Designing for Development

Fine Motor Skill Practice Through 3 Toy Concepts

Arild Nilsson

DIVISION OF INNOVATION | DEPARTMENT OF DESIGN SCIENCES
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MASTER THESIS

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Department of Design Sciences
Faculty of Engineering LTH, Lund University
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Supervisor: Anders Warell
Co-supervisors: Nicolai Sørensen and Thomas Harrit
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Abstract

In light of recent debate regarding declining fine motor abilities in children this thesis aims to relate these issues to the field of product design by proposing three concepts that can be used for practice.

This is done by first providing a basic understanding of fine motor skill and development through an explorative literature study. This part of the thesis outlines why fine motor skills are important, how they are learned as well as what sub-components of overall fine motor ability there are. A section of the literature review also focuses on technology's impact on fine motor ability, highlighting why a physical product should be developed as opposed to e.g. a digital application.

The thesis relies heavily on field studies conducted at pre-schools in Sweden as well as by interviewing professionals within the field of occupational therapy. These interviews and field studies provide the basis for establishing user needs related to development of toys in which fine motor play is encouraged.

The established user needs as well as relevant implications derived from the literature study are used in an extensive concept generation process where 10 concepts for fine motor development are presented. Three of these concepts are then further developed through an iterative prototyping process. The result is 3 final concepts that can be further developed into wooden toys allowing children of different ages to practice different grips important for fine motor proficiency.

Keywords: design, toys, fine motor development, product development, pre-school material

Sammanfattning

Till följd av senare tids debatt angående barns försämrade finmotoriska förmågor så har detta arbete som mål att sammankoppla detta med produktdesign och föreslår därmed tre koncept som kan användas för att utveckla barns finmotorik.

Detta görs genom att först skapa en underliggande förståelse för finmotorisk förmåga och utveckling genom en explorativ litteraturstudie. Denna del av arbetet klargör varför finmotoriska färdigheter är viktiga, hur de utvecklas samt vilka subkategorier som övergripande finmotorisk förmåga innefattar. En del av litteraturstudien behandlar teknologins påverkan på finmotorisk förmåga vilket belyser varför en fysisk produkt ska utvecklas i motsats till t.ex. en digital applikation.

Studien baseras till stor del på fältstudier bedrivna på förskolor i Sverige samt på intervjuer med personal inom arbetsterapi. Dessa intervjuer och fältstudier utgör grunden för fastställandet av användarbehov för leksaker som uppmuntrar till finmotorisk lek.

De fastställda användarbehoven samt relevanta implikationer från litteraturstudien används i en omfattande konceptgenereringsprocess då 10 koncept för finmotoriskutveckling presenteras. Tre av dessa koncept utvecklas vidare genom en iterativ prototypframtagningsprocess. Resultatet av detta är 3 slutgiltiga koncept som kan vidareutvecklas till träleksaker som möjliggör övande av finmotorisk färdighet med olika handgrepp i olika åldrar.

Nyckelord: design, leksaker, finmotorisk utveckling, produktutveckling, förskolematerial

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Arild Nilsson

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1 Introduction

This project was performed in collaboration with the industrial design studio HarritSorensen who has a wealth of experience within the realm of toy design through their collaboration with the Danish toy company Gonge. These toys have been highly popular as tools for improving children's gross motor abilities.

In light of recent debate regarding children's declining fine motor skills HarritSorensen considered this to be an interesting area for development of new toy concepts. Furthermore, they had found that it was difficult to find toys aimed at specific skills included in the overarching concept that is fine motor proficiency. The task of examining this further and developing new toy concepts was therefore given as a basis for this project.

2 Goals and limitations of the project

The goals and limitations outline the scope of the project and are applied throughout the entirety of the thesis.

The goal of this thesis stipulated by industrial design studio HarritSorensen who the project was conducted for was to create a concept aiding in fine motor development of the hands. The concept should be possible to manufacture in natural materials, preferably wood. The toy was to be aimed at a pre-school environment, which entails that the target age group is between 1 and 5 years old. The concept was to be shown through prototypes and images showing how the product should eventually look.

The following limitations were applied throughout the thesis. During the literature study this affected which articles were relevant for the study. During the field study the limitations influenced what statements were deemed relevant for further data analysis. Limitations also affected concept generation by guiding the otherwise intuitive process.

Conditions affecting development or performance of motor skills, both fine motor and gross motor, such as Autism Spectrum Diagnosis, Developmental Coordination Disorder or Cerebral Palsy were not studied specifically. However, commonalities between properties in products for children with typical development and children with these diagnoses were taken into consideration if they were encountered in literature or during interviews and study visits. This limitation in research was imposed to obtain user needs for a target group with the largest possible size. It should be noted, especially taking universal design considerations into account, that the goal of research conducted was to find specific user needs and design criteria suitable for the majority of children regardless of ability.

Fine motor ability includes not only hand use but also function of muscles in the feet, lips and around the eyes (UK Department for Education, n.d.). This study was limited to hand function which to some degree also incorporates visual aspects. Feet and functioning of other parts of the face were not considered as the goal of the project was to practice hand function through toy design.

Potential cultural difference's impact on fine motor development were not taken into consideration during the initial literature study. This as the goal of the literature study was to establish underlying themes regarding development and ability. As such cultural differences were not deemed to impact the results of the study to a degree where it was considered necessary to exclude certain articles based on e.g. their country of origin. Regarding cultural differences, it should be noted that Swedish sources were studied more extensively during the literature study as primary research would later only take place in Sweden with the exception of one interview taking place in Denmark.

Gross motor skills affect the ability to perform fine motor activities to some degree. To use one's hands the arms must be able to be positioned effectively e.g. (Lantz & Melén, 1992). However, to limit the scope of the study somewhat gross motor skills were not incorporated. This decision was also influenced by the desire of HarritSorensen to develop a tool specifically aimed at fine motor development of the hands.

3 Background Research

Background Research is performed through an explorative literature study to obtain an overview of perceived areas of interest for the study.

3.1 Method

3.1.1 Establishing Areas for Secondary Research

Areas of interest for the literature study were established in cooperation with external supervisors at HarritSorensen. Studying how motor skills are developed was considered a basic prerequisite for future product development aimed at facilitating this. Furthermore, it was of interest to examine what tools and toys related to this development that are mentioned in the literature. Potential sub-skills of fine motor ability were also of interest as these could provide suitable target areas for products to practice. More effective tools for motor development could potentially be created if knowledge concerning what areas to focus on was first obtained.

Finally, from a marketing perspective, it was of interest to study whether literature mentions the importance of fine motor proficiency. Answering why fine motor skills are important and what they are used for legitimizes the introduction of a new product to practice these skills. This was also discussed in relation to an increasingly digital society. If fine motor skills are mainly used for handwriting and drawing, do they need to be practiced as extensively as they have been in the past now that these activities are often performed digitally? Literature pertaining to technology's impact on fine motor development was also relevant to establish the legitimacy of a physical product as opposed to e.g. a digital application.

3.1.2 Selection of Articles

Articles for the literature study were obtained by using Lund university databases (Lubsearch) as well as by using Google to find reliable sources that were not necessarily scholarly. Search terms were established based on the outlined areas of interest, these were then refined to obtain a reasonable number of search results, the goal being to yield less than 1000 hits (It should be noted however that the search term “fine motor skills” yielded upwards of 7000 results).

Search results were sorted by ‘relevance’, in the cases where there were too many search results to inspect them individually relevant articles were considered to be within the first 200. This was decided after assessing results past article 200 using the scope of the study as a reference. Results were reviewed in order. Not exceeding this numerical limit was reasonable considering the aim of the explorative literature study being to create a basic understanding and not to establish a comprehensive review of the literature.

Several articles were also found though the reference lists of articles considered relevant using the snowball sampling.

3.1.3 Search Terms

Articles related to the areas: Importance of Fine Motor Skills, Development of Fine Motor Skills and Motor Development Tools and Toys were found through below described search terms. Finding articles related to the areas: Effects of Modern Technology on Fine Motor Development” and “Sub-Categories of Fine Motor Proficiency” required different processes and search terms and are therefore described separately under their own sub-headings.

To establish a basic understanding the search term “fine motor development in children” was used as an initially. As this yielded only 18 search results the search was widened somewhat by removing the specification of children resulting in the search term: “fine motor development”. To find more articles pertaining to what abilities are linked to fine motor ability “fine motor skills” was also searched.

Efforts to find information related to Sweden specifically yielded few results on LUBsearch, Swedish searches on e.g. “finmotorik “and “finmotorisk utveckling” gave no usable results, therefore a Google search using “Finmotorisk utveckling barn” was performed. This led to sources outlining areas such as fine motor assessment and developmental norms used by Swedish health care providers.

The Google search yielded other types of results than those from LUBsearch and as such it was deemed valuable to also repeat the search “Fine motor skills” on Google to obtain greater depth in the source material for the literature study.

Finally, the website of the American occupational therapist association (AOTA) was consulted, found through searching for “occupational therapy”. This to achieve a more international perspective than that provided by “Rikshandboken”, a guidebook for child healthcare in Sweden, which was found through previously mentioned Swedish google searches. Articles from AOTA were obtained through searching for “fine motor” in the website’s search function.

3.1.3.1 Effects of modern technology on fine motor development

Technology AND fine motor development in children was selected as an initial search term.

As this search term yielded too many results that were deemed irrelevant, an attempt was made to refine it by adding citations according to the following: *Technology AND "fine motor development in children".* Using this search term no results were found. It was assumed that this could be remedied by decreasing the specificity of the phrase within the citation marks: *Technology AND "fine motor development".*

3.1.3.2 Sub-Categories of Fine Motor Proficiency

Tests for motor skills were theorized to be a possible source for information to establish sub-categories of fine motor proficiency. This assumption was made as fine motor tests were thought to be likely to divide the complex problem of fine motor skill into quantifiable and testable parts. In this area it was deemed relevant to see what tests were used in Sweden as their relevance and use could later be verified by interviewing health care professionals. Tests used were found partly by searching "bedömning motorisk förmåga" on Google which once again led to the Swedish guidebook for child health care, "Rikshandboken". On this website referenced books within the occupational therapy field were found in which relevant chapters to outlined areas of interest were studied.

