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Studying the relations between motives and motivation – How young children develop a motive orientation for collective engineering play

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Abstract

This paper reports on the results of a study that investigated how teachers and young children engage in engineering practices in an early childhood classroom. As an educational experiment (Hedegaard, 2008), the study followed two teachers and two classes over one year as they designed motivating conditions for children's engineering play through storying (Robin Hood) and imaginary PlayWorlds (Fleeer, 2018). How children aged 4 to 6 years were oriented to engineering practices and developed a motive orientation to engineering was studied and analysed using the cultural-historical concept of motives (Hedegaard, 2014). The findings show that teachers orient children to engineering thinking through creating motivating conditions. As children's engineering competence develop, the themes of child initiated play changes and 'as if' imaginary narratives become more complex with 'as if' engineering solutions. Free play becomes collective, play narratives align as children orient to each other in the common imaginary engineering play, and children appear to actively draw upon engineering concepts to deepen their play.

Keywords: PlayWorlds, conceptual play, Engineering, cultural-historical, early childhood

Introduction

Societal values shape the practices of the educational institutions (Hedegaard, 2014) and these in turn create the conditions for children's play, learning and development within educational settings. Science, Technology, Engineering and Mathematics (STEM) discipline knowledges and expertise have become increasingly important as a societal goal in many countries (Bagiati et al., 2015; Australian Industry Group, 2017). These societal values create new demands upon schools and early childhood settings for the development of new practice traditions for STEM learning. What appears to be particularly new is a societal expectation for the teaching of *engineering principles* in schools from the beginning of primary school (Australian Industry Group, 2017) and increasingly for early childhood settings (Bagiati and Evangelou, 2016; Bairaktarova, Evangelou, Bagiati and Brophy, 2011; Gold, Elicker, Choi, Anderson and Brophy, 2015; Hallstrom, Elvstrand and Hellberg, 2015; Lippard, Lamm, Tank and Choi, 2018; McClure et al., 2017).

This paper seeks to examine if motivating conditions for engaging with engineering concepts and practices can orient children to an engineering motive within free play settings. To achieve this goal, this paper begins with a review of what is known about engineering for young children, followed by details of an educational experiment where two teachers and 15 children from one setting were followed for one year as they developed new practices for the learning of engineering principles. The paper concludes with a discussion of how motivating conditions for imagining and exploring engineering concepts and practices support the building of a common play narrative amongst children during free play periods.

Engineering practice traditions

Not surprisingly, the literature into engineering practices in play-based settings is limited. As a new practice tradition, researchers have tended to explore what might be the affordances for

learning engineering through examining the resources and structures of free play settings that already exist in preschools (Bagiati and Evangelou, 2016; Gold et al., 2015).

What is known from these studies is that first, the resources in the preschools are full of potential for the learning of engineering principles and concepts. Through examining the actions and structures of the play-based setting, researchers have drawn upon common engineering concepts to study the everyday concepts of children with the resources, such as the block area, the outdoor environment and climbing equipment, the construction kits, and the imaginary play area of the home corner. What is interesting is that the researchers have all focused on either engineering processes, such as, planning and designing or engineering principles, such as structures (Lippard et al., 2018). Together, they have concluded that the play-based environments are full of possibilities for learning about engineering.

The second finding that has emerged in the broader literature is in relation to the outcomes for young children in school settings when teachers use a curriculum and a model of practice, known as *Elementary Engineering*. The empirical studies surrounding this curriculum show that this program does support the potential for learning engineering concepts by young primary aged children (Capobianco, Diefes-Dux, Mena and Weller, 2011). These evaluation studies in non-play based settings positively report on the learning outcomes of children, and how children become knowledgeable about what is an engineer.

The third area to be found in the literature is directly related to outcomes associated with knowing about engineering professions. That is, studies focused on children's perceptions of what is an engineer and what might be the work they do. This research has shown that the engineering profession is poorly understood (Capobianco et al., 2011; Penuel, 2016). Children draw images of engines and discuss the people in their drawings as fixing engines, and doing technical or manual work. Researchers conclude that engineering professions are poorly understood by children, and that this finding appears to be also prevalent in the broader community. Further, it is argued by Pantoya, Aguirre-Munoz and Hunt (2015) that when curriculum is designed around an engineering storybook, discussions and drawings of an engineering design cycle, that an engineering identity develops.

Fourth, many of the studies report that teachers when interacting with children, either formally or informally, do not actively take a role in promoting engineering concepts (Lippard et al., 2018). This finding is based on a view that teachers already know what are the core discipline concepts of engineering and a belief that they will find this knowledge valuable in its own right to teach when opportunities present themselves during interactions with children in group settings or informally during free play time. These studies suggest teachers need professional development to support their confidence and competence in the teaching of engineering to young children.

