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Abstract

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Early childhood education has gained increasing interest over the last decades, especially for its effect on the lifelong learning process. Particularly important for lifelong learning is the child's self-confidence and positive emotions for learning experiences. Natural science is an important part of the preschool setting as it meets children's natural curiosity of their surrounding environment while at the same time developing their social, linguistic and fine motor skills. However, very little is known about subject-specific concept development of preschool children, and most of the research efforts, so far, have focused on the fields of biology and physics. This project aimed to contribute to research method development as well as to increase our understanding of children's emergent science and especially children's emergent chemistry. The project takes as its basis cultural-historical theory and makes use of the methods derived from this theoretical perspective, i.e. play-based learning and the genetic research method. In order to analyse emergence, i.e. the process of concept development, a longitudinal study was performed, and a series of play-based learning activities with chemistry content were designed, implemented and assessed in an iterative manner. The study followed 20 three-year-old children over two years, and all the sessions were video-recorded using visual-ethnography. Results show the importance of the teacher's role in planning activities, maintaining focus and moving the children beyond informal learning. The teacher's own knowledge of natural science is key to building upon science content in the children's discussions and moving the discussion forward while maintaining it within the children's zone of proximal development. Data also show the importance of working with small groups of children due to the swiftness of the change in discussions and focus of children at this age. The abstract chemical concept chosen for this study was the concept of 'small'. Initially the children did not have any experience of the sub-microscopic level, and it only began to emerge once the children had been provided with the visual experience of the transition from the macro to the microscopic level, which is a finding that may be one part of solving the decade long discussion on how to increase pupils' and students' understanding of the sub-microscopic level of particles.

KEY WORDS: chemistry, cultural-historical theory, emergent science, preschool, visual-ethnography

Svensk sammanfattning

Förskolan ses som en viktig del av personens utbildning eftersom forskning har bevisat hur kvalitets lärande i de första år bidrar till långsiktiga fördelar i barnens utveckling. På grund av detta har regering investerat i den här perioden, med tanken på att förberedda barn att ta emot utmaningar från 21 talet. Till exempel, i den svenska läroplan för förskolan finns det "barnens förståelse av enkla kemiska processer" som ett mål att sträva efter. Men detta är inte lätt för förskollärarna att nå enligt svenska forskare. Därför har den här studie designat kemi aktiviteter för förskolebarn och analyserat vad händer när de introduceras till kemi.

Först, hittades kemi innehållet som var tillämpligt och anpassat till barnens intresse. Sen, valdes 20 barn i tre års ålder från två förskolor i Sverige och de delades i grupper av fem med en pedagog. Dessa barn följdes för två år och alla tillfälle filmades med video-kameror. En barnpsykolog och en kemist utvärderade de aktiviteterna och justerade dem enligt varje grupps behöv. Lekbaserade aktiviteter hade som fokus att bjuda barnen med vardags erfarenheter som de kunde lätt koppla till vetenskapliga begrepp. För att övervinna de utmaningar som abstrakta begrepp som man kan inte observera direkt (liksom molekylär nivån), pedagogiska verktyg skapades för att hjälpa barnens förståelse. Två exempel var; video animeringar och 3D molekylära modeller som representerade vad händer när is få värme och rörelsen från vattenmolekyler förändras till flytande form.

Preliminära resultat visar hur viktig pedagogens roll är genom att välja rätt aktivitet som följer barnens intresse, förbereda material och innehållet som barn kan lätt koppla till, behålla barnens fokus och utmana dem med ledande frågor som fördjupar eras förståelse. Genom att visa aktiviteter som fungerade bra och peka vad gick fel i dem som inte lyckades, författarna hoppas att inspirera förskollärarna. Förhoppningsvis ska detta leda till att pedagogerna vågar att prova någonting som är utanför eras vanlig praktik.

"Wherever there is a child there is curiosity
and where there is curiosity there is science."
(Howitt & Blake, 2010, p. 3)

"Human mind is historically rooted,
socially constructed and
culturally shaped."
(Nikolai Veresov)

Contents

Introduction

The overall purpose of this thesis is to explore children's emergent science and, more specifically, children's emergent chemistry in the preschool environment. The word emergence is used to emphasise that interpretations of the children's own refracted version of chemistry content are explored. There are no conclusions drawn regarding whether this science is correct or not. This approach aligns with Swedish preschool culture, where the child and his/her experiences and interests are the starting point for educational efforts. The aim of the present study is by no means an uncomplicated subject. Some authors argue against academic influences in preschool (Bradbury, 2019; Fleer, 2020; Lazzari et al., 2015; Moreno et al., 2019) while in other communities there are developed curricula or science programmes with science content, such as, *Preschool Pathways to Science*, *Early Years Learning and Development Framework* and *Head Start* (Gelman & Brenneman, 2004; O'Brien & Herbert, 2015; McDermott et al., 2014). Due to the differences among countries and settings, it is important to place this thesis in its context.

This thesis originates from a Swedish preschool context, where the curriculum is designed to be an emergent curriculum with no achievement goals, only goals to strive for. Such a curriculum provides preschool teachers with the freedom to base their efforts in children's own experiences and align the focus of activities with children's interests. This approach also affords the means for taking a holistic approach by combining different areas of subject-specific content. The goals are formulated in a holistic way:

> *"The preschool should provide each child with the conditions to develop:*
>
> *an ability to discern, express, investigate and use mathematical concepts and their interrelationships;*

an understanding of natural sciences, knowledge of plants and animals and simple chemical processes and physical phenomena;

the ability to discover and explore technology in everyday life…" (Swedish National Agency for Education, 2019, pp. 13-15).

The Swedish curriculum (LpFö-18) was revised in 2018, and formulations such as education and teaching were introduced. *Education* is defined as "stimulating and challenging" the children and as aiming at "encouraging development and learning" among the children (Swedish National Agency for Education, 2019, p. 7). It is specified that *teaching* should also be based on content that is planned or appears spontaneously. To maintain this culture and context while conducting this project, play-based learning activities in the form of *educational experiments* (Hedegaard, 2008) were designed and implemented.

Aim and research questions

The aim of the project was to explore children's emerging chemistry and children's refractions of chemical content. Subdivisions of the project are as follows, with each paper contributing to the study and answering the research questions as stated:

Paper I

- Designing play-based learning activities with theoretical chemistry content and chemistry skills for the preschool environment.
- Evaluating the activities using the quality markers for play-based learning.

Paper II

- What features characterise children's emergent scientific understanding of the concept of "small"?
- What methods and activities assist and provide experiences to support children's emergent understandings of concepts in chemistry?

Paper III

- How do motivating conditions and science content develop science activities?
- How do motivating conditions affect the science content of the activities?

Paper IV

- How can abstract concepts like "atoms" and "molecules" be introduced to preschool children?

Literature review

The importance of science in the preschool environment

During the last decades, early childhood science education has gained much interest (Heckman & Masterov, 2007; McCain & Mustard, 2002; Sylva et al., 2004; Wylie & Thompson, 2003). The reasons for this attention are manifold. From one perspective, quality preschool education is seen as a foundation for further *academic achievement* (Makles & Schneider, 2017), something that may even have an impact on the *life-long learning* process (European Union, 2019). From another perspective, natural science is seen as a part of our *cultural background* (Holton, 1975) and, as such, a natural part of all our educational efforts.

The goals of science education also span beyond natural science itself, especially when looking at natural science in the preschool context. Science in preschool also has developmental goals. It is widely recognised that science efforts for this age group have impact on numerous different developmental areas. Activities with science content do indeed help children to develop proficiencies in a diverse range of competencies, such as, enhancing *social development* (Hedegaard & Fleer, 2013), building *linguistic* and *conceptual foundations* (Akerblom et al., 2011; Clements & Sarama, 2016; Conezio & French, 2002; Guo et al., 2016; Henrichs & Leseman, 2014; Leung, 2008; Menninga et al., 2017; Parsons & Bryant, 2016; Seewald, 2007; Spycher, 2009), developing *motor skills* (Baruch et al., 2016; Hedegaard & Fleer, 2013) and practicing *problem-solving skills* (Conezio & French, 2002; Flannagan & Rockenbaugh, 2010). Other goals concern *equality*, namely, equipping children with enough information to make informed decisions for a sustainable society, as children are sometimes seen as agents for change (Caiman & Lundegård, 2014).

Aside from the above-mentioned reasons, early introduction to science is also seen as a way to connect positive emotions with science and a way for early years education to meet children's natural curiosity and to sustain and increase children's *motives* and *positive attitudes* for science (Eshach & Fried, 2005; Baruch et al., 2016; Ferreira et al., 2017; Mantzicopoulos et al., 2008; Pattison & Dierking, 2019; Ummanel, 2017). These positive associations with science are seen not only as an important part of future formal learning, but also as affecting later *informal science learning* (Alexander et al., 2012).

