as an Artefact

The following example comprises a sequence from the very first documented technology activity at the *Imagination Preschool*, focusing on wheels. The children sit on chairs positioned like seats on a bus. The preschool teacher Fiona sits on the chair behind Carl (age 3.1) and next to Martha (age 3.0), who in turn sits next to Philip (age 2.5). Fiona introduces two stroller wheels to the children, handing Carl and Philip one each. She allows the children to explore and play with them while taking out a large bike wheel from the cupboard behind her. The children's play is characterised by loud motor noises and shouting.

Excerpt 1

Imagination Preschool_191016: Turn 100.

Turn	Participant	Non-verbal interaction	Verbal interaction
100	FIONA	Holds a large bike wheel in front of her. She talks loudly over the pretend motor noises, taps the spokes and moves her fingers along the spokes. She makes eye contact with the children and looks confused	But what—what do we have here in the middle - what is this? What are those sticks?
101	Martha	Looks at Fiona and smiles	Biky!
102	FIONA		Yes it belongs to//a bike]
103	Carl	Holds the smaller stroller wheel and uses it as a steering wheel	//WROO]//OOM!]
104	FIONA	Moves her fingers up and down the spokes	//What are those sticks] called? Do you remember what the sticks are called?
105	Carl	Becomes silent, turns around on his chair and looks at Fiona and at the bike wheel. He grabs hold of the wheel	
106	Philip	Holds the stroller wheel still and looks attentively at Fiona	Wheel!

Turn	Participant	Non-verbal interaction	Verbal interaction
107	Martha	Looks at the spokes on the bike wheel and then up at Fiona. Feels with her hand on the spokes	Biky!
108	FIONA	Articulates the word clearly and speaks with emphasis	Spokes!
109	FIONA	Surprised and excited facial expression	Ohh!
110	Philip	Looks at Fiona	Sokes
111	Carl	Pushes the spokes sideways, as if to spin the wheel	
112	FIONA	Stops Carl's movement of pushing the spokes for a few seconds	There are many spokes on a wheel
113	Martha	Puts her hand on the rim and pushes it sideways as if to spin the wheel	
114	FIONA	Spins the wheel	And it can spi//in!]
115	Philip	Moves his stroller wheel as a steering wheel and screams in a loud and high-pitched voice	//IIIA]AAAH!!
116	FIONA	Makes a circular movement with her hand near the hub. Glances quickly at Philip and then looks back at the hub	And do you know what this is in the middle? This is the hub!
117	Philip	Turns silent and looks at Fiona	
118	FIONA	Holds her hand on the hub. Looks at the hub	It's what is stuck together with the whole bike wheel
119	Martha and Carl	Feel the hub with their hands	

The teacher, Fiona, gets the children's attention using a loud voice and a confused expression. She taps the spokes and asks, 'What are those sticks?', thus using non-verbal interaction and everyday concepts to orientate the children's focus towards the spokes and thereby separating them from the wheel as a whole (turn 100). The wheel as a cultural tool (Säljö, 2009) mediates different knowledge and ideas, and the teacher here negotiates the children's perspective of the wheels as a prop for their pretend play, by shifting to a perspective where the wheel can be talked about for what it is – a technological artefact, as their common ground for communication. Martha's response 'biky' (turn 101) shows that her attention is on the vehicle to which the wheel belongs. Fiona confirms Martha's response (turn 102), and, cutting their interaction short, Carl makes motor noises in pretend play (turn 103), which shows that he is not sharing their focus on the wheel as an artefact. Their different perspectives on the activity obstruct the process of establishing intersubjectivity. Fiona ignores Carl's pretend play and instead reintroduces the wheel as an artefact by naming its parts (turn 104). This mediates a process of establishing sufficient temporary intersubjectivity (Linell, 2014) between the participants (turns 105–111), with a mutual focus on *technology as an artefact* (DiGironimo, 2011).

Next, Carl (turn 111) and Martha (turn 113) spin the wheel, which is analytically understood as alterity (Linell, 2014), in which a new direction can be perceived in the interaction. From directing attention to the parts of the wheel, the participants now focus on the functionalities of the wheel, aspects that can also be placed related to the dimension of *technology as an artefact* (DiGironimo, 2011). Fiona promptly responds by rotating the wheel in her hands while simultaneously verbally communicating 'and it can spin' (turn 114), indicating that temporary intersubjectivity is re-established. Philip picks up Carl's previous play frame (turn 115), deterring further intersubjectivity around the spinning of the wheel. Fiona ignores his pretend play and instead points out the hub (turn 116, 118). The interaction is analytically perceived as an alterity process, with new directions in their possibilities of acknowledging *the wheel as an artefact* through its parts. The children's responses imply their renewed attention, now on the hub, by Philip looking at Fiona (turn 117) and by Carl and Martha touching the hub (turn 119).