3.1.4 Limitations of literature study

The goal of the literature study as secondary research was to achieve a base understanding of current research on the subject. This to be better prepared for later primary research. As such the literature review presented here is by no means an exhaustive study of the current state of knowledge concerning children's fine motor development. Instead, this explorative literature study serves as a backdrop for the later primary research with interviews and observational studies. Due to the goal of the literature study only enough articles and sources to achieve an overview of reoccurring themes within the chosen areas of interest were studied.

Concerning motor development tools aand toys, it was difficult to obtain information from LUBsearch and reliable sources from Google. In this case it was decided that information pertaining to what toys and tools are already used and how was an area of interest more suitably studied extensively on site in e.g. a pre-school environment.

3.2 Result

3.2.1 Importance of Fine Motor Skills

There are two often highlighted areas of importance regarding the use of fine motor skills. The first being its influence on academics and children's activities in school and the second being the ability to perform everyday tasks, e.g. maintaining personal hygiene. Concerning fine motor skills in school, comprehensive research has been performed on fine motor skill's effects on areas such as handwriting.

Mohamed and O'Brien (2021) find that graphomotor abilities (motor abilities used in the act of writing) and visual spatial integration (VSI), i.e. perception of one's surroundings in combination with motor skill, are important factors in obtaining literacy. Furthermore, they make the argument that it is hard for a child to focus on the cognitively difficult tasks of reading and writing whilst simultaneously struggling with holding a pencil. Mohamed and O'Brien (2021) also found a correlation between handwriting and reading- and spelling skills. Similarly, Traynelis-Yurek and Strong (1994) highlight the connection between reading and writing, claiming that a connection between the two in learning might be beneficial for children's skills in both proficiencies. They also claim that fine motor deficiencies might potentially impede reading.

Carlson, Rowe and Curby (2013) also examined the effects of VSI on academic achievement but also included visual motor coordination (VMC), i.e. the skill of translating visual information to accurate movements. They found that only VSI seems to be significantly linked to academic achievement. They stipulate that this might be due to children developing VMC skills during preschool years whilst VSI skills might continue developing for a longer period. It is further stated that VSI proficiency mainly is related to math and written expression but not to reading and oral expression. It should be noted that even though the only part of fine motor activity that Carlson, Rowe and Curby (2013) could link to academic achievement was VSI, they still emphasize the importance of all type of motor activities: "With each new motor skill they learn, children continue to integrate necessary motor information, thus continuing development of their higher-order cognitive abilities." (Carlson, et al., 2013, p. 517)

Abbott, Berniner and Fayol (2010) highlight the complex relationships between different aspects of language and communication, such as handwriting and reading both individual words and entire texts. In their extensive longitudinal study relationships between handwriting and spelling and reading individual words could be found. As such handwriting skills seemed to be at least somewhat relevant in development of skills regarding the written word.

There are also studies finding no relation between handwriting and other language skills. Suggate et.al. (2023) e.g. find no clear benefit to handwriting skills in children attempting to decode imaginary words. Comparing typing skills with handwriting, no obvious difference in the decoding could be observed between the two methods. Suggate et.al. (2023) did however record an increased degree of progression for children with higher degree of fine motor skill. It was also found that when fine motor skill demands were too great, decoding skills suffered. This is much in line with the argument posed by Mohamed and O'Brien (2021). When performing cognitive tasks, effort should not be centered on e.g. holding a pencil.

Certain studies highlight the limited effect of fine motor skills on overall academic ability. Fisher, Suggate and Stoeger (2022) e.g. could not find any link between fine motor skills and calculative skills when examining potential effects on numerical competencies. Only finger counting was, somewhat expectedly, affected by finger agility. Piek et.al. (2008) studied the effect of early fine motor trajectory and its effect on later academic ability and could find no clear correlation. It should be noted that the study group was somewhat small however with only 33 children being studied. Carlson, Rowe and Curby (2013) also point out that Piek et.al.'s (2008) study relied on parent questionnaires and not a firsthand assessment.

There are some differences in findings regarding whether fine motor skills effect other useful skills for children attending school. This link might also become harder to prove if handwriting takes a smaller role in learning how to read and write in the future with introduction of more digital tools. However, fine motor skills are important notwithstanding the relation to academic achievement.

Marr, et.al. (2003) found that children spend a large part of their day performing fine motor activities. In their study they found that an average of 37% to 46% of children's days in pre-school is occupied with fine motor activities. Caramia et.al. (2020) build upon Marr et.al.'s (2003) study in their replication study and achieve a similar result in which between 37% and 60.2% of the day is occupied with fine motor activities. They also add a few noteworthy observations not present in Marr et.al.'s (2003) study. It was found that less paper and pencil tasks were performed in comparison to the results of the 2003 study. However, there was not as much technology use in the classroom as expected, less than 15% of the school day. What Caramia et.al. (2020) also highlight is the fact that fine motor use is prevalent throughout the entire school day, and not solely in structured activities. One example mentioned is the opening of a child's backpack, something which requires considerable manual dexterity. This also explains why children who have fine motor difficulties might potentially struggle with many things throughout the school day.

The importance of fine motor skills is further highlighted by the British department of education in their *help for early year providers*. They note that fine motor skills extend beyond the use of a pencil stating that fine motor skills are integral in eating, getting dressed as well as manipulating objects (UK Department for Education, n.d.).

3.2.2 Sub-Categories of Fine Motor Proficiency

"Fine motor skill" is a term encompassing a multitude of different sub-skills. These sub-skills can e.g. be identified by analyzing tests used to assess fine motor proficiency.

Krumlinde-Sundholm (2016) mentions several tests for evaluating hand function in children in her text concerning assessment tools for mapping and evaluating within the field of occupational therapy. A number of these aim to assess fine motor skills, e.g. The Peabody Developmental Motor Scales (PDMS-2), MovementABC-2, Jebson-Taylor Hand function test, Children's Hand use Experience Questionnaire (CHEQ), Bruinicks Oseretsky Test of Motor Proficiency-2 (BOT-2) and Assisting Hand Assessment (AHA).

The PDSM-2 test has two subcategories for fine motor skills, grasping and visual motor integration, i.e. the combination of using motor skills with visual skills (Physiopedia contributors, 2023a). MovementABC-2 assesses hand function by evaluating manual dexterity through e.g. inserting coins into slots, threading beads and tracing. This test also contains sub-tests of throwing and catching (Physiopedia contributors, 2023b).

Jebsen-Taylors hand Function Test assesses ability to move 7 different objects during a given time and the CHEQ test similarly assesses grip ability. The BOT-2 test has a larger number of subcategories for fine motor assessment including fine motor precision, fine motor integration, manual dexterity, bilateral coordination as well as upper limb coordination (Krumlinde-Sundholm, 2016).

Assessment methods for fine motor development for children in Scania County include Movement ABC, BOT-2, PDMS-2, Lantz and Melén Fine Motor Development Status as well as Miller Functional and Participation Scales and Miller Assessment for Preschoolers (Vårdgivare Skåne, 2017).

Lantz and Melén (1992) highlight that fine motor proficiency is a result of interplay between hand motor skills, gross motor skills, perception and cognition. In their evaluation tool for fine motor development activities include drawing, using scissors, throwing and catching, threading beads and building with blocks.

The BOT-2 test is widely used in scientific studies, examples from referenced studies in this report are the those by Tanner et.al. (2020), Ohl et.al. (2013) and Ling-yi, Rong-ju and Yung-jung (2017).

Fine motor evaluation in Region Stockholm is performed using tests involving throwing and catching objects, drawing and using scissors as well as threading beads on a string (Habilitering och hälsa Region Stockholm, n.d.). Throwing and catching is part of what is known as upper limb coordination, i.e the coordination required to move the hands to a certain location (Shirota, et al., 2016). Activities such as drawing and by extension also e.g. cutting along lines fall under what is known as fine motor precision (Liutsko, et al., 2020), however, both catching, throwing, drawing and cutting are skills that naturally are encompassed by visual motor integration as neither one of the activities could be performed effectively without use of sight. Threading beads on a string relates more to manual dexterity (Cambridge University Press & Assessment, u.d.).

The Swedish National Handbook for Child Health Services also provide recommendations for evaluation of children's fine motor skills. Children 4 years of age should be able to hold a pencil using thumb and forefinger grip. The child should also be able to throw and catch large and small balls (Johansen & Persson, 2017). Activities recommended for evaluation are e.g. threading beads on string, drawing and building with blocks, e.g. Lego (Reuter & Lindblom, 2017). From these guidelines it can be deduced that the national recommendations for evaluation, although more detailed, are in line with tests performed by motor evaluation professionals in Stockholm.

Eliasson and Rösblad (2013) present several fine motor sub skills in their description of normal and deviant hand function in children. Grasp and release skills are highlighted and specifically being able to control the release of objects. Two hand use and learning to use the hands independently are also important skills to learn. Children up to age 10 often mirror hand movements instead of using them individually for two different tasks. They also mention that positioning of the hands to the right location as well as planning movements and the grip to take is of importance. Once the hand has been positioned and grip taken, adapting the use of force after the given object is crucial for correct handling. The importance of creating memory representatives of movements is also emphasized, one example is remembering how heavy a milk carton is and adapting grip beforehand after this memory model is. They also mention several more detailed skills concerning the handling of objects. E.g. in hand manipulation, a skill which can be further divided into three components: Translation which is moving objects from the palm of the hand to the fingertips, shift which is moving objects between fingers and rotation which is rotating an object whilst holding it using the fingertips.

3.2.3 Development of fine motor skills

As with all skills related to movement of the body fine motor skills need to be practiced. As such the main way to develop fine motor skills is to perform fine motor activities (Sutapa, et al., 2021). Within the intersecting fields neuroscience and occupational therapy, dynamic system theory highlights the importance of repeating tasks that are "functional" and in a relevant context (Persson & Johansen, 2017).