Previous research on natural science in the preschool

In order to conduct an inclusive literature review of the field, the Web of Science and Google Scholar databases were searched using a series of keywords and topics (Kindergarten OR preschool OR early childhood education). This wide search yielded 53,781 results, with the earliest paper published in 1901. Narrowing the search by selecting the specific document types of articles and reviews produced a total number of 46,739 papers. Of these, only a limited number, 1,409 papers, remained after the second refined search, which involved looking through the results for "science". Out of these, 263 articles contained natural science content and involved research concerning children aged 1-6 years old. This last selection was made manually.

Another search was then performed using the terms "kindergarten AND chemistry", "kindergarten AND biology" and "kindergarten AND physics". The search term "kindergarten" was then replaced by "preschool" and "early years", and additional searches were carried out. In the case of early publications, reference lists were further read in order to find additional studies. Papers not published in English were excluded, as were conference abstracts and other related documents with limited accessibility to the general scientific community.

Two of the first articles published with a natural science content date back to the 1970s and 1980s. These two studies focused on what today are referred to as "science skills" (Johnston, 2014), and they explored children's ways of sorting and making *classifications* (Olmsted et al., 1970) and their *problem-solving skills* (Pepler & Ross, 1981). Since these first published articles, the number of publications within this field has increased exponentially over the last decades, covering a wide range of topics.

The teacher's role

Today, the importance of the teacher's role in planning and helping children expand their everyday experience is widely recognised as a key feature for children's learning (Hadzigeorgiou, 2001; Segal and Crossgrove, 1993; Fleer, 1996). Therefore, some research efforts have been dedicated to exploring what role teachers have on the number and quality of learning opportunities provided to the children. Some findings suggest that the teacher's role is highly important for the quality of the activities and reveal a need for improving preschool teachers' *knowledge about the nature of science* (Edwards & Loveridge, 2011) and their *scientific conceptual understanding* (Timur, 2012; Saçkes & Trundle, 2014; Alisinanoglu et al., 2012; Trundle & Bell, 2010; Henrichs & Leseman, 2014; Piasta et al., 2015; Strbac, 2011). Other studies suggest that the issue is not so much the teacher's content knowledge; instead, the teacher's *enthusiasm* and *sciencing attitude* are more important for the outcome than his or her subject-specific knowledge (Fleer, 2015a).

Context of the child

Another important aspect of children's learning is the context, with some studies oriented towards children's science learning in situations outside the preschool environment, for example, exploring children's science learning in informal settings, such as the home environment as well as museums and libraries. Indeed, the factor common to all these studies points to the importance of extending science learning to everyday situations outside the preschool to increase science experiences in the daily life of the child. These research efforts include the toddler's everyday life at *home* (Sikder & Fleer, 2015), the use of *science activity packs for families* (Reinhart et al., 2016), and setting up science activities in *local libraries* (Hobbs, 2015) and at *museum exhibitions* (Bernarduzzi et al., 2014; Strang & Aberg-Bengtsson, 2009; Van Schijndel & Raijmakers, 2016). Results show different kinds of lessons in which adults and children work together to *expand the children's ideas about science* (Hall & Schaverien, 2001), as well as improving positive emotional factors, such as *self-competence* and *independence for learning science* (Mantzicopoulos et al., 2013).

Pedagogical tools

Working with young children involves a great deal of creativity in both the research design and the development of pedagogical tools. Today a multitude of technological approaches are available, and science has moved into games and apps as new software is being developed. Examples found in the literature are the *PICCO* software program concerning astronomy (van der Aalsvoort et al., 2008), *Hippo* app (van der Graaf et al., 2016), *computer game* (Hsu et al., 2011), *educational game* (Fernandez-Oliveras et al., 2016), *emaps* (evolutionary maps) (Navarro, 2014), *Scratch* (Ntalakoura & Ravanis, 2014), *Slowmation* (Fleer & Hoban, 2012; Fleer, 2013) and even *robotics* (Cejka et al., 2006) is being explored as a tool to further children's learning by providing new experiences.

Other approaches include *didactic objects*, such as with Poddiakov (2011) who aimed to develop children's experimental thinking. His results show that preschool children can combine activities, make systematic explorations and find hidden relationships. This finding supports the idea of the child as naturally curious. More traditional approaches/tools, of course, are also implemented today, such as using *play* (Wight et al., 2016) and *literature* as a basis for science (Fleer, 2013; Katz, 2011; Kilia et al., 2015; Leung, 2008; Mantzicopoulos & Patrick, 2010; McLean et al., 2015). The different pedagogical tools also bring about different types of learning, and in the environment of the preschool, gestures, bodily memories and body language become a natural link between *verbal communication* and the different contexts and activities (Henrichs & Leseman, 2014; Herakleioti & Pantidos, 2015; Hsu et al., 2011).

Children's subject-specific learning

The increasing number of studies and topics of science efforts in preschool also shows a wide variety of imaginative interventions and a focus of activity design on specific-subject knowledge, such as biology and physics. Some examples are *forensic science* (Howitt et al., 2011), the *nature of science* (Akerson et al., 2011), *light* (Henrichs & Leseman, 2014; Herakleioti & Pantidos, 2015; Hsu et al., 2011; Leung, 2008; Ravanis et al., 2013a; Segal & Cosgrove, 1993), *air pressure* (Henrichs & Leseman, 2014), *the balance beam* (Nayfeld et al., 2011; Zacharia et al., 2012), *mechanical stability* (Hadzigeorgiou, 2002), *thermal expansion* (Ravanis et al., 2013b), *friction* (Klaar & Ohman, 2012), *water flow* (Christidou & Hatzinikita, 2006; Fragkiadaki & Ravanis, 2015; Levy, 2013; Sackes et al., 2010; Siry & Max, 2013; Strang & Aberg-Bengtsson, 2009), *the rainbow* (Siry & Kremer, 2011), *floating and sinking* (Hong & Diamond, 2012), *snails* (Monteira & Pilar Jimenez-Aleixandre, 2016; Rybska et al., 2014), *earthworms* (Smith & Landry, 2013), *insects* (Danish, 2014; Samarapungavan et al., 2008; Shepardson, 2002), *growth* (Christidou & Hatzinikita, 2006; Witt & Kimple, 2008), *living beings* (Martínez-Losada et al., 2014), *animal species* (Allen, 2015), *genetics* (Elmesky, 2013), *planets* (Ampartzaki & Kalogiannakis, 2016; Best et al., 2006; Dogru & Seker, 2012; Kilia et al., 2015), *day and night* (Kallery, 2011; Sackes, 2015; van der Aalsvoort et al., 2008) and *sustainability* (Britsch, 2001; Caiman & Lundegård, 2014; Ertürk Kara et al., 2015; Ferreira et al., 2015; Weeks, 1984; Witt & Kimple, 2008). This initial literature review (performed in 2017) only yielded one publication with *chemical content* (Ferreira et al., 2017).

Learning science

Results from the research literature point to some important aspects of children's science learning. With respect to children's learning of biology, research shows that already at the age for preschool, children have what is sometimes referred to as "naïve" biology, that is, they have experience with and have already formed ideas about a number of aspects of biology. Studies reveal that preschool children have *core distinctions* and *reasoning devices* (Inagaki & Hatano, 2002) for distinguishing between living and non-living things. These distinctions are often derived from their everyday experiences of the human world. Living things are, for example, often seen as having the capability to move, grow and regrow if damaged. Indeed, children are also capable of predicting short and long-term effects of *human impact on the natural environment* (Ergazaki & Andriotou, 2010).

Other aspects of the natural world seem not only to go unnoticed, but can even sometimes be taken for granted. For example, different studies of *light* (color, shadows, rainbows) show that although children have experience of light, they do not perceive it as an independent entity (Guesne, 1985; Ravanis, 2013a). Another example is a study performed on the *decomposition of leaves* (Hellden, 2004) where children suggested that autumn leaves that have fallen on the ground just disappear, and this explanation the children did not see as requiring any further elaboration. This research result shows the importance of focusing on the non-living environment surrounding the child.

Researchers have also taken a more holistic approach by including other aspects of science learning into their studies, such as the child's motivation for science, scientific skills and the nature of science. Within all of the studies, teacher support is again emphasised, and when teacher interventions/activities are planned and evaluated, it has been shown that preschool children can successfully engage in and conduct *empirical explorations*, generate questions, make predictions, observe, record data and communicate their findings (Howitt et al., 2011; Samapungavan et al., 2008).