Fiona repeatedly points out and names the parts of the wheel, the wheel as an entity and the bicycle to which the wheel belongs, using non-verbal and verbal actions, which makes mediation of knowledge about the wheel as a *technological artefact* (DiGironimo, 2011) possible.

We could Design Our Own Wheel!—Presenting Technology as a Creation Process

In Excerpt 2, the preschool teacher Fiona and the children Kerstin (age 2.5) and David (age 2.10) are actively partaking in a design activity, designing a representation of a wheel.

Fiona introduces the activity as Technology Day and presents a stroller wheel.

Excerpt 2

Imagination Preschool_191205: Turn 26.

Turn	Participant	Non-verbal interaction	Verbal interaction
26	FIONA	Holds the stroller wheel in her hands over the table between herself and the children. She looks at the children and communicates in an enthusiastic tone of voice	But do you know what? I thought that we could design our *own* wheel today in the workshop!
27	Kerstin	Looks away and moves around on chair	Yes… // (inaudible)]
28	FIONA	Puts a piece of paper on the table	//What did you say–] but first we have to make a design so we know how it will look like
29	FIONA	Takes a pen from the basket on the table and holds it in the air between herself and the children. She looks at the children, while they look at the pen	And that's why I brought a pen
30	FIONA	Points with the pen at the wheel and makes a circular movement along the outline of the wheel	But! What *shape* is the wheel?
31	David	Makes a large circular movement with his hand in the air in front of him. He then points at the door, from behind which a child is crying	Eh
32	FIONA	Makes a circular movement along the outline of the wheel	But what shape is the wheel?
33	David	Looks at Fiona and makes a smaller circular movement with his hand in the air in front of him	Yes. That one
34	FIONA		Yes. What does that look like then?
35	David		Eh. Lack
36	FIONA	Nods and puts her index finger up in the air	Yes black it's black yes
37	FIONA	Makes a circular movement along the outline of the wheel, and then above the piece of paper	And *round*. And this we can call the shape of a *circle*. So then we have to make the same here in our design what it shall look like what it shall *look* like our…
38	FIONA	Points with the pen, first at Kerstin and then at David	So shall I draw a circle or shall you? Or you?
39	David	Places his hand on his chest and attentively looks at Fiona	Aa…
40	Kerstin	Puts her hand on her chest, nods and attentively looks at Fiona	
41	FIONA	Leans in over the piece of paper and draws a medium-sized circle	Yes! We can make an circle each! Shall I make the first circle?
42	FIONA	Hands Kerstin the pen	Now you can make a circle next to my circle
43	Kerstin	Takes the pen and draws a circle on the piece of paper	

In Excerpt 2, Fiona introduces a perspective of the activity as a design process (turn 26). Kerstin responds using both a verbal interaction that Fiona does not apprehend and non-verbal actions, both of which indicate that she does not share Fiona's perspective (turn 27). Fiona interrupts her and continues to verbally present the activity—to draw a design. She puts a piece of paper on the table (turn 28), and by presenting a pen (turn 29), the need for tools for drawing a design is mediated through the artefacts themselves and by verbal communication (Vygotsky, 1934). She subsequently verbally directs their attention to the shape of the stroller wheel while simultaneously making a circle-shaped gesture with her hand (turn 30). In response, David makes a circle-shaped gesture in the air in front of him (turn 31). In this way, technology knowledge is mediated through the artefact and the participants' non-verbal and verbal communication, and temporary intersubjectivity is analytically understood to be established, sufficient for the participants to go on with their interaction. Fiona responds non-verbally and verbally (turn 37) by making a circle-shaped movement around the actual wheel and by verbally communicating terms like 'round' and 'circle'. Thus, the interaction indicates that intersubjectivity has been negotiated and established concerning the shape of the wheel. The participants then go on to draw one circle each on the piece of paper, and by participating in an activity of designing a wheel by acknowledging the shape of the wheel, using both artifacts, gestures and the actual drawing of a representation of the wheel. The children could by these elementary activities be said to engage in initial *creation processes* involving technology.

In Excerpt 2, it was shown how cultural tools such as artefacts, and non-verbal and verbal actions mediate technology knowledge of the wheel's shape, enabling further elaboration on how to draw a circle. The established intersubjectivity in these activities is thereby analytically understood as opening up for the children to take an active part in *technology as a creation process* (DiGironimo, 2011).