Finally, there are some studies that show gendered patterns of block use and construction play. However, there are also other studies that report that there are no differences between girls and boys when engaged in free play with construction materials (Gold et al, 2015). Those studies that have shown gender differences, identify that girls design with a goal in mind and play with their construction, whilst boys tend to build a range of structures but do not generally build to play with their construction. Importantly, one study by Hallstrom et al. (2015) showed that girls primarily take an auxiliary role in the block area, passing blocks to the boys so they can design and build structures. Whilst no other recent studies of preschool engineering could be found that focused on gendered practices, the longstanding research into gender differences in preschools has shown that there are significant differences in the play

practices of children, with the outdoor area and construction spaces usually dominated by boys.

Taken together the limited research into engineering for young children tends to focus primarily on free play periods and this research positively shows that the resources and structures do give many opportunities for children to engage in exploring at the everyday level engineering principles whilst playing. The research also shows that teachers are not oriented to engineering and do not orient children to engineering concepts or principles. This research suggests that there is a need for professional learning of teachers to help them see the engineering affordances of the play-based environments and to positively engage in engineering interactions with children. This literature also recommends building teacher confidence and competence in teaching engineering in preschool settings. What is missing from this research is how teachers can draw upon the everyday concepts and interests of children to support the development and expression of engineering play that is personally meaningful to them. It seems that very little is known about how children develop a motive orientation to engineering practices and concepts in the early childhood period (birth to eight years). The study reported in this paper seeks to address this gap through concentrating upon how young children enter into, and express through their play, engineering practices and concepts.

Educational experiment

In light of the research need and central problem discussed in this paper, we used the methodology of an educational experiment to study children and teachers in play-based settings. In an educational experiment both the planned activities of the teacher and the children's actual activities are conceptualised as part of the intervention. Specifically, we examined how teachers developed motivating conditions to orient children towards a motive for engineering thinking, play and activity, as well as how children enter into the new activity settings and contribute to, and shape the activity setting of the planned engineering practices.

An educational experiment "implies a cooperation between researchers and educators" (Hedegaard, 2008, p. 200) and this drove how we engaged in the research process. The formulation and revision of the planned activities "are seen as a dialectical process" between the teacher's pedagogy and the theoretical knowledge that is the content of the teaching. In this study, the theoretical knowledge related to the core concept associated with engineering principles, such as working/playing as a team, structures and force, materials, design (plan view, side elevation, 2-D, 3-D) and simple and complex machines. To support engineering principles being personally meaningful for children, it was important to take the everyday practices of the children as a starting point. In this study, the teachers used the story reading of Robin Hood to create a collective imaginary play situation for the children which could support a motive orientation towards learning about different engineering structures through generating personally meaningful problems within the storying and free play - such as, rescuing the dragon from the castle, lifting the treasure from the dungeon in order to re-distribute wealth to the villagers. Engineering principles and concepts became part of the educational experiment in order to support the children's design work. We were interested to know how children's appropriation of knowledge and thinking were contributing to their imaginary play and enhancing their play and supporting the learning of engineering principles over time.

An educational experiment has its roots in cultural-historical theory, notably the work of Davydov (2008) where different knowledge forms have been theorised as part of researching

new educational practices. Specifically, narrative, empirical, and theoretical knowledge forms are discussed by Davydov as important for the cultural formation of children. It was theoretical knowledge of engineering that was key to this study. Unlike empirical knowledge, where facts build upon each other like building blocks to be learned, theoretical knowledge is conceptualised relationally as a core model and this core model is determined through an analysis of the essence of the content to be taught. A core model contains within it all of the relational characteristics that work together to realise the whole. For instance, in human biology the cell of the human body represents all of the genetic content of the human. It is the core unit of the whole system (see Hedegaard, 2002). In the study of biology, a core model of an ecosystem can be understood through the example of the relational characteristics of organism, habitat and food sources (Fleer, 2011). When one part of the core model changes, such as the habitat through climate change, it affects the food source, which in turn can lead to structural changes or extinction of a specie. All characteristics are related to each other, and together they make up the whole. Organism, habitat and food source can be understood as the smallest relational unit which makes up the whole system or core concept. That is its essence (Fleer, 2011) or germ cell (Hedegaard and Chaiklin, 2005) or core model (Davydov, 2008).

In our expanded theorisation of an educational experiment (Hedegaard, 2008) into play-based setting, the core model of practice for engineering also meant determining what might be the essence or core relational characteristics of engineering principles, activity and thinking for play-based settings. That is, we had to determine in our educational experiment what were the core concepts associated with engineering that could support children's play and learning. We determined from the literature that the core model of engineering principles and practices included, wondering/problematising/questioning, working/playing/researching as a team, structures and force, materials and their properties, designing (plan view, side elevation, 2-D, 3-D) and simple and complex machines, all realised through a cyclical practice process of planning/designing, enacting/making/prototyping/modelling and evaluating/reviewing. In our study, modelling also included the embodied practices through imaginary play. Hedegaard (2008) has argued that an educational experiment in schools should unveil how using models in teaching helps students to formulate their own models which create connections between theoretical concepts and specific events. In our study, prototypes and play were central to understanding children's modelling.