This literature review revealed a lack of research literature regarding preschool children's emergent chemistry, as only one research article with chemical content was found (Ferreira et al., 2017). No publications (to the best of our knowledge) concerning the process of the emergence of theoretically based chemistry for preschool were found. In addition, no publications that identified and assessed chemical content and methods suitable for this environment were obtained in this literature review.

Learning chemistry

In order to explore subject-specific aspects of what is included in learning chemistry, it was necessary to turn to literature comprising studies undertaken with older learners. Chemistry as a subject has its special challenges, as chemical phenomena can be experienced on the visual, macro-level, but chemical explanations are found on a theoretical, non-visual, sub-microscopic level. This is a level that is difficult to provide experience of and is quite different from the items and phenomena that can be experienced in everyday life. This fact lies at the heart of many of the problems that learners seem to have with chemistry.

Chemistry, thus, requires a great deal of imagination. Unfortunately, it seems like Vygotsky may have been correct when he suggested that imagination is based in experiences and that it is difficult to imagine something that you have not experienced (Vygotsky, 2016). Many of the difficulties learners have with chemistry seem to derive from applying macro-level experiences to the sub-microscopic level (Gabel, 1999), which can create alternative understandings, i.e. an understanding that is different from the scientific one. Some examples of alternative understandings taken from research regarding young learners are that matter is seen as continuous and static (Andersson, 1990; Novic and Nussbaum, 1981) and that soft substances are made of soft particles (Andersson, 1990). The experiences that are used for explanations and descriptions of events seem to be based mainly in visual experiences, since it is not uncommon to view particles as disappearing during phase transitions to the gaseous state (Andersson, 2010) or disappearing during dissolving. These aspects were included when planning the present project.

Theoretical background

The foundational texts of cultural-historical theory

This project is placed within cultural-historical theory (CHT). This theory is based on the work of Vygotsky, who explored the very process of human development. Vygotsky did not present a complete theory of development, and within CHT, his work has been elaborated and expanded on. Some of the fundamental concepts on which CHT is based are described below. These fundamental concepts (see Figure 1) are not easily separated from each other, as they are sometimes quite similar and entwined.

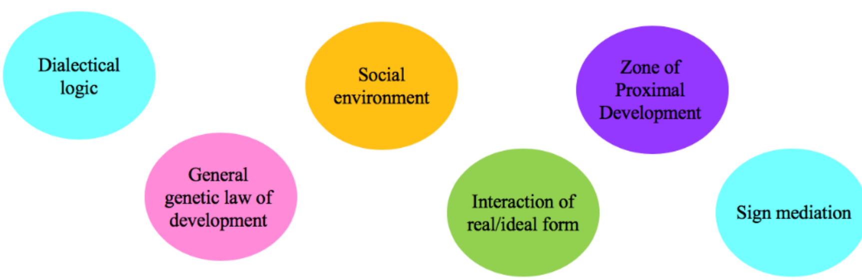


Figure 1. Fundamental concepts in cultural-historical theory.

CHT defines human development as "a complex *dialectical process* of sociocultural genesis of the human mind" (Fleer & Veresov, 2018, p. 49). Indeed, for CHT the concept of dialectics is general and fundamental. It is a complex concept, partly derived from *dialectical logic* where human development is emphasised as non-dualistic (Stetsenko & Arievitch, 2010). Traditional developmental psychology theories regarded either biological or social factors as the main aspects influencing development. Dialectic logic in connection to development is a perspective that instead includes all of the social world that is experienced by the child as the *source of development* (Fleer & Veresov, 2018). This view places all events and individuals in an inclusive context; "a thing itself stands in relation to other things and develops itself in such relations" (Dafermos, 2018, p. 78). In other words, the development of a child, from a dialectical logic, is regarded as being affected by all of the circumstances experienced by the child, while at the same time, the child is also affecting the circumstances surrounding herself/himself.

The social situation of development (SSD) is a concept that reflects the dialectic interaction between the social and the individual during the process of development (Veresov, 2017). SSD is described as the "unique relation specific to the given age, between the child and … the social reality" (Vygotsky, 1998, p. 198). A child will be affected in different ways when facing the same event depending on how he/she interprets the situation at the specific point in time. Vygotsky saw development as a dynamic and nonlinear process where different functions can be found in different developmental stages. The metaphors he used for these developing functions were buds, flowers and fruits, suggesting that some functions are just about to begin to develop, while others are currently developing, and the third kind is already developed.

The driving force of development can in fact be derived from the *general genetic law of cultural development*; the law connects development to the sociocultural genesis of the human mind and indicates the social environment as the source of development:

> *"...any function in the child's cultural development appears on stage twice, that is, on two planes. It firstly appears on the social plane and then on a psychological plane. Firstly, among people as an inter-psychological category and then within the child as an intra-psychological category." (Vygotsky,1983, p. 145)*

This translation by Veresov (2004) includes the word *category*, which in Russian means crisis or dramatic event (Rubtsova & Daniels, 2016). By adding this word, the law's formulation gains a new sense: placing drama or contradiction as the moving force of development (Veresov, 2016). However, not every drama or contradiction necessarily leads to development. In order to differentiate them, Vygotsky coined the concept of *perezhivanie*, which he defined as "how a child becomes aware of, interprets, and emotionally relates to a certain event" (1994, p. 340). For Vygotsky, those parts of the social environment that were refracted by the individuals were what were important for development (Vygotsky, 1998, p. 294).

How the social becomes the individual can be studied through the analysis of the interaction between ideal and real forms (Veresov, 2010). What the child can learn depends on the ideal forms. The ideal form is what can be found in the environment surrounding the child. One example of this interaction is the "pointing gesture". A baby stretches out an arm to reach an object (real form), and an adult interprets the gesture and gives the object to the baby. When the baby becomes aware that by extending his/her arm the adult will give him/her the object, the child can then start using his/her pointing gesture as a communicative function (ideal form).

Another important concept for this project and for CHT is the concept of *sign mediation* (Veresov, 2010), which provides the tools for cultural development. Signs allow for abstract theoretical thinking, viewed as "the transition from *direct,* innate, natural forms of behaviour to mediated, artificial mental functions that develop in the process of cultural development" (Vygotsky, 1998, p. 168). It is because of the use of cultural signs that we can move beyond the physical world towards theoretical learning.

In order to facilitate the child's development, it is necessary for the preschool teacher to work together with the child within the *zone of proximal development* (ZPD). Vygotsky defined ZPD as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (1978, p. 86) (see Figure 2).

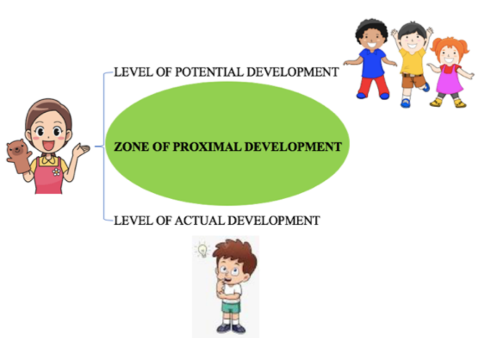


Figure 2. Illustration of the zone of proximal development (ZPD).

Although ZPD is one of Vygotsky's most well-known ideas, scholars today question some of the previous interpretations of Vygotsky's texts. At the heart of the discussion lies the argument that since there is a distance between the two levels of development, there is no *zone of actual development* or *zone of potential development* (Veresov, 2004). Today the concept of ZPD is being expanded on in conjunction with *play*, and some of these theoretical ideas take the perspective of the child. Veresov (2004) suggests one such expansion: *potential development* moves beyond proximal development as only being reduced to the interaction of the child, the adult and the task at hand, and it includes the child's "individual attitude" as one of the aspects that will affect development, and therefore the child's attitude should be included in the concept of ZPD. Other suggestions for elaborating the concept place focus on the adult and include the importance of the time given to the child/children for his / their own initiative and creativity (Bredikyte, 2011).

Learning and development in contemporary CHT

Today CHT has developed further, becoming a comprehensive theory of development that is inclusive, embracing both the personal and the social aspects of learning and development. Other advances derived from this theory are methodological developments. Those relevant to this project will be introduced below, namely, play-based learning which is a methodology for turning theory into practice within the preschool environment and the genetic research method which turns fundamental concepts into research design.

Contemporary CHT defines *learning* in a broad sense, as any change in a "person's relations" that "provides the person with possibilities for new activities" (Hedegaard & Fleer, 2013, p. 183). The learning process includes *internalisation* of social interactions, which does not occur in the same manner for all learners. Within CHT, learning is seen as an emotionally sensitive, dynamic and individual process, since it depends on our different ways of viewing and interpreting the world. This individual "prism" that affects what we pay attention to, and our interpretations of it, is referred to as *perezhivanie* (Veresov, 2016).