Memisevic (2013) found, through testing for fine motor development with pegboards and the Beeri Visual motor integration test, that development rate is not constant. Rather, it seems that there is a faster rate for fine motor development in pre-school children compared to other age groups, as such it is important to facilitate and enable this development early in life. Marr et.al (2003) also highlight the importance of fine motor skills for later development of handwriting skills. They therefore encourage development of these before handwriting is undertaken in e.g. a school setting.

Suggestions for activities to perform vary depending on who is consulted. By typing in "fine motor development practice" in a search engine a plethora of occupational therapists promote their own training regimes. In a somewhat dated recommendation from the United States department of education Thompson (1993) recommends a variety of different motor activities in her program for child development. Regarding fine motor development for the age group relevant to this study the following activities are recommended:

- Pouring rice and/or beans between different containers held in each hand
- Drawing in shaving cream
- Playing with water using cups, spoons and funnels
- Target practice by throwing objects into a bucket of water
- Drawing with crayons.

Common denominator for these activities is use of small hand muscles, application of visual coordination, precision in movement as well as use of both hands simultaneously.

In Suggate, Stoeger and Pufke's (2017) study of the relationship between activities and fine motor development they found that playing with small toys and home crafts, such as cutting with scissors or drawing, benefit development. It should also be noted that it was found that younger children primarily use toys whilst older children tend to perform more crafts. They also found, somewhat contradictory to e.g. Lantz and Melén (1992), that gross motor skills are independent of fine motor skills, meaning that opportunities for both fine and gross motor skill play and practice have to be offered separately. Important to consider is that fine motor abilities cannot reasonably be entirely separated from gross motor abilities as use of the smaller muscles in the hand require positioning and stability of larger muscle groups in the arms and shoulder (Cambridgeshire Community Services NHS Trust, 2021).

Of great importance to encouraging development is continued motivation in an activity. Malone and Lepper (1987) have studied this extensively over the course of several studies and created a taxonomy for constructing instructional environments based on their findings. A motivated activity is according to them defined as something engaged in for its own sake. They note 4 categories for creating motivation: challenge, curiosity, control and fantasy.

An activity should be challenging but at an "optimal level" for the user to promote self-esteem. Furthermore, clear feedback should be provided. The user should also have access to different goals that are not reached with certainty. Regarding curiosity, an experience can appeal to sensory curiosity, e.g. light, touch or sounds, or cognitive curiosity which is knowledge based. The desire for more information drives the continued motivation for interaction. The user also needs to feel in control of what is happening through 3 different aspects:

- Contingency, i.e. that outcomes of the activity are dependent on user response
- Choice, the user has the possibility of making choices that have an impact
- Power, that user actions have powerful and noticeable effects.

An activity should also evoke mental images. Preferably endogenous to the activity itself, i.e. the activity should be related to the mental image it has provided the user with. Malone and Lepper (1987) also highlight the importance of the user being able to identify with e.g. characters in a game. Finally, they highlight interpersonal motivational factors primarily cooperation and competition.

Eliasson and Rösblad (2013) highlight the importance of gaining experience in applying and developing fine motor skills. This as planning of movements is based on experience and later corrected using feedback. As such development of effective movement requires experience to diminish the need for later correction.

3.2.4 Motor Development Tools and Toys

Suggate, Stoeger and Pufke (2017) found that home crafts, e.g cutting with scissors, drawing or weaving and playing with small toys benefit fine motor skills. However, they find no specific link between toys promoting some sort of construction (these toys are often referred to as manipulative toys) and fine motor development. Marr et.al (2003) disagrees though, claiming that manipulative play, e.g. playing with Lego or Play-Doh, is something which prepares children for the more demanding tasks later faced in a school setting. It should be noted that many toys of this type are of a size conducive to smaller movement of the hands and incorporate visual integration and cognitive aspects, e.g. by following instructions, into play.

Yakimshyn and Magill-Evans (2002) found that grasp patterns could be altered by changing the objects that children interact with. Studying pencil grasps using different writing utensils it was found that a small crayon and a vertical writing surface encourages a more advanced grasp. This is most likely due to the child not being able to use a palmar supinate grasp (a grasp in which the writing tool is held as within a fist) on an object of this smaller size. The orientation of the writing surface provides further difficulties for users of more primitive grasps of the utensil. Yakimshyn and Magill-Evans (2002) point out that even though a more advanced writing grasp could be promoted this might not lead to more effective development than if children are presented with more grasp opportunities. However, the study still proves that grasp patterns can be influenced by object design.

Mironcika et.al (2018) also found the size of objects to be of importance, noting in their development of a game to promote fine motor practice, that child manipulation of pieces would be easier if these were smaller in size. Their study also adds further recommendations for design of objects conducive to fine motor development. Smoothness in movement is pointed out as a main indicator of motor proficiency. As such games and or toys should promote this skill. Another design factor which is noted is the importance of adaptability of the toy to cater to variances in child motor competency something which is also noted by van Delden, Aarts and van Dijk (2012).

In her description of children's development from their first months until school Eliasson (2016) notes that understanding of more complex play situations can be obtained through activities such as stacking blocks and building with Lego. Furthermore, she highlights that play can only be developed through learning of play strategies, memory, spatial perception as well as hand precision.

3.2.5 Effects of modern technology on fine motor development

The problem of delayed fine and gross motor development in children has been the subject of a multitude of scientific articles. Technology's effect on these skills has also been studied extensively. An area which is increasingly relevant as more children have access to e.g. touchscreens. In their study Bedford et al. (2016) found that 92.05 % of children ages 2-3 had access to a touch screen device. A number which seemed to increase rapidly with age. The assumption could be made that the vast majority of children 3-7 years of age also have access to these devices. Concerns have been raised that increased use of screens and touchscreen devices might impair normal development of motor skills used in everyday life. Summarized clearly by the following quote: "The actions involved when using a touch-screen tablet are different from those required for most people's typical activities of daily living" (Lin, et al., 2017, p. 464)

Lin et al. (2017) could observe differences in motor development for children performing traditional fine motor activities (e.g. drawing and cutting with scissors) as opposed to using touch screen tablet apps aimed at fine motor development. Posttest evaluation of fine motor skills was performed using the BOT-2 on two groups who were encouraged to practice their fine motor skills with results showing that children using manual techniques scored higher in fine motor precision, fine motor (visual) integration and manual dexterity.

This result supports the hypothesis that current decreased motor ability of children might be the result of increased use of touchscreens by young children.

Coutinho (2017) instead argues, in a comment on Lin et al.'s (2017) study, that controlled usage of touch screen applications can instead be beneficial for children.

She notes that use of e.g. tablets can be more motivating and enjoyable for children in comparison with more traditional activities.

This increased motivation and engagement is further noted in Coutinho et al.'s (2017) study regarding iPad application's effect on visual motor skill development. Here no statistically significant difference between children using traditional methods and touch screens could be observed. However, iPad use was controlled by adults and applications were selected based on perceived needs of the child.

This begs the question whether this type of development also occurs in a normal setting involving a child and a touch screen device. Can app usage always be controlled and monitored resulting in beneficial use?

A reoccurring theme in literature on the subject is that e.g. touch screen usage lacks the variation and complexity of physical activities even if the outward appearance of an application and a real-life scenario might be similar, e.g. finger painting. This specific scenario is studied by Price, Jewitt and Crescenzi (2015) in their comparison of children using paper and finger paint and an iPad application emulating the same activity. They note that the traditional method offers the interaction of different objects i.e. paper, paint and finger. These all have different characteristics, materials and textures creating complexity. As such advanced movement patterns, physical relationships and conceptual thinking (e.g in mixing colors and different application techniques) are explored further. iPad usage mainly activates the index finger whilst more fingers were used when painting in the physical world, something which might promote further motor development. The lack of complexity in digital applications is something which is also stated by Martzog and Suggate (2022).

Martzog and Suggate's (2022) results are in line with those of Gaul and Issartel (2016) where reasons for children's development not occurring at the expected rate was studied. Gaul and Issartel (2016) state that "motor skill proficiency tends to fall below established developmental norms" (Gaul & Issartel, 2016, p. 78). They claim that the most likely reason for this is changed environmental conditions for children. They highlight that increased standards of living might lead to changes in play activities which means that the observed change in motor skills might not be entirely caused by increased screen usage. The study also notes that many of the tests within the BOT-2 assessment method which is used are based on handling of a pencil or pen. This might be something that children today are exposed to less than before. Instead, Gaul and Issartel (2016) note that increased use of technology can lead to development of new fine motor skills such as precise tapping abilities and more proficient use of game controls.

Bedford et al. (2016) also claim that touchscreens can be beneficial for children providing sources of "sensitive/ cognitive stimulation". Bedford et al. (2016) find no significant correlation between touch screen use and motor skill development. However, it should be noted that their study is based on questionnaires given to children's parents. Thereby a certain subjectivity is introduced in the assessment of child ability. Axford, Joosten and Harris's (2018) also highlight the positive aspects of screen usage for children, their results show that app usage can lead to increased fine motor ability. However, they only compare apps developed for motor development with other screen applications. As such it is not clear whether more traditional methods would be more beneficial given the same circumstances.

3.2.6 Implications of secondary research

3.2.6.1 Importance of Fine Motor Skills

The learning of fine motor skills is an important part of development for children as it can aid in many aspects of life. Increased graphomotor, i.e. motor use in writing, skill seems to facilitate development of literacy skills (Mohamed & O'Brien, 2021; Traynelis-Yurek & Strong, 1994; Abbott, et al., 2010). However, fine motor proficiency is not only an integral part of writing, but also an important part of the entirety of the school-day as well as in activities such as eating and maintaining personal hygiene (Caramia, et al., 2020).