Let's Go!—Engaging in Technology as Human Practices and Its Role in Society

In Excerpt 3, the activity around wheels has been taken outside. Fiona has rolled out a large wheeled garbage bin from the fenced-off bin area in the preschool playground. She points out the wheels to the three children, Martha, Carl and Philip, and then asks if they want to help her put it back.

Excerpt 3

Imagination Preschool_191016: Turn.

Turn	Participant	Non-verbal interaction	Verbal interaction
451	FIONA	Fiona, Carl and Martha push the bin into its place. Philip stands still and watches	That's good that there are wheels on this that probably makes it easier when you empty it. Everyone who works with garbage disposal can just roll it out!
452	Martha and Philip	Move to just outside the fenced-off area, and run around in small circles screaming loudly	
453	Carl	Walks up to a smaller bin to the right and looks at its wheels	
454	FIONA	Walks up to Carl and points at the wheels while she counts them	One *two*! Two wheels!
455	Carl	Grabs the handle of the bin as if to push it. He looks up at Fiona	
456	FIONA	Shows Carl how to tip the bin on its two wheels and pushes the bin a bit forward	Do you want to push? This is the way to push it when it only has two wheels; you have to push it like this
457	Martha	Comes running and stops when she sees Fiona pushing the bin. She looks up at Fiona and communicates in a questioning tone of voice	Fiona?

Turn	Participant	Non-verbal interaction	Verbal interaction
458	FIONA	Looks at Martha for a second and then asks	Do you want to push?
459	Martha	Nods, and moves towards the bin and grabs the handle	
460	FIONA	Shakes the handle to show Martha where to hold	Come on! Here! Here the handle! Let's go!
461	Philip	Stops mid-running, pauses a second and then joins the others, grabbing the handle of the bin	Et's go!
462	Carl	Also comes running and grabs the handle	
463	FIONA	Pushes the bin together with the children a short distance	Eh… We have to tilt it because it only has two wheels
464	FIONA	Stands the bin upright and tries pushing it	Because look here if we stand it upright we can't push it
465	Carl, Philip and Martha	The children let go of the handle and look at Fiona. Then Carl moves on to the sandbox, while Philip and Martha start running around the bin, screaming	

As they start pushing the bin, Fiona directs the children's attention to the role and function of the bin's wheels (turn 451), both verbally by telling them about how wheels are good for moving heavy objects and non-verbally by pushing the bin back to its place. While Martha and Philip run off in physical play (turn 452), Carl walks up to the smaller bin and intently looks at its wheels (turn 453). Fiona responds by pointing at and counting the wheels (turn 454). Carl grabs the handle of the bin (turn 455), and Fiona exposes their shared focus of attention and non-verbally and verbally mediates the wheels' function (turn 456). Carl's action is analytically perceived as adding a new direction to the interaction, thus alterity (Linell, 2014) opens up for a negotiation and re-establishing of intersubjectivity on the functionality of the wheels and of how to use them to move the bin. Martha runs up to them and watches intently (turn 457). When Fiona asks Martha if she wants to push (turn 458), Martha responds by nodding and grabbing the handle (turn 459), and they push the bin together. Their shared action of pushing the bin indicates the temporary establishment of sufficient intersubjectivity about the wheels' function, enabling the participants to coordinate their perspectives on how to use the wheels to move the bin. Their actions catch Carl's attention, shown in his response (turn 461) to Fiona's verbal invitation, 'Let's go!' (turn 460), and then Philip joins them (turn 462). While pushing the bin with a joint focus, Fiona describes and explains their action of tilting the bin. Thus, the artefacts, along with non-verbal and verbal communication as cultural tools, mediate technological knowledge about the function of the wheels (turn 463). She puts down the bin and tries to push it to show the children that this is much harder (turn 464). The children attentively watch Fiona's actions (turn 465), but do not maintain this perspective; thus, further establishing of intersubjectivity is deterred. Engaging themselves in the actual pushing of the bin in combination with Fiona's comment on how the wheels ease occupational tasks connected with garbage disposal (turn 451), open up for the children to gain initial knowledge related to the dimension of *technology as human practice*. This is analytically understood to emerge through the actions of the participants, in terms of cultural aspects on work environment regulations.

In this excerpt, the preschool teacher directs the children's focus to the garbage bins outside the preschool, and they engage themselves in pushing the garbage bin, experiencing the function of the wheels and how to tilt the bin to roll it. This is analytically understood as knowledge related to the dimension of the *current role of technology in society* (DiGironimo, 2011), and of how the wheel can be used in real life circumstances in the participants' immediate proximity of society. In this way, the analysis of the interaction presented in Excerpt 3 shows how the established intersubjectivity analytically is understood as opening up for the children to learn about initial knowledge related to the functionalities of the wheel and of technology as human practice, alongside knowledge of the implications of this in today's society.