The social processes for the child can be described using the wholeness approach. Here the individual as well as the institutional and societal levels are included (Hedegaard, 2012). The societal level for this study is the cultural-historical backdrop of the Swedish society (see Figure 3). Within this societal level, several institutional levels/contexts can be derived, such as those of the school, home and leisure time. Each institutional level has different settings, such as the kitchen in the institutional level of the home or a biology class in the institutional level of a school. Also, one can have many activities in an activity setting. One example of an activity can be cooking in the activity setting of the kitchen. This study is placed within the institutional level of the preschool and science activities. The wholeness approach, however, does more than just place the learner in an inclusive perspective; it also provides means for specifying the concepts of motive and motivation as well as the concepts learning and development.

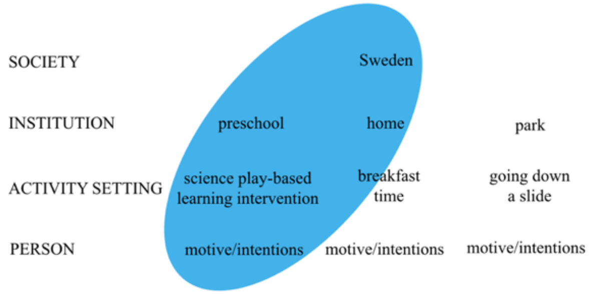


Figure 3. Wholeness approach scheme.

The differences between the concepts of motive and motivation are here seen as motivation explaining a person's actions in an activity setting, while motives can describe the relationship between the child and his/her surroundings over extended periods of time, because they are interconnected with children's *long-term development* (Hedegaard, 2002). In other words, whereas the motivation to play may vary from dinosaurs at one time, to princesses another time, what remains stable is the interest of the preschool child to take objects and play. There are different kinds of motives:

- *Meaningful motives* drive the child to explore his/her surroundings.
- *Dominating motives* are associated with the activities that are central for the person's life.
- *Leading motives* describe the qualitative relation that the child has with his/her environment (Elkonin, 1972).

Motivational conditions are seen as having shorter time spans and as existing within an activity, for example, the use of a mobile phone within an activity. *Development* can also be conceptualised as a process in which "children's motive orientation and engagement in different activity settings change qualitatively" and as a consequence, the leading motive changes (Hedegaard & Fleer, 2013, p. 183).

Sustained shared thinking

A teaching situation within this perspective would ideally include all aspects of the cultural-historical perspective, especially the ZPD. Sustained shared thinking is one approach that fulfills these requirements. The concept can be traced first to an educational effectiveness study (Sylva et al., 2004) designed to establish the level of children's development of pre-reading and early number concepts in 141 schools in England. The schools where the children showed the best results were then further analysed for pedagogical approaches. In the results, the pedagogical approach shown to be the most effective was named *sustained shared thinking,* and it was defined as "an interaction where two or more individuals 'work together' in an intellectual way to solve a problem, clarify a concept, evaluate activities, or extend a narrative" (Sylva et al., 2004, p. 718). The study pointed to several areas of importance for sustained shared thinking, which are the quality of the adult-child interaction as working together, all participants contributing to the discussion with thoughts and reflections, everyone engaging in open-ended questions, and the teacher providing the children with formative feedback as well as modelling the desired behaviour.

Here the term sustained shared thinking is used for the situations when the teacher and children work together expanding the child's everyday experiences. The teacher has a key role within this play pedagogy as actively participating in the children's discussions, while encouraging them to adopt an inquiring attitude towards the phenomena at hand. This, together with the use of scientific terms, constitutes the main difference in comparison with discovery learning (Fleer & Pramling, 2015).

Play-based learning

One way to turn all of the theoretical concepts and perspectives of CHT into practice is play-based learning, which together with the idea of *conceptual play* (Fleer, 2011) provides practical ways for introducing science into preschool settings. Play-based learning pedagogy is also currently being researched within the Swedish context by other scholars, who have coined the term *play-responsive teaching,* pointing to the importance of following the child's interests (Pramling et al., 2019).

When taking the ZPD into consideration, it becomes important for teachers to take children's everyday concepts as a starting point for all teaching efforts. Everyday concepts are here defined as all of the concepts and experiences that children bring with them into a planned learning situation. The teacher expands on these concepts and intentionally introduces other concepts. Those related to science are here defined as scientific concepts. Once the scientific concepts have become a natural part of the child's experiences, they can be viewed as both science and everyday concepts, depending on the unit of analysis.

Play-based learning is a general method that is suitable for all kinds of topics and content. The teacher is active and participates in the play, making space for sustained shared thinking. Play-based learning takes both emotions and conceptual content into consideration by placing emphasis on the narrative, connecting activities to positive emotions and interests. It also takes content into consideration by moving in and out of play, providing opportunities for children to bring their experiences into the imaginary situation. Conceptual play is a term used for play-based learning that places focus on concepts.

Emergent science in the preschool

The concept of emergence initially stems from research on *emergent literacy*, where the process of progression of language skills was emphasised (Hall, 1987). The idea of sustaining and supporting the process of individual development was then elaborated on and transferred to curricula and formulated in terms of an *emergent curricula* (Edwards et al., 1993). Such a formulation in the curriculum provides autonomy for the teachers to plan activities to meet children's individual needs.

Based on these concepts, Siraj-Blatchford (2001) introduced the term *emergent science*. In doing so, he maintained the focus on the process of progression and added the thought of *enculturation* to science with the goal of creating "emergent awareness" (Siraj-Blatchford, 2001, p. 3). This can be achieved through play by combining *conceptual* and *contextual intersubjectivity* (Larsson, 2013).

Today, the term *emergent science* has been used in different ways, sometimes with focus on the science content itself, with one example being *emergent science skills* as suggested by Johnston (2014). Others use the term when describing the process of learning science content (Larsson, 2016). Additional variations with more specific meanings can also be found, such as "emergent science competencies" (Andrews & Wang, 2019), which was used for describing children's developing ideas concerning the *nature of science*. In the present work, the term emergent science is used in the same manner as Larsson (2013; 2016) as a way to describe the actual process of children's science learning as well as children's use of *science content*.

The genetic research method

Just as for play-based learning, CHT can be turned into practice with the research design by applying the genetic research method. This method is developed from CHT, and it has guided the design of this research project using these five principles as the basis. The first principle incorporates Vygotsky's concept of *buds of development.* Researching something that is not yet known by the child is a requirement for exploring emergence. The second principle is the interaction between *the real and the ideal form*, where the activity design is meant to provide the ideal form and instigate these interactions. The third principle is *drama*. Drama is a concept applied for describing a crisis or, for the child, an important event. This principle guides analysis of data by aiding the selection of significant moments. The fourth principle concerns *developmental tools*, here connected to signs and symbols used in the activities. The fifth principle involves the sustainability of changes (Veresov, 2014).

Methodology

The design of the project

This project was planned with three different general objectives. The first and most wide-ranging objective was to identify chemical content suitable for the preschool environment, i.e. what can be included in chemistry content? To establish the appropriate subject matter for the preschool setting, three different aspects of the culture of chemistry were addressed in the study: chemical content, chemical methods as well as science skills. The second general objective was to explore children's emergent chemistry, and to be able to do so, the third general objective was to identify what methods can be used to implement chemical content in the preschool.

Chemical content

The core concepts for chemistry were drawn from what was perceived as a chemist's general view of the surrounding world, which is a world composed of particles of various sizes in perpetual motion that take part in processes of arrangement and rearrangement (assembly and disassembly). The core concepts suggested are the following:

I) *Matter is composed of tiny, invisible particles.*
II) *Particles are of different size and composition.*
III) *All particles have movement.*

Through a discussion of the core concepts, the first one was turned into theoretical content deemed suitable for children aged 3-5 years old; namely, how does the concept of *small* emerge?

Chemical methods

In regards to the methods used in chemistry, those that are simpler and more common were considered to be the most accessible to children. Chemists have many physical procedures for manipulating matter, such as grinding and stirring as well as different types of separation methods, such as filtering, evaporation, sedimentation and solubility. In addition to these, phenomena such as dissolving, freezing, melting, and boiling are not only central for the culture of chemistry, but also are easy to implement in this specific environment, because they are commonly found on the outdoor playground and they are extensively used indoors, mainly in the kitchen.

Another source that served as an inspiration was the work from Areljung (2020), which focused on the use of verbs when working with science in the preschool. Collectively, these provided a variety of methods to choose from in the activity design.

Science skills

The skills of importance for any natural scientist, and not only chemists, were also included as essential for this environment (Johnston, 2014). These skills were named "emergent science skills", and they include observation skills, classifying skills, raising questions, planning skills, predicting, handling variables, hypothesising, recording skills, writing reports, drawing pictures and diagrams, analysing, concluding, and communication. Some of the emergent science skills relevant to preschool science are presented in Table 1.