3.2.6.2 Sub-categories of Fine Motor Proficiency

To facilitate targeted efforts to develop fine motor skills using developmental tools and toys sub-categories of fine motor skills are established based on the studied literature. The BOT-2 test surfaces frequently in studies where evaluations of children's fine motor skills are performed. BOT-2 has several sub tests to evaluate fine motor skills. These are: Fine Motor Precision, Fine Motor Integration, Manual Dexterity, Bilateral coordination, and Upper-Limb Coordination (Pearson Clinical, n.d.). As these categories were also part of the other evaluation methods they constituted a basis for development of Sub-categories.

For the purposes of later product development these categories were rewritten as: Precision, Visual integration, Dexterity, Bilaterality and Coordination. These terms were considered somewhat self-explanatory within the context and thereby easier to communicate. Precision involves the use of accurate movements in e.g. drawing, cutting with scissors along lines or grasping and placing objects. Visual integration involves the use of sight in fine motor activities. Dexterity describes the ability to use the muscles of the hand skillfully, this sub-category itself contains many parts, e.g. in hand manipulation (i.e. moving objects within the hand in different ways). Bilaterality involves using both hands in a coordinated manner. Coordination entails being able to move the hands to the correct place. Cognition is a category which was added to those derived from the BOT-2 test as planning and memory representations are important for effective fine motor use (Eliasson & Rösblad, 2013).

Figure 1 shows the different established sub-categories of fine motor proficiency as established based on the literature study together with clarifying icons.

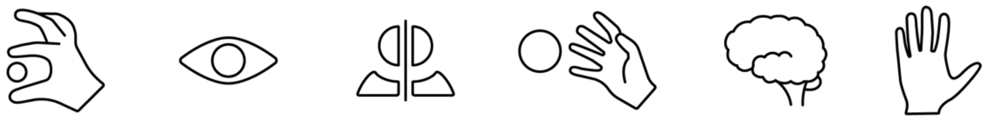

Figure 1. Established fine motor sub-categories

3.2.6.3 Development of fine motor skills

Practice of fine motor skills is especially important at an early age as motor development occurs at an accelerated pace during this time (Memisevic & Hadzic, 2013). As such, practice activities yield more results if applied during childhood as opposed to later in life. Developmentally appropriate activities should involve the use of small hand muscles, application of visual coordination, precision in movement as well as use of both hands simultaneously (Thompson, 1993).

Another important factor to take into consideration for design of toys to develop fine motor skills is maintained motivation. This is achieved through consideration of an activity's level of challenge, inspired curiosity and fantasy and perceived control. Relatability with the given activity or present characters in play as well as cooperation, competition and encouragement from others are also important factors (Malone & Lepper, 1987). These aspects allow for children to take part in instructional activities for their own sake and not because they were instructed to perform said activity.

3.2.6.4 Motor Development Tools and Toys

Toys of a small size resulting in fine motor practice is a reoccurring theme in the literature. This can be considered quite natural as use of complex hand and finger movements require the object to be small enough to be manipulated using only the hands. Especially in the case of objects for children, a smaller size can facilitate in hand manipulation (Mironcika, et al., 2018).

In the case of older children, examples of activities for fine motor development are e.g. cutting with scissors, weaving and drawing (Suggate, et al., 2017).

A relevant observation for product development is how grip patterns are affected by object size and orientation. The finding that a tripod grip (correct pencil grip) can be induced using a short and thick writing utensil on a vertical surface might be applicable on toy design for children developing different grip patterns (Yakimshyn & Magill-Evans, 2002).

Tools for motor development should also be adaptable in difficulty to take the different abilities of children into consideration (van Delden, et al., 2012).

3.2.6.5 Effects of modern technology on fine motor development

The need for physical products to practice fine motor skills is highlighted by the trends of decreased development of fine motor ability that can be observed when children substitute more traditional activities with touchscreen use (Lin, et al., 2017; Price, et al., 2015). The higher level of complexity often associated with traditional activities such as painting also provide a bigger cognitive challenge för children (Price, et al., 2015). Physical products with the aim of developing fine motor ability might be an important part of guaranteeing that children reach the expected levels of motor development in a world that is increasingly digital. During development of such a product the motivation children have when interacting with technology (Coutinho, 2017) must however be rivaled.

3.3 Discussion

Due to the explorative nature of the literature study the implications presented merely serve as a backdrop for the later conducted primary research. Due to the goal of later performing interviews and observational studies the secondary research was not of a more exhaustive nature as this was deemed an ineffective use of time.

The literature study proved effective in establishing the legitimacy of creating a physical product for development of fine motor proficiency. Without implications provided by the secondary research one could e.g. argue that a digital application would be a more effective way of providing fine motor practice. Furthermore, a valuable framework of fine motor sub-categories could be established for later guiding in the concept generation process.

4 Field research

Interviews, site visits and observations are conducted to serve as a basis for establishment of user needs for fine motor products within the pre-school environment.

4.1 Method

4.1.1 Gathering Data

In accordance with Muratovski (2022) data- and methodological triangulation was used to achieve more reliable results. Multiple methods to gather data from various sources led to a more credible basis for guiding later establishment of user needs and thereby product development. A combination of methods outlined by Muratovski (2022) within his descriptions of Ethnographical and Phenomenological qualitative research were conducted. This in the form of semi-structured interviews as well as observational studies. Lastly a group interview took place involving 3 occupational therapists and one physiotherapist at Lund University Hospital.

4.1.1.1 Interviews

Interviews were conducted with, amongst others, professionals active in Scania County within the fields of occupational therapy, habilitation and daycare. Semi structured interviews were used as this was perceived as the most natural form of interview to conduct whilst simultaneously performing observations (during on-site visits at day care facilities). A completely structured interview also presented the risk of guiding the participants based on knowledge gained through the literature study. Being more unstructured, the interviews could instead be used to confirm or negate findings from the literature review. Furthermore, the emphasis being on the interviewee's perspectives and experiences achieved through this interview format was considered beneficial to the study (Interaction Design Foundation - IxDF, 2017).

Before conducting interviews, an interview guide was created which can be seen in Appendix B. The Interview questions in Appendix B merely provided an outline for what questions to seek an answer for and rough estimation of what direction the conversation should ideally take. The questions were initially more open-ended and then became increasingly specific, the open-ended question were important to not guide the interview subject too much so that spontaneous answers could be obtained. Questions were initially more centered around activities and play patterns and then later became more focused on products and specific toy/product properties. This interview guide was followed during all on site visits at pre-school to outline activities, play-patterns and toys relevant for fine motor development specifically as well as to establish more general guidelines for toy design.

The goal of interviewing professionals within habilitation was partly to confirm information obtained through the literature study or potentially add to it. The interview guide was followed even for these interviews but had to be rephrased somewhat to be suitable for professionals not working directly with larger groups of children.

On site visits at 5 different preschools were performed where interviews with teachers took place. An occupational therapist in Malmö was also interviewed. Two more interviews were conducted with individuals not active within Swedish habilitation or pre-school. One of these was with a Danish motor consultant contacted by supervisors at HarritSorensen. The other was a professor of occupational therapy at a Swedish University which was a beneficial source of first-hand information regarding the more scholarly aspects of the field. For all interviews not taking place in a pre-school environment the interview guide was rephrased someshat.

A combination of audio recordings and note taking served as documentation of the interviews. The degree of audio recording that was conducted was largely dictated by the nature of the study visits. When there were children in the same room no recording was conducted as this was deemed to encroach on their personal integrity. Only interviews conducted with consenting adults in the room were recorded.

4.1.1.2 Observational Studies

At the 6 pre-schools mentioned, observations of toys and children's interaction with them were conducted simultaneously with interviews being held with a teacher. To affect the everyday life of the children as little as possible the fly on the wall method as described by Curedale (2013) was used. This is an observational method which is as non-intrusive as possible which was deemed appropriate as the pre-school is a sensitive environment to study. It should also be noted that due to the ethical considerations of observing at pre-schools the focus of the visits was the toys present and the teacher's opinions of them not on the children or how they played.

Observations during site visits were noted alongside notes from interviews.

4.1.1.3 Group Interview

At Lund University Hospital a group interview was conducted with 3 Occupational Therapists and 1 Physiotherapist. The method applied was the same as during the other interviews with non-daycare professionals.

4.1.2 Summary of Participants in Field Research

In table 1 below, a summary of interviewed professionals is presented. All visits at pre-schools also included observational studies. To not shift focus onto any specific source all interviewees were anonymized.

Table 1. Summary of interviewees

Interviewee	*Profession*	*Workplace*
A	Occupational therapist	Lund University Hospital
B	Occupational therapist	Lund University Hospital
C	Occupational therapist	Lund University Hospital
D	Physiotherapist	Lund University Hospital
E	Occupational therapist	Scania Region, Malmö
F	Occupational therapist	Scania Region, Lund
G	Pre-school teacher	Sofielunds förskola, Malmö
H	Pre-school teacher	Björkhagens förskola, Malmö
I	Pre-school teacher	Bollens förskola, Malmö
J	Pre-school teacher	Gullängens förskola, Malmö
K	Pre-school principal	Studentgårdens förskola, Lund
L	Professor Occupational Therapy	Swedish University
M	Motor Consultant	Danish habilitation firm

4.1.3 Data Analysis

Using notes from interviews and observations as well as audio recordings all information considered potentially relevant were summarized in documents, one for each interview/site visit. The result was 10 interview documents (the group interview was recorded in 1 document). Information from audio recording and notes taken during interviews were summarized in one sentence bullet points. This was considered a natural structure of data recording as notes taken whilst observing were often only one sentence. Therefore, the one sentence bullet points were deemed to be an effective way to make the data from different sources more easily comparable. Transcription of interviews was not performed as not all the interviews were recorded due to ethical considerations. As such transcribing only certain interviews would lead to more emphasis being put on these compared to data from site visits where recordings could not take place.

To simplify comparison of data from different sources categorization of statements was conducted in accordance with the method for inductive qualitative data analysis as prescribed by e.g. Faulkner and Atkinson (2023) and Wildemuth and Zhang (2009).