Motivating conditions in support of a double move

Hedegaard (2008) has said, "In the building of conceptual models, teachers can create a wholeness orientation rather than focus on a single learned element of a subject area" (p 191). This is particularly significant in preschools because STEM activities are usually introduced as an event that can be spontaneous (noticing an insect and it becomes a teaching moment), informal (science table) or as single formal lessons (Tu, 2006), depending upon the model of practice the teacher adopts. Because the literature shows that engineering has as yet not entered into everyday preschool practices, we know that similar expectations for informal or spontaneous engineering could arise, such as, engaging in collaborative block building where some opportunities for learning engineering could be featured if the teacher is tuned into the possibilities. But these practices may not be enough for children to build conceptual models surrounding engineering principles. We also know that models of practice for preschool engineering exist, and therefore a wholeness orientation could be achieved, such as that of Lippard et al. (2018) for goal setting questions, explanations of how things are built or work, actual behaviour of building or making things, problem solving and some form of evaluating.

What is central here is that, “The teaching activities should seek to combine these elements with the educational goals and subject matter knowledge in ways that transform and combine children’s everyday knowledge and goals, with their motives and interests, *into new motives*” (Hedegaard, 2008; p. 188; my emphasis).

Children’s engagement and motive development are central for all learning activity, especially when new practices are being introduced, such as engineering. Hedegaard (2008) has said, “The teaching activity must consider children’s engagement with each other and the demands of solving tasks together; it should also ensure that the tasks draw on the children’s everyday knowledge and interest, and promote shared engagement” (p.188). Specifically, an educational experiment is based on the theoretical conceptions of where to lead the children, both from a subject matter perspective and from a personal developmental perspective. This double move is characteristic of Hedegaard’s model of research and practice and is foundational to an educational experiment. In Table 1 we capture how the educational experiment acted as a process in support of the collaboration between the researchers and the teachers in developing children’s engineering thinking and activity. Figure 1 Column 1 is drawn from Hedegaard’s (2008) empirical and theoretical writing on a double move and this drove the development of motivating practices of the educational experiment (discussed further below).

Table 1

A double move of concepts and practices in the educational experiment

Development of theoretical concepts – Double move (Hedegaard, 2008)	Motivating practices – Conceptual PlayWorlds (Fleer, 2018)
Children formulate goals about the thematic relationships that compromise the main problem – initial relations to be researched.	<i>Group time:</i> Story of Robin Hood creates motivating conditions for solving a social problem that needs engineering solutions
Formulation and expansion of the initial relations into a core model of the problem area being investigated.	<i>In place of table top activities:</i> Children enter into imaginary PlayWorld of Robin Hood to embody the everyday problem situation within imaginary play situation
Children take a critical position on the conceptual relationship being investigated.	<i>In place of table top activities:</i> Children engage in research related to the central engineering problem, by interviewing the Castle engineer, taking photographs of engineering structures, and by watching YouTubes
Children draw upon conceptual knowledge to build theoretical models as part of the research process	<i>In place of table top activities:</i> Children design and prototype models
Children evaluate the outcomes of their research	<i>Group time:</i> Children test their model
Children use their theoretical knowledge in child-initiated play during free play periods in the preschool	<i>Free play period:</i> Children initiate the collective building and construction work in the free play area and express their engineering knowledge and practice

In line with Hedegaard’s (2008) conception of an experimental intervention which she

theorised as a form of a teaching activity which can influence a child's learning and development, we adopted the Conceptual PlayWorld to guide our work with creating motivating conditions for the development of engineering thinking and activities (Figure 1 Column 2). We had learned from previous research (Fleer, 2011) that a Scientific PlayWorld (Fleer, 2017) created conditions that brought play and learning together for children in ways that supported conceptual development of science discipline content so that it was personally meaningful to children. In line with this work and Hedegaard (2008) conceptual model (Table 1, Column 1), we used a Conceptual PlayWorld (Table 1, Column 2) as the basis for the educational experiment where researchers and teachers discussed and planned the new engineering activity settings that were planned as part of existing practice traditions of group time, table top activity time and free play time.

Participants: Two classrooms – 4's and the 5's were involved. The former is a preschool (4 year olds) and the latter is a school classroom (5 year olds). A total of 13 children consented to participate in the study. Of these, 5 were aged 5.9 years (5.5-6.4 years) and 8 were aged 5.1 years (4.7-5.5 years). Two qualified teachers led the teaching program (Ruth and Olivia), and they were supported periodically by a computer technician (Alex).

Video observations: The study period ran over two years. The data from the second year of teaching program are the basis for the study reported in this paper, and which totalled 123 hours of digital video observations. A total of 35 data gathering trips were made to the preschool and a total of 52 sessions were recorded, representing 61 periods.