Table 1. Some examples of emergent science skills, adapted from Johnston (2014).

Observing	*Using all senses* *Identifying similarities and differences* *Identifying patterns between objects and scientific phenomena*
Classifying	*Sorting objects according to a single category* *Re-sorting objects according to a number of criteria* *Classifying an object according to more than one criterion at the same time*
Analysing	*Describing what has happened in an exploration or investigation* *Using a more scientific language in descriptions and analysis* *Providing own ideas for why something has/may have occurred*

The activity design drew upon these skills listed above. At the outset, chemistry skills also appeared to function as tools for our analysis of outcomes in order to separate words and concepts, i.e. distinguish between what is a concept and what is a word. These had served their purpose after the initial analysis in paper I.

We turn to the second general objective: what methods do we use? There were two different levels of method design: the first level regarded the general activity; how do we create a play-based learning situation? The second aspect considered the implementation; what educational tools/methods can we use in preschool? For these purposes, we planned another palette of methods and tools to choose from, such as drama, film, experiments and deconstructions (see Figure 4).

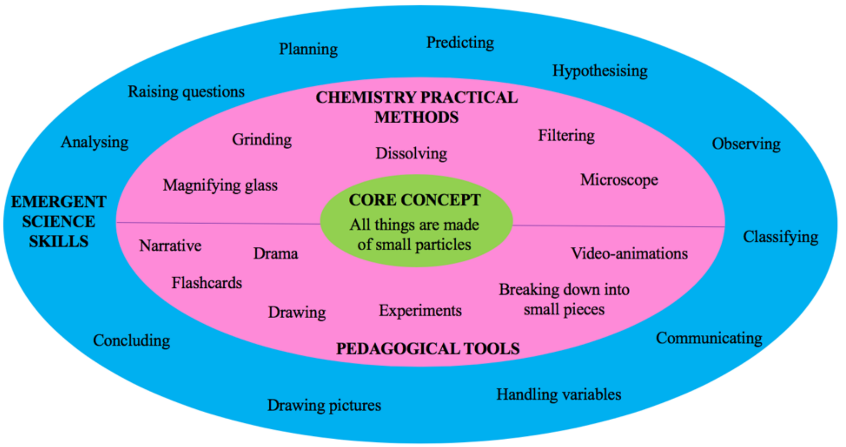


Figure 4. General activity design.

Since the focus of the project was on children's emergence of science as well as the processes that bring about this emergence, a *longitudinal study* (Cohen et al., 2007) was adopted, and the length of the research extended over a two-year period.

The overall project was planned as an educational experiment as defined by Hedegaard (2008), which is an approach that includes a continuous assessment and readjustment of the activities in an iterative manner. The implementation of the activities was viewed and discussed on a daily basis by the researchers. As a result, the planned activity could be modified and adjusted to the children's needs and interests (see Figure 5).

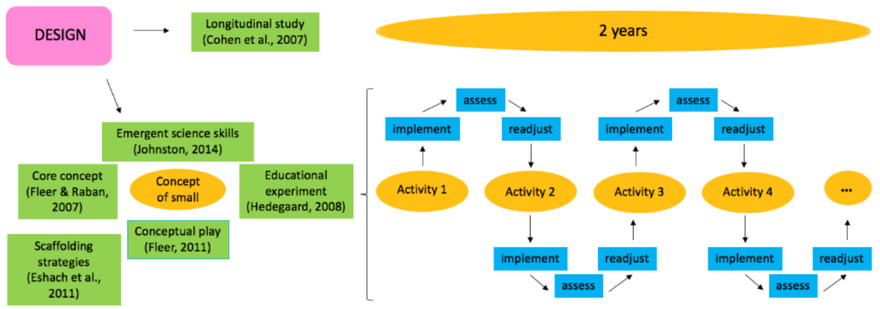


Figure 5. Project design scheme.

Creating a narrative

The researcher collecting data participated in the preschools prior to data collection in order to get to know the children and to observe their play to find a common theme. These observations led to developing a narrative of the king and his family as the children often used royal characters in their play.

The story of the king's birthday was composed, where the king had received some gifts, one of the gifts being a magnifying glass, and so began his and his family's quest to look at small things. Several other scenarios were developed as the narrative expanded over several activities; an example was preparing lemonade for the king's birthday party and accidentally having things fall into the lemonade. All of the activities had one thing in common, which was the emergence of the concept of small. Accordingly, modifications were chosen and implemented after analysis of the previous activity.

Each of the activities was designed while taking into consideration all the elements stated above, together with *scaffolding strategies* as described by (Eshach et al., 2011). An example of a concrete activity can be seen in Figure 6.

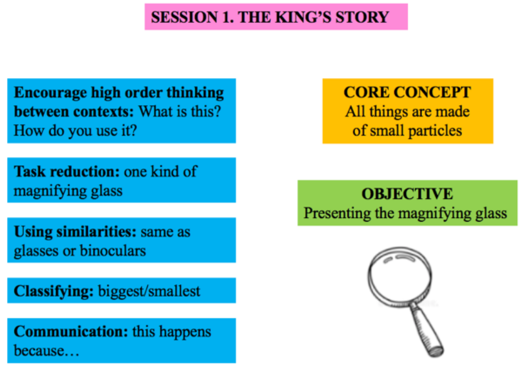


Figure 6. Activity design example.

Collecting data through visual ethnography

Visual ethnography was chosen as the method for data collection as it provides means for "being a part of an environment rather than from that of asking someone to tell you about it in spoken words" (Pink, 2013, p. 106). Here the researcher takes an active role in the everyday lives of the participants so that everyone becomes accustomed to each other's presence (Corsaro, 2016). Indeed, participatory data collection allows for exploring the process of learning as a collective effort (Pink, 2013).

There is a risk, however, that this method could contribute to possible bias in the analysis as the researcher is personally immersed in the studied environment. As a way to avoid such a threat to the validity, *inter-rater validity* has been used (Robson, C. & McCartan, K., 2016). This way, all the collected data was first analysed individually by two researchers independently. Then upon a joint discussion of their results, they had to reach 80% agreement in their judgements.

The method also involves working with video-recordings and video analysis which are of great importance when working with children as young as 3-5 years old, as their body language is an important part of their interaction and communication. Also, the dynamics and swiftness of events occurring in a group of young children requires video-recordings for a detailed analysis. The choice was made to use small action cameras, since they were assumed to be less intrusive due to their small size. These cameras also produce videos with a wide-angle perspective.

In order to capture the facial expressions of all the children, a strategic set up of the cameras was made to cover all angles (see Figures 7 and 8).

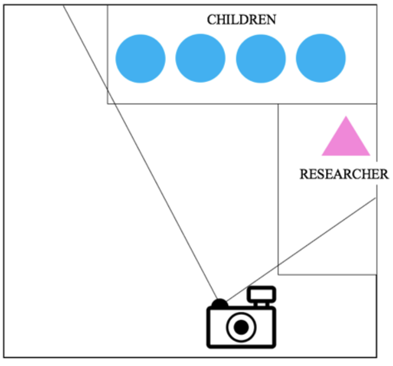


Figure 7. Camera setting on the sofa corner.

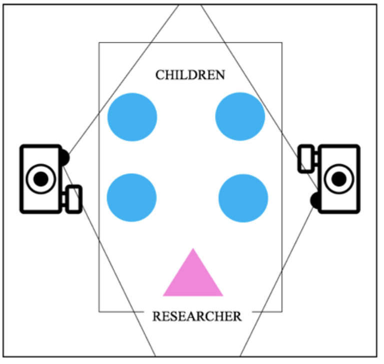


Figure 8. Camera setting on the work table.

Analysing data through conversation analysis

In qualitative studies, the unit of analysis is the essential concept for data processing as it defines on what level of detail the analysis is made. In very much the same way, the analysis of the properties of water yields different results from the analysis of the properties of the components of water, namely, hydrogen and oxygen (Veresov, 2016). As the project included different units of analysis, the data was analysed using mixed methods.

For the first part of the project, duration times and events made up the unit of analysis. For this purpose, ELAN (a software developed by the Max Planck Institute of Psycholinguistics) was used. The software provides means for working with video-recordings through categorisations of duration times for specific previously determined events. The software made it possible to add several layers of analysis to the video-recording within the same time interval (see Figure 9), which was necessary in order to analyse the quality indicators for play-based learning in such a dynamic situation.