The process of categorization was also somewhat inspired by the method for conducting thematic analysis prescribed by Rosala (2022) for the Nielsen Norman Group as well as the K-J method (more commonly known as affinity mapping) (Scupin, 1997). These 2 methods were not conducted exactly as prescribed though, coding or categorization was done digitally, in Excel, and was not performed in a group setting. The reason that the methods were not followed rigorously was the difficulties encountered when large data sets are involved and the process is physical (Sanders & Stappers, 2012). These adaptations were intended to streamline the process.

Initially an inductive approach to coding of sentences was used as the nature of the research phase was somewhat explorative. It was also beneficial for themes to be established in a natural manner without intervention from the previously conducted background research. This as applying codes derived from the literature study with its explorative nature in a deductive manner on the primary research could lead to unsatisfactory categorization and potential introduction of bias from the established areas of interest.

Using Excel sentences that were deemed to relate to the same theme or "team" in accordance with Scupin (1997) was grouped in a column and assigned a name. Thereafter teams could be grouped into larger families containing related teams. Due to the large amount of data gathered three overarching groups were created to further divide the large number of families: "Background Information", "Product Applicable Aspects" and "Play in Pre-School".

Background information contained all statements pertaining to e.g. how fine motor skills are developed and technology's impact on fine motor development. Here, a combination of deductive and inductive categorization was performed. This was done as applying areas of interest established during the secondary research phase provided easier confirmation of findings from the literature study using the primary research. The only area of interest that was not deductively applied to the group "Background Information" was Motor development tools. This was instead treated in the "Play in Pre-school" group. The family "development and age" was inductively established in "Background Information" as it was relevant for product development to know what fine motor skills children tend to have at different ages.

The group "Play in Pre-School" contained all statements/observations regarding what toys are present in the pre-school environment as well as mentioned play patterns. This data provided a basis for identifying what toys there are in the pre-school environment as well as what type of play is related to fine motor development.

The group "Product Applicable Aspects" contained all statements considered directly related to the product development process and was used to establish user needs.

An overview of established teams, families and groups can be seen in Appendix C.

4.1.4 Establishing user needs and user needs hierarchy

Using established teams within the group "Product Applicable Aspects", user needs were established in accordance with the following guidelines prescribed by Ulrich and Eppinger (2014):

The user need:

- Describes what the product should do, not how
- Has the Same level of detail as raw data
- Is a positive statement
- Describes as property in product
- Avoids the words must and shall

At least two statements perceived to relate to the same need was required to establish a user need. These statements needed to come from different interviewees to avoid potential repetition from an individual skewing the perceived importance of established need. With the goal of creating a hierarchy between different user needs for later prioritization during concept generation primary user needs were identified. These were needs which had between 5-10 statements from different interviewees related to them. 5-10 statements were chosen as this generated a satisfactory number of key user needs deemed to be few enough to not restrict the concept generation process. Secondary needs had 3-4 statements related to them whilst tertiary needs had 2 statements. If opinions on a subject differed greatly within the same team of statements no user need was established.

Once user needs had been established, some were considered too specific to inspire development of varied product concepts, e.g. the primary need "the toy practices pencil grip". If these user needs were applied in the same way as those that were more general during concept generation and evaluation there was a risk that the variation in concepts would be limited. The user needs deemed as being too specific were therefore marked with: (s) to distinguish them during the later parts of the process

4.1.4.1 Examples of Statements Within a Team Leading to a User Need

In Table 2 statements from the team "patience and being careful" within the family Motivation and Interest is shown. The letter next to each statement denotes what interviewee the statement is from (interviewees and their assigned letters can be seen in Table 1. Summary of interviewees). These statements later led to the formulating of the user need "The toy does not need to be played with carefully".

Table 2. Statements from the team "patience and being careful"

Interviewee	*Statement*
A and D	Difficult to motivate children who have fine motor difficulties if task requires too much patience or is too difficult
G	All children don't like fine motor activities requiring a lot of patience.
J	Children with patience enjoy playing with Lego
J	Kapla, regular wooden blocks are popular but require patience
G	Beads and beadboards can get destroyed easily, e.g. lego requires less patience
G	Kapla promotes too careful play
I	Magnatiles are popular as children today do not have that much patience
H	Magnatiles hold together as opposed to toys that require children to be more careful
H	Toys that can be toppled and destroyed lead to frustration

4.1.5 Noteworthy aspects

When categorizing data many statements from interviews contained more than one theme, these were divided for easier classification and grouping. Multiple statements from a single interviewee were often repeating opinions, these were not noted separately as this might later skew the perceived importance of a given subject. Instead, one statement regarding the repeating subject was noted and then used in the categorization in Excel.

At least two related statements from two different sources were required for establishing a team. The Occupational therapy panel discussion was divided into persons A-D and were considered as individual sources in data categorization.

4.1.6 Limitations of primary research

Variances in socio economic status between different pre-schools studied were not considered in this study.

Primary research was only conducted by interviewing adults, children themselves were not asked regarding fine motor skills or needed toys. This was due to ethical considerations needed for studies involving this group.

4.2 Results

4.2.1 Validifying of secondary research

In the group background Research, much of what was established during the Secondary Research phase could be verified.

4.2.1.1 Importance of Fine Motor Skills

The importance of having fine motor skills when starting school was highlighted by many of those interviewed e.g. by occupational therapist A who noted that focus should be on learning the alphabet not on how to hold the pencil in school. Children who have not achieved enough fine motor competence for movements to be automatic spend extra energy on this as opposed to learning. It should be noted that the ability to use scissors was mentioned frequently, 6 different interviewees talked about use of scissors. This is something which requires practice to learn, furthermore, the handling of this tool is applicable on many other fine motor skills, such as using a pencil.

4.2.1.2 Effects of modern technology on fine motor development

The lower level of complexity in the use of e.g. iPads was highlighted by occupational therapist B during the group interview. Furthermore, early digital introduction for children was said to constitute a hindrance in e.g. fine motor development. As such the interviewees confirm much of what was established through the literature review.

The motivation that technology can contribute with was confirmed by occupational therapist E in Malmö and occupational therapists A-C as well. Physiotherapist D in Lund further emphasized that any new toy needs to compete with the quick feedback and entertaining nature of mobile applications.

4.2.1.3 Development of fine motor skills

Both pre-school teachers and the interviewed professor within occupational therapy L, highlighted that brain plasticity is greatest at a younger age and that practice within fine motor ability as such can start as early as possible.

Occupational therapists as well as pre-school teachers interviewed highlight activity and play based training to learn new skills. Activities that children think are fun are emphasized by several interviewees confirming the importance of motivation established through the literature review.

4.2.1.4 Sub-categories of Fine Motor Proficiency

Many of the tests examined during the establishing of sub-categories for fine motor development were highlighted by interviewees within the field of habilitation and occupational therapy. These included the Lantz and Mélen evaluation tool, BOT-2 test, ABC-movement and the AHA-tool. Basing the established categories on these tests could therefore be deemed reasonable.

Previously established sub-skills that were also mentioned by interviewees include visual integration, cognition, Bilaterality and precision. Force modulation was mentioned by several professionals within occupational therapy with interviewee E also mentioning the skill of applying force in a desired direction. Force modulation is important in performing precise activities, e.g. in stacking blocks and can as such be considered part of the sub-skill fine motor precision.

Grip and release skills, as well as in hand manipulation and wrist stability were mentioned by several occupational therapists. Specific finger sub-skills such as using one finger at a time (finger isolation) and using opposing fingers (finger opposition) were also highlighted in an interview with the Danish motor consultant, M. Grip and release skills can be considered a part of precision skills whilst wrist stability falls somewhat outside the established categories. Mentioned Finger sub-skills are considered to fall within the realm of fine motor dexterity.

4.2.1.5 Fine motor skills and age

The primary research phase made it clear that targeted development of a toy required adaptation after a certain age group. Based on interview statements a crucial development step for fine motor abilities is reached at 3 years of age. Most pre-schools are also divided into 2 departments, one being for children of age 1-3 and the other for ages 3-5. Table 3 shows an overview of relevant age-related information derived from interview statements.

Table 3. Overview of age-related information

Age	
1 Year olds	Children start pre-school
	Use of a palmar grip (fist)
	Pincer grip develops
	It is fun when objects disappear and reappear
2 years old	A dominant hand has developed
	Can have small objects whilst under supervision
4 years old	Children have almost full hand ability
	Practical skills and cognitive challenges are needed
	Can use a pair of scissors
	Can stack up to 10 blocks
	Can thread beads on string
6 years old	Children start school
	Need to know how to use a pencil and pair of scissors
	Pencil grip should be almost fully developed

4.2.2 Common fine motor toys in the pre-school environment

As all interviewees at the pre-schools visited knew that the aim of the project was to create a toy to develop fine motor proficiency toys shown and discussed were toys they perceived to be related to fine motor development. The number of occurrences that each toy was mentioned specifically in interview statements can be seen in Table 4. Arts and Crafts are also included here as they were often mentioned in relation to toys that were perceived to aid in motor development skill.

Table 4. Mentioned toys during site visits

Toy	***Number of times mentioned in statements***
Magnatiles	11
PlusPlus	10
Lego	9
Beads/Beadboards	7
Duplo	4
Kapla	4
Arts and Crafts	3
Blocks	3
Brio	3
Puzzle	2

Regarding play patterns and activities related to fine motor skills mentioned by interview subjects, activities/toys related to building was mentioned significantly more than any other category. It should also be noted that almost all interviewed professionals mentioned building in some way with it being mentioned during 7 distinct interviews. Playing with water and crafts were mentioned second most often, however only by pre-school teachers and not by occupational therapists. Other activities such as planting plants, drawing and outside pay were mentioned as well but only in between 2-3 different statements.

4.2.3 Identified User Needs

User needs were established based on product applicable statements using the method described in section 3.1.4. The needs are displayed in Table 5 where the family that need is part of is displayed in the left column. Whether the user need is a primary need (***), secondary need (**) or a tertiary need (*) is displayed in the middle column with the need itself being displayed in the right column. All needs are to be read as if they are preceded by “The toy…”. User needs that were deemed specific for a single type of toy or that were too limiting for the concept generation and evaluation process are marked with: (s).