Discussion

In this study, we explored how technology education is enacted in the interaction between a teacher and children within in situ technology activities in a Swedish preschool. The analysis has shown instances when knowledge related to the five dimensions of the nature of technology is made possible for the children to learn given that intersubjectivity is established in the interaction between the participants.

Technology Education as Enacted in the Interaction in Preschool

The results show how the teacher introduces, presents, and engages children in planned teacher-led technology activities. The analysed activities illustrate typical didactic situations where the teacher's receptive pedagogical approach balances between directing children towards the content knowledge in a goal-oriented activity and allowing children space to play and freely explore the artefacts.

Theoretically, human technology knowledge is understood as embedded in cultural tools (Säljö, 2009) such as the wheel. Our results illustrate how the teacher's work is led by pursuing a clear focus on technology knowledge, involving the specific concepts of a wheel, and by offering hands-on activities to mediate technological knowledge. This is done through interaction *about* the artefact, which as exemplified by communication about the parts of the wheel (Excerpt 1) and the creation process of designing their own wheel (Excerpt 2). In the teacher-led activities, the teacher introduced technology concepts to enable a mutual parlance of technology. The results of this study thus support the study of Looijenga et al., (2015), in which teacher-led activities were shown to aid in a shared language about technological aspects. This is also done through interaction *with* the artefacts, for example, when they try pushing the garbage bin tilted on its wheels (Excerpt 3). In contrast to findings in Kilbrink's et al. (2014) study, where hands-on materials were observed to sometimes obstruct the participants' view of the learning object, the results of this study suggest that the artefacts can support a mutual focus. Furthermore, new directions in the interactions around the artefacts are repeatedly exemplified by the participants' communicative actions and by their responses, for example, when Carl in Excerpt 3 grabs the handle to push the bin and Fiona responds. Like the study by Thorshag & Holmqvist (2019), which showed how play-based collaborative activities can allow children to make choices, the results of our study imply that tangible artefacts offer children possibilities to contribute with alterity in the interaction through both non-verbal and verbal communication. Also, our analysis shows how the teacher uses artefacts to coordinate children's attention and actions towards the technology content.

The analysis of the empirical data illustrates how the children's play frame can deter intersubjectivity on technology from being established, like when Philip pretends to steer and makes motor noises (Excerpt 1). This also shows that the wheel, as a cultural object, can be understood as mediating different kinds of knowledge (Säljö, 2009). In this case, the teacher ignores Philip's perspective of the wheel as a play prop and responds by pointing out the hub, directing the children's focus and actions towards the technology content and concepts. This sequence illustrates how the teacher-led structured activity with a clear focus on the technology content emerged through the teacher's actions. At the same time, the teacher allows for the children's play initiatives to shape the activity as it unfolds, but without abandoning the focus on the technology content. While supporting Mawson's (2013) study, where children's understanding of technological processes appeared to reach a higher level when the activities were clearly organised by the teacher, by emphasising a structured activity and clear focus on the technology content, the results of this study also reveal the significance of simultaneously allowing for and exploiting a play-oriented approach. The results of our study show how the participants' actions and responses move in and out of the process of negotiating the intersubjectivity of technological knowledge on the wheel. The teacher's responses, by alternately responding to the children's communicative actions directed at technology content and ignoring actions focusing on other aspects mediated by the wheel as a cultural tool (Säljö, 2009), contributed to this process. Thus, through well-defined and sensitive orchestration, our results show that it is possible for the teacher to enact an organised goal-oriented activity with a play-oriented approach and simultaneously pursue interaction mediating the technology knowledge of cultural tools.

Negotiated Intersubjectivity Related to the Dimensions of the Nature of Technology

With respect to our second research question, the analysis illustrates how sufficient temporary intersubjectivity of technology is negotiated and recurrently established in the interactions between the participants. Thus, it is possible for children to develop technological knowledge of the wheel as an artefact and of its properties and functionalities, about how the wheel can be part of a creation process used in human practices, and about aspects of the current role of the wheel as technology in society.