Professional development: The teachers participated in ongoing professional learning, meeting with the researchers weekly in the field or through skype. The focus of the meetings was on their reflections of the children's experience and their own understandings of children's development in the Engineering PlayWorld. All sessions were video recorded.

Overview of the Engineering PlayWorld practices: The Conceptual PlayWorld is centred on the story of Robin Hood of Sherwood Forest. A chapter book is read to the children each time they meet. The children meet on a log that is outside of the outdoor play area before entering into the shared imaginary situation of Sherwood Forest with the teachers. They also meet on a large wooden platform and fort in the outdoor area where they imagine going into a time machine to return to the time of Robin Hood. Here they meet the castle engineer. The outdoor area becomes 'Sherwood Forest'. Over 12 weeks, the whole group of children enter the physical play space of 'Sherwood Forest'. Over time problems arise that need to be solved. For instance, designing a simple machine to 1) get the treasure; 2) rescue the dragon from the castle; and this means making models and researching back in time by visiting and interviewing the castle engineer.

Analysis: The dialectical concepts of motives and motivation informed the analysis. Vygotsky suggested that a child's cultural development can be conceptualised as period within which certain motive orientations dominate, such as communication, play or learning. This does not mean that only one motive is evident, but rather that a child appears to primarily orient themselves in activity settings in relation to their dominant motive. Hedegaard (2002) in drawing upon the Vygotskian (1998) concept of motives has elaborated this theoretical concept by introducing dominating motives, as the child's leading motive, meaning-giving motives where the relations between a child's motives and the social situations orient children in particular ways, such as to learning or to play. A stimulating motive can be used to develop other motives, such as, using the dominant motive of play to create motivating conditions which can orient a child to engineering.

Hedegaard has argued that a child's motive has to be seen as part of the social situation and as a relation towards orientating the child within the activity setting. Vygotsky argued that a change in a child's motive orientation is suggestive of a change in the child's development. Hedegaard (2008) has elaborated this further by suggesting that, "An important way to support the development of the learning motive is to create engagement and shared experiences among the students by letting the class participate together in events" (p. 193). By paying attention to how a child enters into the engineering activity settings as part of a collective where children are oriented to an imaginary play situation, we can learn about what they are interested in and their motives. At the same time, when studying the motivating conditions of the activity setting, it becomes possible to analyse using the double move, both the engineering principles and everyday practices that are related to engineering. In this way, we can better understand children's engineering thinking and activity in the context of a motive orientation to engineering that the teacher is creating in the activity setting. As argued by Hedegaard (2008):

Motives develop in institutional practice and can be seen as the dynamic that characterise a person in different activities. Motive development takes place in activities where a shared engagement and orientation in social interaction exists between the participants in the situation. When a teacher creates a learning motive the task is to identify the activities that are engaging for the students and these in turn, reduce the demands on the teacher (p. 192).

Our study sought to see how children enter into the theoretical knowledge that is featured in the new activity setting. We did this by following how children enter into subject matter and make the content personally meaningful. To achieve this analysis, we examined the development of children's thinking strategies and changes in the conceptual models they made where engineering practices and engineering principles were featured. Important to the focus of this paper, was how the new practices of engineering supported "children's active explorations and their own development of motives" (Hedegaard, 2008; p. 187) as expressed through child initiated play. We therefore focused our attention on the children's motives within the free play periods in the classroom to see if and how concepts were expressed in their imaginary play in the construction areas. We looked for child initiated play actions and motives of the children in the free play activity settings that related to engineering principles or practices.

In following how a child enters into the new activity settings associated with engineering (motivating conditions), at the same time as examining a child's intentions within free play time (motives), it becomes possible to study if and how a child's motive orientation changes. It is this dynamic relation between motives and motivation within play-based setting which formed the central analytical frame within our educational experiment.

Findings

Our research was concerned with how the preschool children entered into the activity settings of the Robin Hood PlayWorld over time and progressively developed engineering thinking, activity and a motive orientation towards being/acting as an engineer. The findings of the study are reported first through a brief overview of the motivating conditions for orienting the children towards engineering principles and practices, followed by a detailed study of how the children entered into the new activity settings that were developed through the educational experiment, their intentions, and their dominant and/or changing motive orientation.

1. *Motivating conditions*

Social problems arise: The motivating conditions in the preschool/classroom arise in different ways, but are always part of the narrative of the story of Robin Hood which is read regularly to the children. As a chapter book, there are many adventures, and there are many different ways to expand the storyline of Robin Hood. The storyline of Robin Hood sets up many social problems that were expressed by the children after hearing the story. For instance, the child initiated responses to the story in Period 2 included, “If they steal money all the people won’t have money to buy things”, and “The bad guys aren’t sharing”. The storyline created motivated action of the children who wished to help the villagers. Fairness dominated the children’s comments, and their call for action appeared to be driven by this, as was confirmed during interviews with Ruth:

...because fairness for 4 and 5 year olds is important – “that’s not fair” that’s the language that they use. Because it is the social and emotional concepts that gives them the motive to want to solve the scientific problem... (Ruth, Period 29)

The children are interested to find out more about Robin Hood and the teachers plan different activity settings in support of the imaginary PlayWorld of Robin Hood that begins to develop in Period 2. In Period 12 the children are introduced to time travel to support the deepening imaginary PlayWorld of Robin Hood.