Table 5. Established User Needs

Family		*User need, The toy:*
Motivation and Interest	***	Is motivating to interact with and sparks interest
	***	Does not need to be played with carefully
	**	Has a clear goal
	**	Provides a challenge
Practicing difficult activities	***	Practices pencil grip (s)
	***	Practices scissor grip (s)
	**	Practices construction analysis (s)
	*	Practices threading (s)
Shape of toys	***	Allows for large scale building (s)
	***	Allows for interaction between different types of shapes
	**	Has possibility to interact with smaller parts
Psychological aspects	***	Does not pose expectations to perform
	**	Stimulates the imagination and creativity
	*	Is cognitively challenging
	*	Can be identified with
Adaptability of toy	***	Has an adaptable difficulty level
	**	Provides varied types of play
Feedback	***	Provides decisive feedback
	**	Gives clear results during play
Materials	***	Is made from wood or other natural materials
	**	Allows for mixing with other materials
Guiding	***	Provides free play with some guiding
Mixing toys	***	Can be mixed in with other toys
Figurative toys	***	Is figurative or has figurative elements
Play setting	***	Allows for play on the floor
Color	***	Has vibrant colors
	*	Has varied colors
Physical Aspects	**	Provides tactile stimuli or has exciting textures
	**	Sticks together in a fascinating way
	**	Is durable
	*	Is cheap and simple
	*	Does not make loud noises
	*	The toy has movable parts
Pre-school education	**	Provides opportunity for communicating e.g. relationships between parts
	**	Allows interaction with teachers
	**	Provides opportunity to understand emotions
	*	Provides opportunity for learning and communication
Market opportunities and target group	**	Targets a specific age group
	**	Is marketable to pre-schools
	*	Develops use of two hands (bilaterality)
Electronics	**	Compensates for lack of electronics using feedback and fascination

4.3 Discussion

How the interviews were conducted in the primary research phase was not reliant on findings from the literature study. As these two methods were independent, they could verify one another, further increasing the credibility of results obtained.

Interviewees might have preconceived notions of what type of toys develop fine motor skills. As such, knowing the goal of the project, this might have skewed statements concerning what products are available to children in the pre-school environment. This is somewhat mitigated by observations being carried out simultaneously with interviews. This should especially be noted regarding the large number of statements pertaining to various building toys. It is possible that this is attributable to building toys being a conventional tool for fine motor development. This also affects the user needs derived from interviews, many are most easily applicable on toys relating to some sort of building. The degree to which building toys are mentioned is relevant to consider when developing concepts for fine motor development. These toys already constitute a significant share of toys already present in pre-schools which begs the question whether there is room for yet another toy centered around building in this environment.

Further research could be performed at pre-schools with a larger geographical spread to obtain a more nuanced picture of that toys are used. This might vary greatly depending on factors such as available municipal funding, agreements with toy providers etc. in different parts of the country. No large disparity in what toys were present could be observed between the different pre-schools in this study. All pre-schools visited were in the central areas of Malmö with two exceptions; One pre-school visit further from the city center as well as one in Lund. The decision to only study pre-schools in this area was due to time limitations in the primary research phase. What pre-schools were visited was also largely dictated by who was interested in participating in the study.

The semi structured interview format used was satisfactory in providing spontaneous answers and obtaining data on what the interviewees thought was important regarding fine motor development and toys whilst still staying on topic. However, it was observed that in a group setting the conversational character of the interview became more prominent. However, this was deemed beneficial for providing unfiltered opinions on the subject at hand and as such no effort to structure this interview more than the others was undertaken.

A potential source of errors in this phase of the project lied in the translation of the statements from Swedish to English.

The categorization process which was conducted digitally proved beneficial in facilitating the handling of the large amounts of data. It should be noted however that a method more in line with conventional thematic analysis, studying physical notes in a group setting might lead to other teams, families and groups being established.

Because of product development being aimed at use in pre-schools it was regarded as sufficient to examine what toys are present within this environment as opposed to performing a more conventional competitor analysis. A more thorough competitor analysis containing technical aspects and data would be less effective in the product category toys. Instead stake holder opinions were used to obtain an understanding of other toys available on the market. A toy and its function are often easy to grasp as opposed to more technical products and an attractive and fun toy concept is hard to quantify numerically.

The categorization process with its teams greatly facilitated the establishing of user needs as many teams could directly be made into a user need. The resulting needs outlined many aspects which could easily be integrated into the concept generation and evaluation process. Here the introduction of the specific (s) user needs marking was regarded to be crucial in diversifying what concepts could later be created based on the performed research.

5 Concept Design

Concept design contains both concept generation and later evaluation. The result is 10 concepts that are evaluated using stake holder opinions and established user needs.

5.1 Method

5.1.1 Concept generation

There was no clear indication from the primary research phase as to what specific type of toys are required for fine motor development within the pre-school environment if the bias towards building toys was disregarded. No clear indication of a certain age group where toys are missing could be established either. As such it was deemed interesting for concept generation to create a spectrum of toys catering to different activities, play patterns and target ages. During the evaluation of concepts, it could then be established what type of activity or age group should be focused on.

To guide the concept development process, implications from the literature study were used as anchor points and inspiration. Here the sub-categories established were especially useful, the basis for a concept was often the intent to practice one of these skills. Inspiration was also derived from the established user needs, with the goal of concepts fulfilling one or preferably several primary user needs.

Concepts were generated with the aim of maintaining a strong connection to findings in the Secondary and Primary research. However, no strict regimen for establishing concepts based on the research was used to not restrict the creative process.

Another method used to establish concepts was inspired by the quote: "We found that design techniques with acting out of movements were very applicable for designing physical therapy games" (van Delden, et al., 2012, p. 232). This method was highly effective in generating concepts promoting a certain movement with the hands. Products were e.g. generated by mimicking a pencil or scissor grip and then imagining what product could fit the hand doing this movement.

The concept generation was intentionally kept as intuitive as possible to promote the creative process, an approach also used by HarritSørensen.

The goal of the concept generation process was to create 10 viable toy concepts that could develop fine motor skills. Concept generation was done in an analogue iterative process in which sketching was the main tool used to develop and communicate ideas. Sketches were then refined in several steps, finally resulting in images of concepts deemed viable for later evaluation by stake holders. An example of early sketching to promote ideation and further concept generation can be seen in Figure 2.

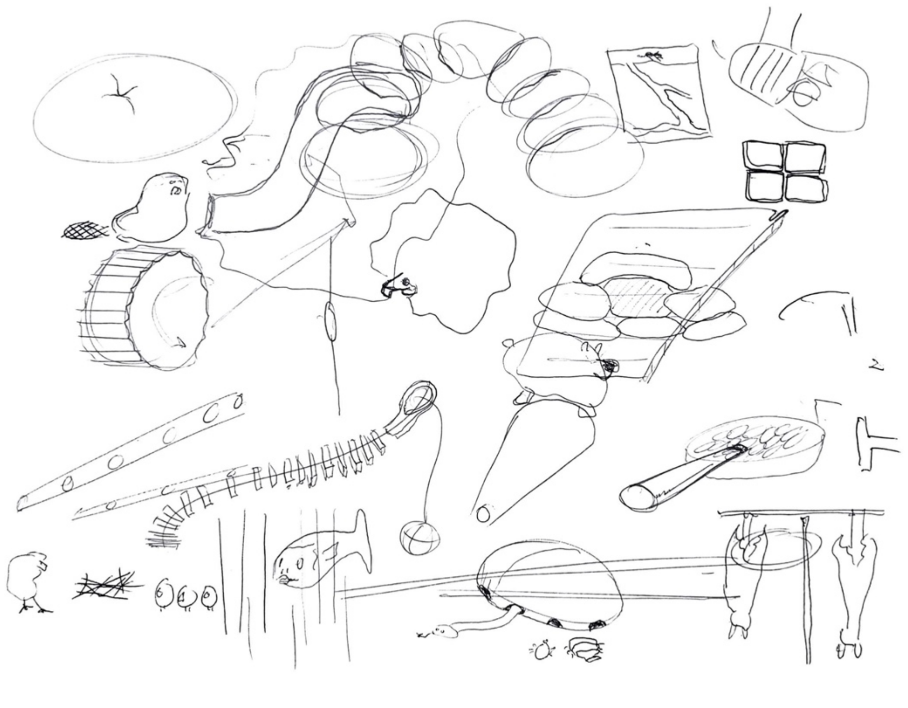

Figure 2. Sketching conducted early in the ideation process

Concept generation focused greatly on products involving animals as this was an easy way to incorporate practice of movement into something perceived as fun and easy to identify with.

5.1.2 Concept Evaluation

5.1.2.1 Design Book

Once 10 concepts had been developed these were summarized in a “design book” with the goal of later showing the concepts to individuals who had been interviewed during field research. This was a method recommended by HarritSorensen as it provides a means of integrating stake holder opinions in the evaluation process. In the design book each concept was introduced in a short text describing how it worked and what fine motor sub-skills it related to. A color image showed the preliminary appearance of the product and a diagram showed how the toy was to be constructed. Two concepts, namely the two more abstract building toy concepts were also communicated with a picture of a prototype that had been constructed. The prototypes had been constructed to test whether the method of putting the pieces together worked. The Design book can be seen in its entirety as it was shown to interviewees in Appendix D. Design Book.

The aim of this process was to have stake holders in the project evaluate what toys they preferred. Previously interviewed professionals who had expressed a desire to contribute further to the study once concept development had started were contacted. Two pre-schools in Malmö, an occupational therapist in Malmö and members of the group interviewed at Lund University Hospital responded and were shown the design book. The limited time of the project resulted in there only being time to interview those that were available on a short notice.

Before the concepts were shown the goals of the project was introduced briefly. Thereafter, the established categories of fine motor development were shown and explained as these were strongly related to concepts shown in the book. Before showing the concepts the interviewee was reminded of the preliminary state of the concepts and encouraged to mention any changes to the concepts they thought were necessary. The interview subject was also asked to think aloud and not be afraid to ventilate negative opinions about the concepts.