In other words, the results of this study showed that knowledge related to four of the five dimensions of the nature of technology emerged from the interactions between the participants. As exemplified in Excerpt 1, Fiona repeatedly points out and names the different parts of the wheel, its functionalities, the wheel as an entity and the bicycle to which the wheel belongs, which is directed at the technology content as part of the activity. Thereby, temporary intersubjectivity is established on the knowledge of the wheel as an artefact (DiGironimo, 2011), including knowledge of the parts and functionality of the wheel. In Excerpt 2, the participants designed a wheel by drawing circles on a piece of paper. The shape of the wheel is critical for developing technological knowledge to engage in creation processes of the wheel as an artefact, and in this sense, the participants' actions making circle-shaped movements with their hands and of drawing circles is perceived as using cultural tools to mediate knowledge (Vygotsky, 1934) about technology as creative processes (DiGironimo, 2011). In accordance with DiGironimo's model (2011), the first two excerpts focus on knowledge related to two of the dimensions of the nature of technology, which together with knowledge related to the dimension of technology as human practice, are defined as 'the shape and structure of technology' (p. 1341). Even if the dimensions are somewhat separated for analytical reasons in our analyses, the first two excerpts also illustrate how they merge with each other.

In the third excerpt, the focus on the nature of technology is related to technology as human practices, and also to what DiGironimo defines as 'the enterprise of technology' (p. 1341) but where the human enterprise that is taken as an example in the studied activity does not make visible how it 'grows from its past' (p. 1341). That is, in Excerpt 3, the participants' joint actions of pushing the garbage bin are analytically recognised as non-verbal and verbal interactions on an artefact, which together mediate knowledge (Vygotsky, 1934) about the function of the wheel and how to tilt the bin to facilitate its handling. This is analytically understood as knowledge related to *technology in relation to human practices* and to also allow a focus on the *current role of technology in society* (DiGironimo, 2011). Consequently, the absence of knowledge related to the historical dimension of the nature of technology (DiGironimo, 2011) is notable in our study. This is particularly interesting given that the wheel is a human artefact that has been around for quite a while, and thus essential human historical knowledge is embedded within the artefact. A challenging factor for implementing the historical aspects of the wheel could be the young age of the children, along with their limited attention spans and communication abilities. This might contribute to why the history of technology is not emergent in the activities. Since the kinds of technological knowledge that are made possible for children to develop understanding of is dependent on teachers' technological knowledge (e.g. Sundqvist 2020; 2021), how activities are organised and what hands-on materials are offered (e.g. Thorshag & Holmqvist 2019), this highlights the significance of ECE teachers' awareness and inclusion of the history of technology to support an emerging understanding of the nature of technology. We acknowledge the importance of including the historical aspect of mechanical technology, especially in relation to developing an understanding of how technology has been intertwined with human development throughout our history of which current high technological societies ensues.

We have applied DiGironimo's (2011) model to study how knowledge related to the five dimensions of the nature of technology emerge in the interaction in a preschool setting, highlighting the need to discuss the implications of employing the model that initially was used for older students in a preschool context. The framework has proven valuable for discerning a broad comprehension of the concept of technology, and the results of our study suggest that the model is useful as a framework for a mutual point of reference within both the research field and professionals in ECE.

Conclusion

Regarding how technology education is enacted, the results from previous research can be categorised into two themes: technology activities organised with either play-oriented or goal-oriented approaches (see also Eliasson et al., 2022). The results of this study instead point to the possibilities and significance of combining a well-planned and goal-oriented learning activity with an open and permissive approach, giving play orientation space within the activity and being sensitive to the children's focus of interest as a basis for teaching technology. In this study it is shown how the teacher moves between using children's play approach and by ignoring it to coordinate a mutual focus on the technology content, thus bringing light to the significant role of the teacher. To enable such a teaching approach, the teacher must be comfortable with teaching basic subject knowledge and be sensitive to the orchestration of the activities. This study contributes with knowledge on how technology education can be incorporated in ECE settings, without losing sight of its essential elements with an equally strong focus on education, play and care.

In closing, to understand technology in today's society, not ignoring the ubiquitous digital technologies, along with its cultural, ethical, and gender implications, it becomes urgent to perceive and understand technology by including both its shape and structure as well as its role in human life and society over time. In line with this reasoning, we suggest that an emerging understanding of a historical perspective on technological artefacts becomes significant, since it is entailed in the very concept of technology, with technological artefacts comprising accumulated human knowledge, often over centuries. This process can start at an early age, for example, by communicating why and when everyday technological artefacts were developed or by discussing what humans used before a specific artefact was invented. Our study has shown that there is no need to re-invent the wheel to implement fruitful technology education with young children in preschool, but preferably point to the significance of the historical dimension of early human inventions such as the wheel. We acknowledge that these findings are based on limited empirical data, and that the inclusion of digital technology activities may entail differing results. However, an important aspect that needs to be revisited is knowledge related to the historical dimension of technology.

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