The children gather in circle where they can see each other. Ruth who is seated in the circle tells the children they are having lunch in the 5’s area in the school. The children collect their lunchboxes and walk outside of the preschool room and line up at the gate to the school and transition into 5’s classroom. The children leave their lunchboxes outside in the ‘castle lunch room ready’ for picnic lunch in ‘Sherwood Forest’.

The children sit in 4/5 pattern in the classroom. Ruth is half a 4 and half a 5. Ben questions if lunch in Sherwood Forest is in real life or their imagination. Ruth poses the problem of how to get treasure from the castle if it is back in time and on other side of world. Ben suggests a time machine. The children brainstorm time travel and then individually design a time travel machine on paper. This is followed up by watching a YouTube on *Forces of Nature* with Brian Cox about travelling in a jet plane faster than the spin of earth and seeing the setting sun rise again. The children discuss what they have seen and then they draw a group design. Ben draws the Earth on the large sheet of paper, but Harrison wants to draw the Earth's orbit around it, and there is a disagreement. He later does this when the children go outside.

The children and Olivia then Ruth sit in an area of the deck that has been designated as the ‘time machine’. They do a count down from 10 and travel back in time wobbling and making engine sounds, whilst also looking out of an imagined window for clues so they know when they have arrived at the castle.

The children land and then explore the outdoor area, changing the meaning of what they see, as though engaged in exploring Sherwood Forest looking for the Sherriff’s Castle. Ruth makes a beeping sound, and the children become excited, and run back to the time machine in order to travel to present day Melbourne.

The children count down from 10 as before, and then walk into the classroom and sit

in on the mat in a circle. Both teachers are seated in the circle with the children. A discussion in the class on what they'll need to find out about next time they visit the castle takes place. Oliva writes down their ideas.

The children have lunch on the deck (which was previously part of Sherwood Forest) and Ruth reads a book about life in a castle. As the children finish their lunch they then move about the play area further playing with the equipment as is their practice tradition after lunch (Period 12).

The demands of the engineering activity settings on the children

The story reading creates new demands on the children that are socially and emotionally oriented. The story generates questions from the children, such as, “How to save the villagers?” and empathetic actions, such as, “How to go back in the time of Robin Hood?” in order to help the villagers. The child initiated questions are indicators of how the story creates motivating conditions for the children to engage with important philosophical questions of fairness and appears to align with a motive orientation for helping. The social and philosophical questions create a new kind of demand upon the children in the imaginary situation, in how to resolve the problem facing the villagers. The imaginary situation, although not real, also requires new kinds of competencies for the children to solve the imaginary problem in the imaginary situation ‘as if’ it were real.

The teachers deepen the children’s imaginary PlayWorld through inviting the children to suggest solutions, and this is where time travel is introduced and the idea of a time machine is suggested by Ben, something that is taken up enthusiastically by the group, and possibly drawn from the children’s popular television culture. The teachers use digital resources of a YouTube on time travel to support the development of new competencies that help the children’s ‘as if’ actions in the collective play travelling back in time of Robin Hood. This also puts demands upon the children because the content is difficult.

The need for engineering competencies arise

In Period 17 the children have had many opportunities to travel back in time, and on this occasion the children and teachers return to the castle and discuss with the castle engineer how to get the drawbridge down – so they can get the treasure out. In anticipation of the children’s developing play narrative, the castle engineer (school technician in role) has set up a crude pulley system on an outdoor play structure in “Sherwood Forest” (see Figure 1) and the children use this to lift a range of real objects, but also children draw into their play the pulley system by imagining through playful actions the lifting of dragons out of dungeons – some children are regularly in role as dragons when visiting Sherwood Forest.



Figure 1. Engineering problems arise – how to lift the drawbridge?

The demands of the engineering activity settings on the children

The prototype of the imagined castle with a pulley system to lift the drawbridge is exciting for the children and in subsequent visits to meet the castle engineer, the children use mobile digital devices to photograph the pulleys, and study cogs and simple machines, prepare castle plans for designing an escape route to discuss with the castle engineer (who wants to help the children), and determine the best time to go into the castle to take the treasure.

It is in these motivating contexts presented as vignettes above, that we were interested to know if a motive orientation to engineering might be evident in child initiated free play. We now turn to two examples of free play of the 5's in Period 19 and again in Period 29.