The concepts were shown one by one where the concept was first explained, thereafter the interviewee expressed their thoughts of the concept. Once all concepts had been observed and discussed the interviewee was asked to select what concepts they considered to be the best ones with a brief motivation as to why.

When evaluating the concepts the interviewees initial responses upon seeing the products as well as what concepts they considered to be the best ones were taken into consideration. Concepts that were not preferred by any of the interviewees were excluded as they would not be appealing regardless of how well they might fulfill the established user needs. However, due to the small number of individuals who were shown the design book their gathered opinion was not deemed statistically significant enough to be the sole factor in selecting a concept for further development.

5.1.2.2 User needs

All concepts that were preferred or thought viable by at least one interviewee were valued against how well they were deemed to fulfill the user needs (or had the potential to fulfill after further development). The user needs thereby became the deciding factor in selecting the final concepts. Here the previously established specific (s) user needs were valuable. It was considered beneficial but not necessary for a concept to fulfill several of these specific needs.

5.2 Result

5.2.1 Concept generation

5.2.1.1 Concept 1: Monkey

Concept 1 is targeted at 1- to 2-year-olds and aims to practice children's ability to use one finger at the time. A skill sometimes referred to as *"finger isolation"* which can be considered part of fine motor dexterity.

The eyes and mouth of the monkey can turn to create different facial expressions. The monkey can also be used to practice and express emotions, thereby also incorporating visual integration and cognitive aspects.

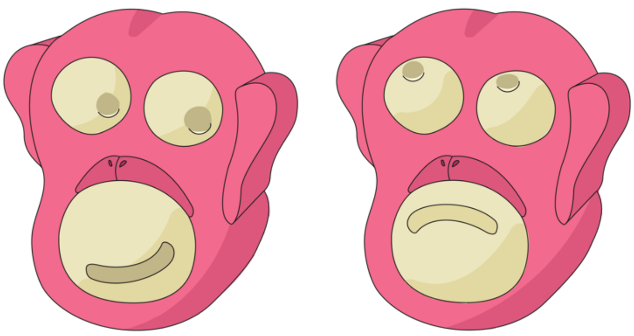

Figure 3. Image of concept 1 from the design book

5.2.1.2 Concept 2: Hat Figure

Concept 2 is targeted at 1- to 2-year-olds and practices bilaterality by requiring the child to use both hands to put the hat on the figure. The protruding nose works as a stop for the hat. The figure works as a syringe, when the hat has been put on the figure it can therefore be pushed down against e.g. a table to blow the hat off showing the surprised face of the figure. Dexterity is also practiced in the act of trying to put the hat on the figure, e.g. using a pincer grip on the brim of the hat.

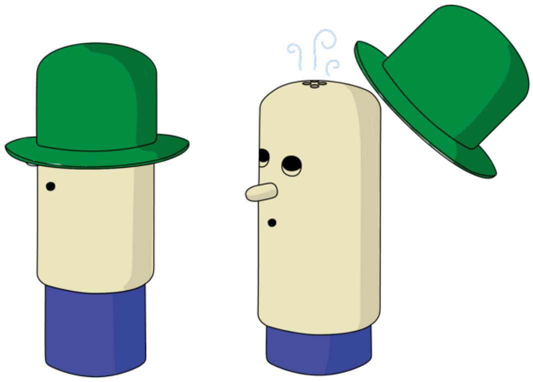

Figure 4. Image of concept 2 from the design book

5.2.1.3 Concept 3: Mouse

Concept 3 is targeted at 2- to 3-year-olds and practices precision by requiring the user to move the handle along a specific path. As a reward for completing the "maze" a mouse pops up out of the top of the barrel. Dexterity is practiced through the effective use of the pincer grip. Solving the puzzle and making the mouse pop up also serves as a cognitive challenge.

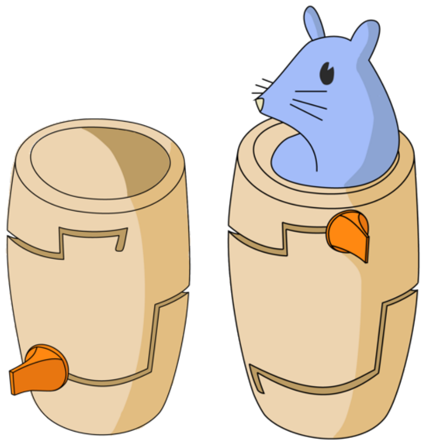

Figure 5. Image of concept 3 from the design book

5.2.1.4 Concept 4: Fishing

Concept 4 for children 2 years old and up, requires synchronized use of both hands, thereby practicing bilaterality, to reel the fish in. Older children can race against each other in seeing who can reel in the fish first

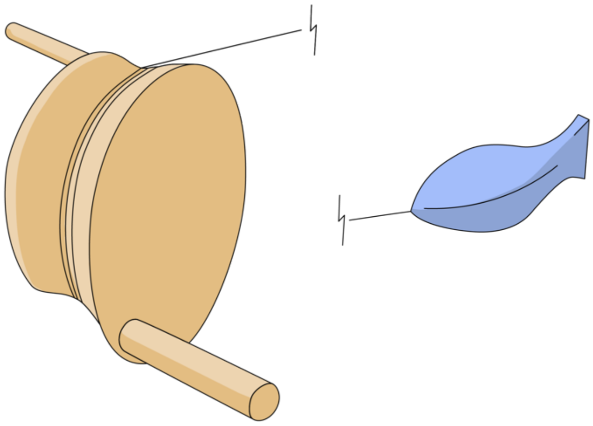

Figure 6. Image of concept 1 from the design book

5.2.1.5 Concept 5: Whale

Field research showed that many children have difficulties with using scissors. This concept for ages 2 and up allows for practicing without teachers having to be worried about the safety risks of leaving children with scissors unattended. The whale opens its mouth when the fins at the back are pressed using a scissor grip allowing it to "eat" the smaller fish. The toy can be used alone as a challenge, or if there are multiple whales, users can compete who can catch the most fish. The scissor grip is important to learn and requires a lot of manual dexterity. Positioning the fish allows for precision practice.

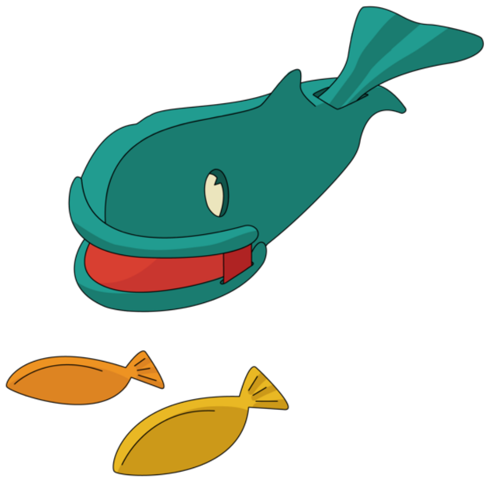

Figure 7. Image of concept 5 from the design book

5.2.1.6 Concept 6: Lady Bug

Concept 6 is aimed at ages 2-3. The ladybug in this concept moves along a path towards the goal at the end, pulled upward by an elastic string. To be able to move, the leaves must be moved out of the way. To do this effectively deliberate and precise movements must be used, especially if the goal is to complete the task as quickly as possible. Moving the leaves requires a pincer grip leading to practice in dexterity.

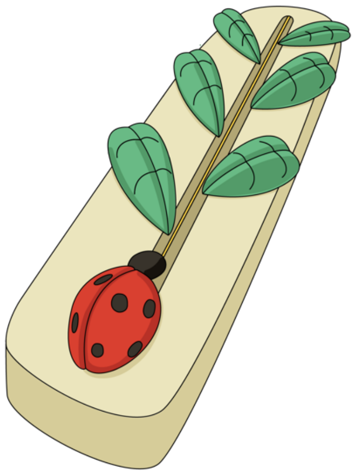

Figure 8. Image of concept 6 from the design book

5.2.1.7 Concept 7: Bird

The bird is a simple building toy for children ages 2-3. Maneuvering the different pieces together requires precision as well as bilateral skills as two hands need to be used to hold the bird upright whilst placing e.g. the wings. Problem solving skills are used to solve the puzzle and create the right bird. Several different types of birds could be combined allowing for mixing and matching of different colors and shapes. In the tail of the bird there is a whistle that sounds when the bird is built correctly providing feedback.

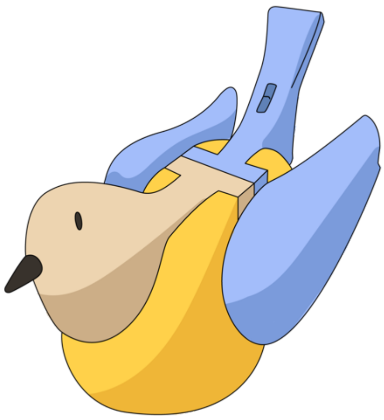

Figure 9. Image of concept 7 from the design book

5.2.1.8 Concept 8: Fish

The fish is another simple building toy for children ages 2-3. The pieces are held together using elastic bands. Threading the elastic bands along the grooves in the fish requires precise movements whilst holding the fish in place. Attaching the head and tail also practices bilaterality. Knowing what part goes where and solving the puzzle of creating a fish provides a cognitive challenge. Several different types of fishes' heads and tails could be combined to create comical sea creatures.

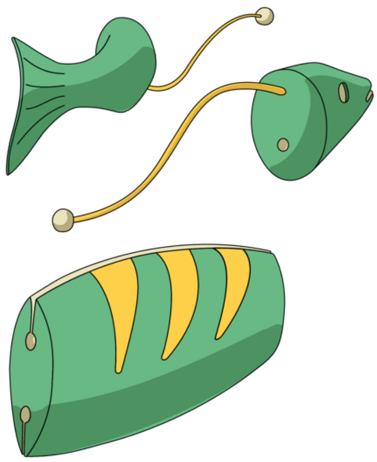

Figure 10. Image of concept 8 from the design book

5.2.1.9 Concept 9: Building toy 1

This building toy allows for assembly through friction between blocks and flat pieces. Younger children than 3 can practice their dexterity and problem-solving skills by building small figures whilst older children can instead build houses and larger structures using more construction-oriented pieces. Compared to traditional wooden blocks the friction fit allows for more stable buildings requiring less patience.