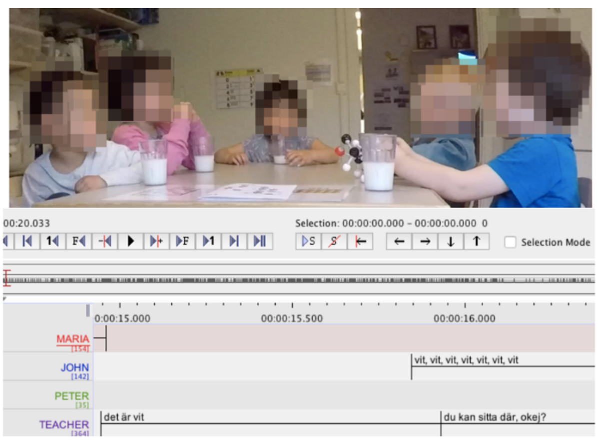


Figure 9. ELAN display screen capture.

For example, when using *focus* as the unit of analysis, three categories were established: focus, no focus, and creating common ground. When designing the project, the importance of the children's focus was discussed in terms of what would be done if the children lost focus on the task at hand. The decision was made that if focus was lost and the child did not himself return to the activity, within a reasonable time, the researcher would ask no more than one question per child in order to attempt to regain the child's focus towards the activity. *Creating common ground* is the category for the question asked to regain attention. The duration times for the three events were marked and exported to Excel, where the percentage of the time of the event was calculated in relation to the time of the whole activity. The percentage derived from Excel was then imported into Python, a program for making graphs. An example of the resulting graph for the first and shortest activity, where the story of the king and his birthday was introduced, can be found in Table 2. The activity was in total 9 minutes long and demonstrates the required flexibility of teachers and researchers working in this environment.

Table 2. Children's focus time in percentages per session.

Session	**Focus**	**Focus** **Interruption** **Creating common ground**
1	82	

The second method used for analysis was ethnomethodology/ conversation analysis (EM/CA) which is a method initially derived from sociology and used for observing people's interactions in everyday situations (Garfinkel, 1967). With this approach, all kinds of data were included for analysis. EM/CA conversation analysis is a development of ethnomethodology that includes conversation analysis. Conversation analysis provides the tools required for detailed analysis of transcribed data, enabling the individual's aspects to be taken into consideration by analysing transcribed observations. Important concepts for this method are multimodality, sequentiality and emotions (Goodwin et al., 2012). All different kinds of communication, including gestures, body language and positions towards others, are taken into account during the analysis (Mondada, 2018) so that as much detail as possible is obtained. Data is organised in a sequential manner (Heritage, 1984) to explore the order in which events take place; then the data is systematised (Melander Bowden, 2019) by the use of transcription conventions as outlined below (See Table 3).

Table 3. Transcription conventions, adapted from Melander Bowden (2019).

,	Comma indicates rising or continuing intonation.
?	Question mark indicates rising intonation.
::	Colons indicate prolongation or stretching of the immediately prior sound.
££	Pound signs indicate that the speech is produced with a happy, playful voice.
_____	Underlining indicates some form of stress or emphasis.
BLEH	Very loud speech is indicated by upper case.
* *	Descriptions of gestures and actions are delimited between two identical symbols.
T	Initial letter in upper-case indicates person is using verbal language.
t	Initial letter in lower-case indicates person is using non-verbal language.
…	Dot, dot, dot indicates breaks in the transcription.

Results are then presented in the form of vignettes, i.e. parts of transcriptions that include significant moments in which a crisis is illustrated. This method aligns with cultural-historical theory and the use of signs and symbols, since "human action is built through simultaneous deployment of a range of quite different kinds of semiotic resources" (Goodwin, 2000, p. 1489).

One example of how the units of analysis were studied in a qualitative manner can be found below. In paper II, the focus was on the concept of "small", and here all the sequences in which the children used this concept were selected. The concept of "small" was defined as the smallest thing children could describe. Through the comparison of the development of these statements, four stages emerged. In the first stage, the children mixed the concept of size with age ("I am this big"; "I am three" showing with their fingers). After that, they focused on the size of objects they looked at, the smallest they knew being "baby insects". During the deconstruction experiments, the children used the "powder level" to refer to size in their discussions and descriptions. It was only after providing visual experience using video-animations that included the transition to the sub-microscopic level that the submicroscopic level of size began to emerge, and the children began discussing atoms as "something that looks like meatballs, but are not", since they are inside everything.

Context, participants and ethical considerations

The research proposal was approved by the regional ethical board (Appendix 1), and informed consent was granted from the principal, staff, parents and children involved in the project (Appendix xxx). The children had the right to leave the activity at any time. In compliance with the GDPR regulation (European Union, 2018), all video-recordings were saved on external hard disks, stored in a safe box, and only viewed by the members of the research group. In order to ensure confidentiality of the participants, pictures of the children were substituted by illustrations and their names were changed to alias.

The children included in the study come from two different preschools from two different contexts. One of the preschools is located in a large city, while the other preschool is located in a small rural town. Four groups for a total number of 19 children were included in the study. Both of the preschools had a similar daily routine, beginning with circle-time where the teachers presented the plan for the day. After circle-time, a theme-activity or outdoor excursion took place, followed by lunch and some time for resting. The afternoons were spent with free-play and doing as many outdoor activities as possible. When the schools were approached for participation in the project, two of the regular staff (one preschool teacher and one childcare-worker) volunteered to be part of the data collection (see Table 4).

Table 4. Participants in the study.

Preschool A	4 children
Preschool B	15 children

The first group of children, group A, was composed of 4 children (two boys and two girls) and ranged in age between three years and three months to three years and 11 months when the intervention started in January 2018. The second group of children, group B, was composed of 15 children (ten boys and five girls) from a big city. Their ages ranged between three years and three years and 11 months. This second stage was launched in November 2018.

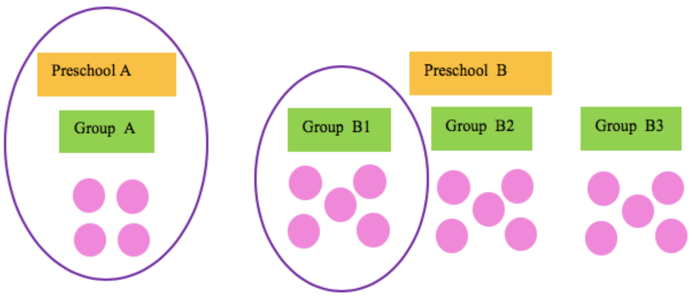


Figure 10. Children's group distribution.

The intervention in the groups A and B_1 was led by the researcher herself, group B_2 was led by a preschool teacher, and B_3 was led by a childcare-worker (circled in Figure 10). Discussions about content and outcomes were held before and after each activity to assess the development of the project, and the data was further analysed by two researchers. The sessions lasted between 15 to 30 minutes, and they took place during the morning for group A (9:30-10) and in the afternoons for group B (14-14:30). All activities were video-recorded and analysed, and field notes were added.

Results

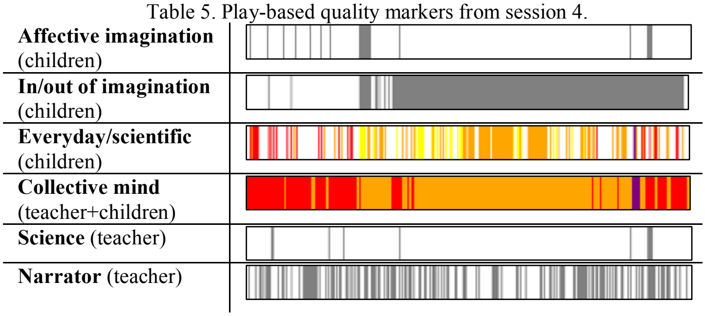
Paper I

The aims of this study were

- to design play-based learning activities with theoretical chemistry content and chemistry skills for the preschool environment.
- to evaluate the activities using the quality markers for play-based learning.

Results from the first analysis show the swiftness and dynamics in an activity including children as young as three years of age. The different layers of analysis were the quality markers of play-based learning. The flow of everyday and scientific words was continuous, and the children were engaged; they participated actively, with the focus time ranging from 70 to 97% of the activities analysed. Regaining focus or creating common ground was required in some of the activities and in some of the activities with more than one child. The teacher did use one question per child as was previously decided. No children left any of the activities completely. An example of a question for regaining focus was, what do you think the king would have done?

Table 5. Play-based quality markers from session 4.



Although the play-based learning activities were drawn from the children's own interests of princesses and princes, the actual items, such as the magnifying glass, took precedence over the part of the play that included the royal family. Nonetheless, all of the quality indicators for play-based learning were indeed found in the activities, which supports the general activity design. Although the initial plan for the context of the activities was difficult to maintain, the results show that affective action was achieved.