2. Children's developing engineering motives

How children enter into free play activity settings – intentions and motive orientation

In the classroom are set up 4 activity settings – drawing/writing area; easel area; box construction area; block building area. The children are free to use the areas as they wish. The teacher is making observations of the children, filming their activities. A group of children have been constructing a block castle, which falls down and the children begin rebuilding. In another part of the room are the tables with writing materials, and there can be found 2 children. Harrison is writing about what he thinks is important for building a castle. He writes: "First you need lots of wood and stons and glas and briks [sic]". The teacher is close by Harrison asks, "Is this how to spell bricks?". Baz is standing at the easel and is drawing a design of a castle. He spends time in carefully drawing turrets, making sure that each is of equal size (Figure 2).



Figure 2. Designing a castle.

On the other side of the easel to Baz is Ben, who also is also drawing a design on the easel. He periodically comes and looks at what Baz is doing. Millie is standing at a table and is looking intently at a circular piece of cardboard. She announces to no one in particular that it is a coin, presumably part of the treasure. She moves around the room observing the activities of the other children and then returns to her treasure making activity at the table. Behind the easel are now two children who are working with large wooden blocks. They have declared that they are building a castle. The children make a drawbridge from blocks, string and sticky tape, the children discuss the weight of the blocks and what kind of material can best act as a pulley to lift up the draw bridge. Finally, they make the drawbridge and close the gate. Ben who is still at the easel drawing the design appears annoyed that the other two children have started making the castle without him. He calls "We are still making the plan". Millie moves over and shows him her coin. She passes him a piece of paper, and Ben unfolds it and asks, "Is that a note?". Millie takes the paper and looks intently at it and confirms it is a note about castle building. Larry who is seated and watching the rebuild says to the teacher, "I am writing a story about the first castle that was built in exactly the same place, but they had to knock it down to build the new castle". He moves over to the writing area to join Harrison and starts writing: "Before this castle there was different ..."



Figure 3. The final built castle.

Ben and Baz now join in the block building, carefully stepping over part of the structure already built. Baz announces that he is building the front wall, as he moves pieces in place, and then declares that he is building the side wall. The other children cooperate and add to the structure. Christopher asks, “Do you like the drawbridge?” as he points to two blocks that have been taped together and pulled up into a closed position. Christopher says, “It’s up! When it’s down, see those little blocks there (pointing), then it’s open”. Ben says, “It goes like this” as he lifts and lowers the drawbridge. Ben declares, “Yeah and then they walk across there” as he gestures to the top of the castle and looks to the teacher who is standing and filming the castle building. The children appear to invite in the teacher at this moment, so she says, “You were talking about some of the rooms in the castle, what sort of rooms were you having in your castle?”. This appears to inspire the children, as they quickly begin moving long wooden blocks to create enclosures. Ben says enthusiastically to no one in particular, “We would have the jail at the back, and we would have the guard next to it”. The children discuss the range and arrangement of the rooms as they cooperatively place long blocks within the outer walls of the castle to form rooms. Baz continues to explore the drawbridge further. More children join the block building – some as observers and others as builders. The children discuss the need for turrets and then collectively look for blocks to serve this function. A range of block shapes are discussed with enthusiasm. The children actively compare the blocks and eventually decide upon using arch shaped blocks. They forget what the purpose of the task was (find blocks for the turret), and eventually put the arch shaped blocks inside the draw bridge – then search for more. The children discuss cylinder shaped blocks, what kind of block that can be put on top of a cylinder, and then announce the need for a canon. The block building continues until the children appear to be satisfied with their prototype of a castle (Period 19).

When Olivia is interviewed at the end of the day about the prototype of the castle built by the children, she points to each block feature in their construction and comments on each part:

It’s always about, you know, keeping the enemy out, you know talking about the guards making sure that the enemy is not able to get in or you know they think very heavily about the things like ... (move to point to a part of the block structure) ... so

Harrison here was talking about the treasure room being under here ... so this tile is in actual fact where the room is beneath, so he's trying to think of how do we actually make that happen. So, he wants to make that happen. But over here (moved to another area) is the trap or the dungeon which are all ... so you can see there that they've got the blocks, they've used the blocks to try and incorporate that [idea] (Olivia, Period 19).

The demands of the engineering activity settings on the children

The children are free to move about these activity settings, as is the practice tradition during the afternoon play period. The teacher is filming each of the activity settings, and from time to time she asks something about their activity or responds to the children's comments – this puts new demands upon the children and they appear to generate new actions, and the actions seem to always be in relation to their play.

Even though the activity settings in the classroom are different, the theme of what the children are doing appears to have been inspired by the story reading and imaginary PlayWorld of Robin Hood and the need to help the villagers. The story creates a common and known narrative among the children, as was evident when Ben became concerned that the building had started before he had finished the design of the castle. The children appeared to be oriented to the collective imaginary PlayWorld of Robin Hood, but also were actively oriented to each other. The collective focus appeared to help align their actions, as few conflicts emerged in their block building.