Paper II

The research questions for this study were:

- What features characterise children's emergent scientific understanding of the concept of "small"?
- What methods and activities assist and provide experiences to support children's emergent understandings of concepts in chemistry?

Initially, the children's concept of small included insect babies and baby geese, suggesting that for them the concept of small included both age and size. The efforts of the first set of activities, in which magnifying glasses and microscopes were introduced together with experiments where different things were dissolved, did not lead to developing the concept of small. A series of deconstructions were initiated in which different everyday items were broken into smaller parts and then looked at through small portable microscopes. These activities did not enable the children to use their imagination to extend beyond the visual level of everyday experiences. Examples of the descriptions of the small things they saw in the magnifying glass were that granulated sugar became *ice blocks* and parts of leaves were called *black spots*. After a series of activities, the smallest things the children could describe were the contents of peas, described as *pea flour*.

Insect babies ⟶ Pea flour

The decision was then made to provide computer-generated visual experiences of the non-visual level. Zooming-in videos that moved from the macroscopic to the sub-microscopic level of several everyday items were shown to the children on several occasions. When the children saw the actual transition from the macroscopic to the sub-microscopic level, a new concept of small began to emerge. Initially, atoms were described as tiny meatballs, thus indicating a three-dimensional view. As the meatballs were found in all of the movies and in all of the everyday items, the children soon realised that they were not meatballs, but that they just looked like meatballs. The teacher then provided the label "atom" to the concept.

Visual experience of the transition between the two levels was indeed the key to unlocking the children's imagination of a world smaller than that which they could possibly imagine at first. This is a conclusion that supports Vygotsky's (2016) claim that imagination needs to be enabled with *relevant experiences*. The activities managed to create the experience of a concept that was then labeled with a name.

Concept ⟶ Label

All of the practical chemical methods were easily adopted by the children; filtering, for example, was something that the children had previous experiences of as they immediately connected it to catching butterflies. At the end of the first year, the children handled microscopes and magnifying glasses in a natural manner.

Paper III

The research questions for this study were:

- How do motivating conditions and science content develop over a year of implementing designed science activities?
- How do motivating conditions affect the science content over a year of implementing designed science activities?

The unit of analysis for the results presented in paper III was motivating conditions. This analysis was performed for two reasons: to explore development and to evaluate the activities. The first year of data collection was analysed, and five vignettes evenly spread out over the year (see Table 6) were chosen so that the development could be traced.

Table 6. Selection of vignettes and their dates.

	Date of data collection
Vignette 1	30th of January 2018
Vignette 2	13th of February 2018
Vignette 3	15th of May 2018
Vignette 4	23rd of October 2018
Vignette 5	10th of January 2019

When the data collection began, the social interaction between the children mainly displayed the leading motive of the self. The children's dominant motive in verbal communication was the competition among one another regarding things, size, age, or even what flavor of birthday cakes was the best. Regardless of verbal interactions among the children, they were very focused on the activities at hand and were eager to participate. The development that occurred over the year shows a change from the self to the leading motive play and from competition to collaboration and play; these are outcomes that coincide with (Siraj-Blatchford, 2009) conceptualisation of the progression in the pedagogy of play.

The children's communication included often positive emotions and positive expectations towards the science activities, which enriched the discussions of the science content. These findings support Hedegaard's (2016) argument about the importance of considering emotional as well as cognitive aspects of the child's development and show that the activities did indeed create a positive motive for science. The increase in communication and emotional alignment among the children, however, also unfortunately made sustained shared thinking more difficult to achieve, since the teacher had to integrate more topics of discussion related to the science content.

Paper IV

The research question for this study was:

- How can abstract concepts like "atoms" and "molecules" be introduced to preschool children?

The unit of analysis for this paper were three of the principles from the genetic research method; *buds of development, drama* and *developmental tools*.

Results show that with the movement from simple observations, where the children's direct sensory experiences were challenged, the children's use of imagination allowed them to think about things they do not see; for example, even though the sugar had dissolved, the presence of the sweet sugar flavor still remains because of the water's remaining sweet taste. However, it is important to note that in coming to this realisation, the imagination included the word they used as a general expression. The teaching aids, such as the picture of the ice, water and gas forms, as well as the 3D water and lactose molecule model, acted as mediating tools that helped the children visualise abstract concepts, like the states of matter and molecular structures. No conclusion as to the children's actual understanding of the concepts can be drawn.

Overarching results

There are general conclusions that can be drawn from this research project, such as that chemistry indeed has a place in preschool. Many of the chemical methods used are easily accessible to the children, and even young children can develop abstract concepts when provided with visual experiences.

Chemistry has been only recently included as a goal in the Swedish curriculum for preschool in 2011, and thus far the experience of what chemical content is suitable for this educational level is only beginning to be explored. The introduction of subject-specific knowledge into any educational level is always a balance between content and practice, which becomes especially important when working with children in their preschool years. Finding a level where the child's own experiences make up the starting point is one of the key aspects of learning within this level of education.

Discussion

This thesis has attempted to contribute to the development of knowledge of how abstract chemical concepts emerge in a preschool setting. Many different aspects of the project explored here need to be further studied for many reasons, one being of course for further validation. The project also raised a series of related questions that can be the basis for further research regarding abstract concepts and the emergence of children's theoretical knowledge.

Visual experience of the transition between the macro and the sub-macroscopic level seems to be one of the keys to unlocking the sub-microscopic level even for young learners. This result may in fact be of importance for chemistry learners of all ages. The zooming-in experience of a variety of different everyday items could indeed be the way to make the sub-microscopic worldview accessible to all learners, and zooming-in could also be a way to minimise compartmentalisation of this sub-microscopic perspective, so that it is moved outside of the chemistry classroom.

In addition, chemistry places focus on the non-living world surrounding the child, which is also important as previous research shows that children sometimes take the non-living aspects of the environment as self-evident and as not requiring an explanation (Guesne, 1985). This suggests that the material world is not something that is addressed in children's everyday life, and therefore something that may need special attention.

Methodology

The intervention was planned as a play-based learning experience, but results show that although the story of the king and his family was used as a backdrop, the activities and the educational tools used soon became unnecessary as the activities themselves took precedence over the story. Was this then always a play-based learning experience? As the activities fulfilled all of the quality indicators for play-based learning, the question becomes one of whether or not the children considered themselves as playing during the activities. There is no data to support or oppose this claim, so the activities may or may not have been experienced as play by the children. The data does instead support what is here referred to as affective action. It was apparent that the children were actively engaged at all times, and they expressed positive emotions and positive expectations towards the activities.

Many of the chemical methods used are easily accessible to the children, and the results show that even young children can develop abstract concepts when provided with experiences (Vygotsky, 2016).

Implications for teaching

The results in *paper II* showed that children could begin to imagine the submicroscopic level only when they were provided with direct **visual experiences** of the transition between the macroscopic and the submicroscopic level. This finding may be of consequence for learners of all ages as it may be one part of the answer to how we best can support learners to include the submicroscopic level in their thinking. Solving this issue has puzzled educational researchers for decades. The results also confirm that preschool children indeed can use their imagination to start thinking about the material world, a feature that is essential for learning chemistry.

The **small size** of the group of children, no more than five children in each activity together with one teacher, proved to be manageable for these activities in *paper I*. The small size allowed the teacher to keep the children's focus on the task at hand and made it possible for her to follow the swiftness of the changes in the discussion. This aspect is crucial for teachers working with science activities.

Another important aspect of this intervention was the type of **communication** that took place between the teacher and the children and amongst the children themselves. How this particular kind of communication enabled the children to develop their understanding of the chemistry content was explored in *paper III*. Sustained shared thinking is the pedagogy that has facilitated these activities, in which the preschool teacher took an active role in extending the children's inquiries (Sylva et al., 2004).

The specific **role of the preschool teacher** has been detailed in *paper IV*. In order to support the children in their discovery, the teacher has had to work within the children's zone of proximal development and use adequate mediating tools that aid extending the children's knowledge. Too difficult tasks could have caused frustration and too simplistic tasks could have caused the children to direct their attention towards something other than the activity. Entwining everyday and scientific concepts allowed the children to enjoy the task at hand and enabled the teacher to create **positive cultural motives** for science (Fleer, 2015).

Having a preschool teacher working together with a chemist for the design and assessment of the activities shows the importance for preschool teachers themselves to learn about natural science in order to prepare them for working with this topic. This entails incorporating natural science didactics **training** within preschool teacher training programmes and offering professional development modules for those already in the workforce.

The continuous assessment and adjustment of the activities has been another practical issue characteristic of this intervention. Working in such a manner requires **planning** and **reflection** time on the teacher's part, as the original design needs to be adapted to the children's specific interests throughout the project. Adapting this practice into a preschool teacher's daily work translates into planning time allotted within their schedule, in which they can prepare the material needed for the activities and can make the adjustments according to the needs detected along the process.