The drawbridge appeared to be focal point for all the children, as this was the first part to be built. It was also the part of the castle building that the children returned to, regularly exploring the mechanism, the cavity that it created, and the opening and closing function. It was also what they wrote about when they were preparing a list of important features for a castle. It was also featured in most of the children's drawings throughout the educational experiment, and the mechanism that operated the drawbridge was usually mentioned when discussing their drawings (Figure 4). During interview, Ruth reported on the significance of the pulley system when discussing Millie's castle design:

The children have taken a real interest and wanting to pursue their own projects. So there have been some children who wanted to do some intricate drawings, so if we look at the drawing of the castle, this is very significant and personal to her, she wanted to get the idea of a pulley (shown in Figure 4) and a guard who is pulling [the pulley] and this gives an idea of castle life in that drawing.



Figure 4. Millie discussing her castle design

Ruth had read to the children about castle life and this becomes incorporated into how children design. The motivating conditions, appear to orient the children to wanting to know more and this supports the emerging competencies which enrich their drawings, at the same time as giving themes for child initiated free play with blocks. The story of Robin Hood creates motivating conditions, which in turn puts new demands upon the children to learn about castle life, and to use this in designing escape routes where it becomes increasingly important to know about engineering principles surrounding the drawbridge, and the everyday life of the people living in the castle – rooms, activities and intentions. Knowing more about engineering within the social frame of helping the villagers appeared to put increasing demands upon the children, which in turn appeared to be expressed in the themes of children's free play, and in child initiated drawings (their designs). The more the children knew, the greater were the demands upon them within the existing activity settings, where the new content was being incorporated into their play, suggesting the engineering content was becoming more personally meaningful to them.

Developing motive orientation to engineering

In summary, it would seem that by Period 19, building a castle and being focused on the drawbridge appears to have become personally meaningful for the children. The teachers had created motivating conditions for this kind of exploration and detailed attention to prototyping a drawbridge. Later in Period 29, the block building developed further and combined with large cardboard box constructions to create castles that are used by the children during rest time, and through the explanation of the teacher during an interview:

They play a lot in here [1 m box and block castle], it's their favourite spot to play, and rest in here. So, it's a bit confused, they talk about forts, so it seems to be a

combination between a fort and a castle. These are beds, and the children, so Larry, this is his bed [as indicated by a photo of him on a tower next to the bed made of blocks]. So, he rests here at rest time, it's not very comfortable but he ... and Christopher and Thomas and Ross. So, this is like ... I think they feel pretty special resting inside of the castle.

This is Christopher's throne, so he sits there. So, there is a lot of play but it's a different sort of play; It's not Robin Hood play; it's fort play that has come from outside to inside, but in a castle, so there is lots of different themes that they're putting together (Period 29, Ruth)

Incorporating life inside the castle with the daily routines of preschool for rest time suggests that engineering competence was becoming personally meaningful for the children. Through the motivating conditions of the Engineering imaginary PlayWorlds the children engaged in new actions of building castles to extend their play, but also creating new spaces for rest time, suggesting that engineering thinking was holistically incorporated through castle life and the daily life of the preschool.

Discussion

Vygotsky (1997a) wrote that research tends to focus primarily on an individual as they develop higher mental functions. He critically said, "The usual question is how does one child or another behave in a group" (Vygotsky, 1997b, p. 107). In problematising this perspective, Vygotsky argued that in cultural-historical research, "We ask how does the group create higher mental functions in one child or another" (Vygotsky, 1997b p. 107). By only focusing on the individual child, only part of the developmental conditions is known. Similarly, in only ever studying the group, we miss how a child enters into, shapes, and is shaped by, the group settings. Studying group settings for their motivating conditions, gives insights into the developmental conditions and this makes it possible to study a change in a child's motive orientation. Both the personal motives and the motivating conditions are equally important in the study of higher mental functions.

In the study reported in this paper, both motivating conditions and children's personal motives were examined. Specifically, the study was interested to know if motivating conditions for engaging with engineering concepts and practices could orient children to an engineering motive within free play settings. That is, could principles and concepts associated with engineering become themes in child initiated play, and would children express their growing competence of engineering content when playing? The study found four key characteristics of the relation between motives and motivation in relation to engineering play. They are discussed in turn.

First, the common experience of exploring engineering problems and imagining and exploring engineering solutions appeared to be collectively expressed in child initiated play during free play periods. What was learned about collective engineering play through the educational experiment, was that the children had the common experience of both the storying and the entering into imaginary PlayWorld of Robin Hood with their teachers, and this meant the whole group built common knowledge which supported the introduction of play themes and collective actions in play. Play actions appeared to be aligned and collective. The children were drawing upon the same storyline, the embodied experience of visiting Sherwood Forest, the fiction and non-fiction books on castle life, YouTube and other

experiences and information surrounding the deepening of engineering content. But also, different themes could be introduced by different children, and different play actions and life inside the castle could be explored in open ended ways. In these moments, children have the possibility to make links and determine conceptual relations as they come to better understand everyday life. As noted by Vygotsky (1993), "...all the many links and relationships which determine its place in the world and its connection to the rest, then one's understanding is a deeper, more real, truer, and more complete reflection than the envisaged one" (Vygotsky, 1993, pp. 204-205).