Contributions of this work

There is no end to a research project, as most research projects raise more questions than they answer. The intention is that the results presented here will contribute to inform practice:

- by providing preschool teachers with ideas and suggestions for what chemical content can be composed of and how to use chemical methods and science skills to expand children's experiences of chemical content,

- by contributing to the research community in general and especially to those who focus on early years education, and

- by making chemistry more accessible for learners of all ages.

The findings highlight the value of including early years education in exploring the emergence of abstract chemical concepts, as interpretations of children's learning processes can provide new perspectives of the content.

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Attachments

Ethical approval

Regionala etikprövningsnämnden i Linköping
Avdelningen för prövning av övrig Forskning

PROTOKOLLsutdrag 1(1)
Sammanträdesdatum
2018-12-11 kl. 13:15 – 16:30
Plats: Konferensrummet, Medfaks kansli

Ledamöter:: Rolf Holmgren, f.d. lagman, ordförande
Åsa Nilsson Dahlström, universitetslektor, *(socialantropologi, kulturarv)* vetenskaplig sekreterare
Lars Björklund, universitetslektor *(utbildningsvetenskap)*, deltog inte vid p 12
Roger Carlsson, (*psykologi, neuropsykologi, psykossjukdomar),* deltog inte vid p 20
Motzi Eklöf, docent *(hälsa-samhälle/vård- medicinhistoria)*
Kristina Gustafsson, docent *(socialt arbete, etnologi)*, deltog inte vid p 18, 21, 26, 27
Maria Gustavsson, professor *(pedagogik i arbetslivet)*
Ulf Melin, professor, *(informatik)*
Elin Palm, universitetslektor *(tillämpad etik)*
Lars Witell, professor *(företagsekonomi)*

Ledamöter som företräder allmänna intressen:
Örjan Albihn, studievägledare
Madeleine Johansson, företagare
Inga Jonasson, arbetsterapeut

PUNKT	ÄRENDE	BESLUT

5. Komplettering av ansökan om etikprövning
Forskningshuvudman: Linnéuniversitetet
Forskare: Karina Adbo
Projekt: Barns emergenta naturvetenskap – en studie av fantasi och kemi.
Dnr **2018/451-31**
Föredragande: Elin Palm

Guardian authorisation in Swedish

Forskningsprojekt

Till vårdnadshavare,

Vi är intresserade av att starta ett forskningsprojekt på er förskola. Fokus för projektet är kemi och kemiska arbetsmetoder. Syftet med projektet är att lära oss mer om barns begynnande naturvetenskap och att hitta olika metoder att arbeta med kemi i förskolan. Vi tänker oss att arbeta så kreativt som möjligt, med hjälp av skapande, sagor, film, teater och experiment.

Studien är longitudinell och kommer att sträcka sig över ett par år. Clara Vidal Carulla, som har en magisterexamen i utvecklingspsykologi och är utbildad lärare för barn i förskoleåldern kommer att vara mest aktiv i projektet. Hon kommer initialt att finnas på förskolan för att lära känna barnen. Ordinarie personal kommer dessutom alltid att finnas med under alla aktiviteter, för er och era barns trygghet.

Vi ber här om ert medgivande för att ditt barn ska få delta i studien. Medgivandet innebär att du som vårdnadshavare tillåter oss att filma ditt barns deltagande i aktiviteterna. Vi kommer alltid, att eftersträva, att barnens ansikten inte ska synas på filmerna och alla deltagande barn kommer vid analys att avidentifieras för att säkerställa deras anonymitet. Deltagandet är alltid frivilligt och era barn kan välja att avbryta aktiviteterna när de själva vill. Resultaten av studien kommer att publiceras i internationella vetenskapliga tidskrifter.

Vi hoppas att ni tillåter oss att arbeta med era barn. Har ni frågor så tveka inte att ta kontakt via mail: karina.adbo@lnu.se eller telefon: 0480446298.

Mvh
Dr. Karina Adbo
Linneuniversitetet

Jag tillåter att barn får delta i forskningsstudien angående barns begynnande naturvetenskap.
Barnets namn: ....
Ort och datum: ....
Målsmans underskrift: ....
Namnförtydligande: …..

Guardian authorisation in English

Research project

To the guardians,

We would like to start a research project in your preschool. The focus of the research is chemistry and its methodology. The purpose of the project is to learn about children's emergent science and check different methods to work with chemistry within the preschool. We are planning to work creatively, by using art, stories, theatre and experiments.

The study is longitudinal and will take around 2 years. Clara Vidal Carulla, who has a master in developmental psychology and is a trained teacher for early childhood, is going to be involved more actively in the project. She will spend some initial time in the preschool getting to know the children. Regular staff will be present with her, for your children's safety.

We want to ask for your permission for your children to participate in the project. Your authorisation will allow us to film the children's participation in the activities. We will always try that the children's faces are not seen in the films and all the children participating will be unidentified during the analysis to ensure their anonymity. Participation is always voluntary and your children can decide by themselves when to stop the activity. The results of the study will be published at international scientific journals.

We hope that you allow us to work with your children. If you have any questions do no doubt to contact us at the following email: karina.adbo@lnu.se or phone: 0480446298.

Regards,
Dr. Karina Adbo
Linnaeus University

I allow my child to participate in the research study about children's emerging science.

Child's name: ....
Place and date: ....
Guardian's signature: ....
Printed name: …………..

Activity log preschool A

STAGE 1. OBSERVING SKILLS (USING ALL SENSES)
25/01/18 - Session 1. The king's story
30/01/18 - Session 2. The magnifying glass
1/02/18 - Session 3. Zooming-in videos
6/02/18 - Session 4. Finding sugar among the powders
8/02/18 - Session 5. Dissolving sugar into water
13/02/18 - Session 6. Filtering play-dough tiny balls
15/02/18 - Session 7. Making a chocolate ball
8/05/18 - Session 8. Using the touch sense
15/05/18 - Session 9. Using the smell sense
22/05/18 - Session 10. Using the hearing sense
30/05/18 - Session 11. Concentrations experiment
31/05/18 - Session 12. Decomposing a chocolate ball
7/06/18 - Session 13. Summary of stage 1
STAGE 2. DECONSTRUCTING (SUB-MACROSCOPIC LEVEL)
15/10/18 - Session 14. Lego name initial and leave
18/10/18 – Session 15. Salt and sugar decomposing
23/10/18 – Session 16. Bath bomb decomposing
25/10/18 – Session 17. Atomic microscope video of a leaf and a butterfly
8/01/19 – Session 18. Atomic microscope video and building 3D atomic models
10/01/19 – Session 19. Digestion video
15/01/19 – Session 20. Decomposing sugar and building 3D atomic models
17/10/19 – Session 21. Changes of state ice-water-gas
19/03/19 – Session 22. Revisiting atoms, molecules and the states of matter
20/03/19 Session 23. Butterfly, leaf and food digestion videos
9/04/19 Session 24. Mixing water with sugar, pepper and cinnamon

Activity log preschool B

STAGE 1. OBSERVING SKILLS (USING ALL SENSES)
12/11/18 - Session 1. The king's story
13/11/18 - Session 2. The magnifying glass
15/11/18 - Session 3. Using the touch sense
15/11/18 - Session 4. Using the hearing sense
16/11/18 - Session 5. Using the smell sense
19/11/18 - Session 6. Identifying sugar
20/11/18 - Session 7. Filtering experiment
20/11/18 - Session 8. Concentrations experiment
STAGE 2. DECONSTRUCTING (SUB-MACROSCOPIC LEVEL)
4/02/19 - Session 9. Lego name initial
5/02/19 – Session 10. Decomposing a leaf
6/02/19 – Session 11. Decomposing a sugar cube
11/02/19 – Session 12. Atomic microscope video of a leaf and a butterfly
12/02/19 – Session 13. Building 3D water molecule
13/02/19 – Session 14. Water molecule game
18/02/19 – Session 15. Changes of state ice-water-gas
19/02/19 – Session 16. Dramatising changes of state ice-water-gas
20/02/19 – Session 17. Water cycle experiment
STAGE 3. EXPERIMENTS AND HYPOTHESISING
29/04/19 - Session 18. Recap (3D molecule model, atoms app video, water jars)
30/04/19 – Session 19. Butterfly and leaf zooming-in videos
3/05/19 – Session 20. Dissolving sugar into water
6/05/19 – Session 21. Mixing water and milk experiment
7/05/19 – Session 22. Mixing water and oil experiment
10/05/19 Session 23. Mixing vinegar and soda experiment