Second, the collective alignment seemed to orient the children to each other in pursuit of their imagined engineering PlayWorlds. That is, the children were acting 'as if' they were together building castles, solving social problems with 'as if' engineering solutions. This was an important finding, because some have argued that PlayWorlds could orient children to teachers, and consequently children may not be oriented to each other and develop competencies in relation to peer play.

Third, it was found that collective imaginary play of engineering showed how children drew upon engineering concepts and made them personally meaningful when playing. Vygotsky (1997a) has suggested that "Functions initially are formed in the group in the form of relation of the children, then they become mental functions of the individual" (Vygotsky, 1997b, p. 107). It was the relations between children in the collective engineering play, but also the relations between children and the teachers in play, that together appeared to have a significant role in how content of engineering could become meaningful to individual children. This is different to previous research in early childhood education which does not advocate for teachers to be involved in children's play, and also is different to what the literature on engineering is advocating – where researchers want teachers to be a part of the play actions of children so they can support an orientation to engineering principles and practices (Lippard et al., 2018).

Finally, the motivating conditions of the engineering PlayWorld built engineering competence, and this competence seemed to amplify the children's collective engineering actions in their play. This in turn appeared to orient the children towards a motive for engineering play. The amplification of an engineering motive orientation as an outcome is in keeping with how "...in studying what the child is capable of doing independently, we study yesterday's development. *Studying what the child is capable of doing cooperatively, we ascertain tomorrow's development*" (Vygotsky, 1997a, p. 202; my emphasis). The motivating conditions for saving the villagers from starvation, meant cooperative play action was 'as if' actions that were realised when designing a castle with a pulley system, preparing escape plans, and block building with moveable drawbridges. The engineering competence of the collective appeared to also be amplifying motivating conditions for developing a motive orientation of individuals towards engineering learning.

Conclusion

This study sought to examine holistically the motivating conditions and personal motives of the children in a context of engineering principles and practices. "A child's motive (i.e., for playing) has to be seen as part of the bigger totality of motives that characterise the child's personality" (Hedegaard, 2008, p. 193). In order to develop children's motives towards engineering, this must be seen as only one small amplifying event, as many are needed to develop a change in a child's motives.

But to create the right conditions for this amplification of a change in motives, a holistic conception of the relations between motives and motivation is necessary. That is, the relation means learning content must be seen as problems that are realised through the children's own questions and worries, such as saving the villagers. The motivating conditions give meaning for learning engineering principles and processes. Reading about castle life to support an escape plan, learning about pulley systems in order to raise the drawbridge and get into the castle, designing simple machines to raise the treasure from the dungeon, are all part of a holistic conception that takes children's everyday personal experiences of wanting to help and explore living conditions, as the primary basis for children's play action and learning.

Vygotsky (1998) has said that child development as periodisation, is where a change in motives from one period to another (such as from play to learning) takes place through some form of drama. Development needs to be conceptualised as a change in a leading motive as a life course change in development. But these changes are not based on one moment in time, but are part of Vygotsky's conception of a revolutionary view of child development. In this paper, both play and learning were under study through how a child's motive for play could create motivating conditions for learning engineering principles. Hedegaard (2008) has argued in the context of schools, "An important way to support the development of the learning motive is to create engagement and shared experiences among the students by letting the class participate together in events" (p. 193). The motivating conditions of the PlayWorld when viewed holistically, achieve this through collective play. But to have confidence that children are being oriented to engineering, then the principles and practices also need to be studied as expressions of children's play for children in play-based settings where the leading motive is to play together with other children. It is important to capture how complex engineering concepts are expressed in children's play 'as if' problems and 'as if' solutions. As noted by Vygotsky (1993), "...understanding, like all the higher psychological processes, develops in no other way than in the *process of collective actions by the child*. Only cooperation brings a child's logic to fruition; *only socialization of a child's thought...leads to the formations of concepts*" (Vygotsky, 1993, p. 205; my emphasis). This is because engineering competence acts as motivating conditions which support motive development of children, but these motivating conditions must always be representing engineering thinking holistically through personally meaningful actions, such as castle life and caring.

The relations between motivating conditions and the motives of the children can be seen in the preschool period as expressed collectively through child initiated play. "Only when we learn to see the unity of generalization and social interaction do we begin to understand the actual connections that exists between the child's cognitive and social development" (Vygotsky, 1987, p. 49). It is in this unity of social and conceptual that the motivating and personally meaningful conditions for children can be found, and this is different to conceptualising engineering practices in preschools as something that teachers should plan for, should develop through just interacting with children in play-based setting where they draw attention to engineering principles when constructing, or by asking children to draw a picture of an engineer and explain what engineers do. Rather, the development of children's engineering competence has to be conceptualised as an engineering motive, where the themes of child initiated play change through 'as if' imaginary narratives that become more complex with 'as if' engineering solutions.

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