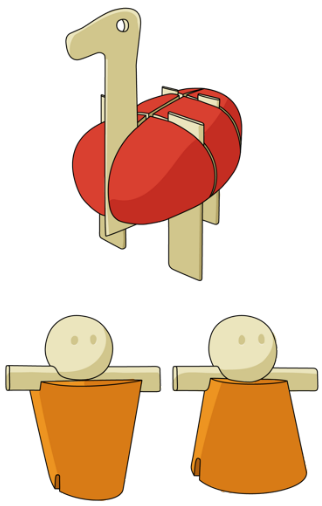

Figure 11. Image of concept 9 from the design book.

5.2.1.10 Concept 10: Building toy 2

This building toy for children ages 3 and up allows for building of different animals held together by sticks. Different head, body and leg pieces can be combined to create interesting mixes. The act of threading the stick through the block practices the pencil grip, requiring dexterity. Bilaterality is practiced by holding both pieces aligned. Seeing how the blocks fit together serves as a cognitive challenge.

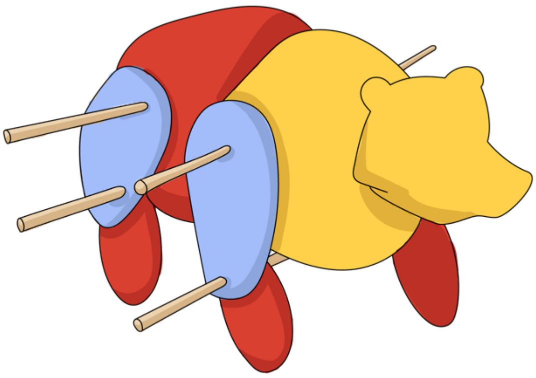

Figure 12. Image of concept 10 from the design book.

5.2.2 Concept evaluation

Two concepts that could be excluded based on stake holder opinions where The Lady Bug (Concept 6, C6) and Fishing (C4) None of the interviewees considered these to be the most interesting concepts.

The rest of the concepts were deemed viable or preferred by at least one of those interviewed. These were thereby valued according to their potential to fulfill the established user needs.

Building Toy 1 (C9) was not selected as building was thought to not require enough fine motor dexterity and precision as a whole hand grip could potentially be used for all assembly. Building toy 2 (C10) offered the same creative play in building whilst also being able to offer practice in pencil grip though the use of sticks. Building toy 1 (C9) could thereby be excluded.

The Hat Figure (C2) was not selected as other remaining concepts were considered to offer more adaptability in difficulty. The other remaining concepts were also considered easier to mix with other toys in play. The same reasoning led to The Mouse (C3) not being chosen for further development.

Five concepts remained at this point. The Monkey (C1), The Whale (C5), The Bird (C7) The Fish (C8) and Building toy 2 (C10). All interviewees liked The Whale (C5) and considered it to be a viable concept, however, most of them noted that it would be best used as a toy for water/bath play. The Monkey was also appreciated by many of the interviewees, especially the pre-school teachers.

The three remaining building concepts, The Bird (C7), The Fish (C8) and Building Toy 2 (C10) did not receive as much attention as the Whale (C5) and the Monkey (C1) during showings of the design book. The Bird (C7) and the Fish (C8) received considerably more positive reactions compared to the Building Toy 2 (C10). It was e.g. mentioned as beneficial that they had different parts that could be combined and that it was fun to mix different animals. Building toy 2 (C10) could however obtain the same properties upon further development. Concept 10 could further allow for practicing of pencil grip (a primary user need) and could offer more varied building. This would lead to a bigger cognitive challenge and more use of the imagination.

Three concepts: the Monkey (C1), The Whale (C5) and Building Toy 2 (C10), thereby remained as the three suitable concepts for further development.

5.3 Discussion

5.3.1 Concept Generation

The intuitive concept generation process succeeded in creating 10 concepts that were varying in aesthetics and intended use. Taking inspiration from established sub-categories and user needs in this process was an effective way of guaranteeing that the concepts were well grounded in both the secondary and primary research phases.

5.3.2 Concept Evaluation

5.3.2.1 Evaluation Using the Design Book

The method of allowing stake holders to voice their opinions on developed concepts was beneficial in establishing a basic understanding of their interest or disinterest in potential toys. This method would not be as effective if the developed product was more technically advanced and thereby harder to understand from an image and a short description.

There were however limits to the effectiveness of evaluation using the design book. During interviews it could be perceived that concepts were often taken at face value based on the description and image provided. As such it could be theorized that ideas that were simpler with a more representative image received more praise than ideas that were harder to grasp. Another downside of the used method was that differences in how concepts were communicated, e.g. colors and composition of pages, influenced opinions greatly. Even though interviewees were reminded that the concepts were preliminary and encouraged to propose changes this seldomly happened. Instead, the image largely dictated the opinion shaped of the concept when the goal rather was to show a means of developing fine motor skills not a certain product appearance.

The fact that the concept page for the two building toys had pictures of built prototypes also greatly affected interviewee opinions. Many commented on the lack of color of the prototype even though the drawn images had color. Building toy 2 (C10) also received many complaints that the sticks were not rounded in the images and that they therefore might pose a safety risk.

As the interviewee opinions tended to not always consider what a given concept might be developed into, evaluating using established user needs was deemed to be an effective method of more objective assessment and final selection.

5.3.2.2 Evaluation Using Established User Needs

Since the concepts were generated with the user needs as inspiration all concepts had the potential to fulfill many user needs. They could e.g. all be made of wood, have vibrant colors and allow for play on the floor. Because of this, objective assessment using the user needs became difficult, especially since no single concept fulfilled all primary user needs.

The specific (s) user needs and concepts not being required to fulfill more than one of these assured that evaluation was not biased toward a certain type of toy. Furthermore, it is likely that a concept that could fulfil all specific user needs simultaneously would require a level of complexity that would make it hard to both produce and understand as a product.

5.3.2.3 Selection of Three Concepts

The three concepts that remained as the best candidates after concept evaluation (the Monkey (C1), The Whale (C5) and Building Toy 2 (C10)) were all deemed to fulfill many of the user needs individually. However, together the three concepts had the potential to fulfill all the established user needs. As such these have the potential to provide comprehensive fine motor practice for children for ages 1-5 practicing different grips and abilities as the children progress. Developing all three concepts was therefore thought to be the best solution for facilitating fine motor development in the pre-school environment.

6 Prototyping

The iterative prototyping process is conducted for the three selected concepts and serve as foundation for the final prototypes

6.1 Method

6.1.1 Concept 1: Monkey

The monkey was modelled in the CAD software Fusion to allow for easy prototyping through 3D printing. The goal of the initial prototype was to test how well the eyes and mouth pieces could be fastened using holes in the baseplates with the same radii in accordance with the section overview in Figure 13.

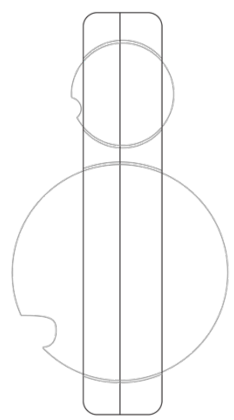

Figure 13. section view of initial monkey prototype

The construction was made up out of two 9 mm plates fastened together to hold the spheres in place. 9 mm was selected as this is one standard measurement of plywood in Sweden. Thicker pieces were not opted for as this would increase the weight of the toy making it harder to use by small children. For the first prototype the spheres were created with fewer expressions than desired for the final prototype. The function was considered more important at this stage.

A second iteration was also created with a more rounded back where only one side of the spheres were visible at the same time. This to allow for the monkey to stand on a table allowing the user to focus on moving the eyes and mouth This version was also scaled down to 65 % of the size of to the initial prototype to be more adapted to the hand size of younger children.

6.1.2 Concept 5: Whale

Many of the interviewed stake holders noted that the whale could be a good bath toy. However, given the project description (and primary user need) outlining that the toy should be made of wood it was considered difficult to make a toy suitable for play with water. Furthermore, making one bath toy and two other toys more suitable for more conventional play would separate them from each other in play. As such it would no longer be a set of toys if one had a radically different area of use. Considering this, it was decided that the whale should be redesigned as a land-living animal to not guide the user towards playing in water with the toy. A bird was selected as the beak could constitute a good gripping point for objects to be gathered.

The bird prototype was also modeled in Fusion to allow for 3D printing. To mimic a pair of scissors more closely and to allow for a more secure grip the back of the bird was designed with finger rings. To obtain suitable proportions for the bird regarding factors such as distance between rings, ring size and location of the fulcrum, comparisons were made with two pairs of scissors. The first, a pair of scissors made for children seen in Figure 14 provided the basis for the location of the fulcrum as well as the ring size.

Figure 14. Children's scissors used as a basis for concept 5

The second pair of scissors seen in Figure 15 was used to establish the suitable measurement between the fingertips at the maximum opening of the scissors. To obtain the measurement the maximum distance between the fingers of an adult using the scissors was recorded. Thereafter the hand size of the adult was noted and compared to the average hand size of a 3-year-old in accordance with European standards for products for children (Swedish Standards Institute (SIS), 2018). The maximum distance between the fingers could thereafter be scaled down proportionally according to the relation between the adult hand and the child hand yielding a measurement of 52 mm.

Figure 15. Scissors used for calculating optimal measurement of distance between fingers.

Several iterations of the Bird were created to develop an ergonomic grip and improve its aesthetics. For the second prototype the beak was made wider to provide easier gripping of objects. This had the added bonus of making the bird look like a duck. The finger rings were also made larger as they were too small on the first prototype to use effectively. However, the grip was still uncomfortable to use at which point a foam mockup was created to investigate the proper thumb position for scissor use, A comparison between the hand position in the mockup and in the second prototype can be seen below in Figure 16.

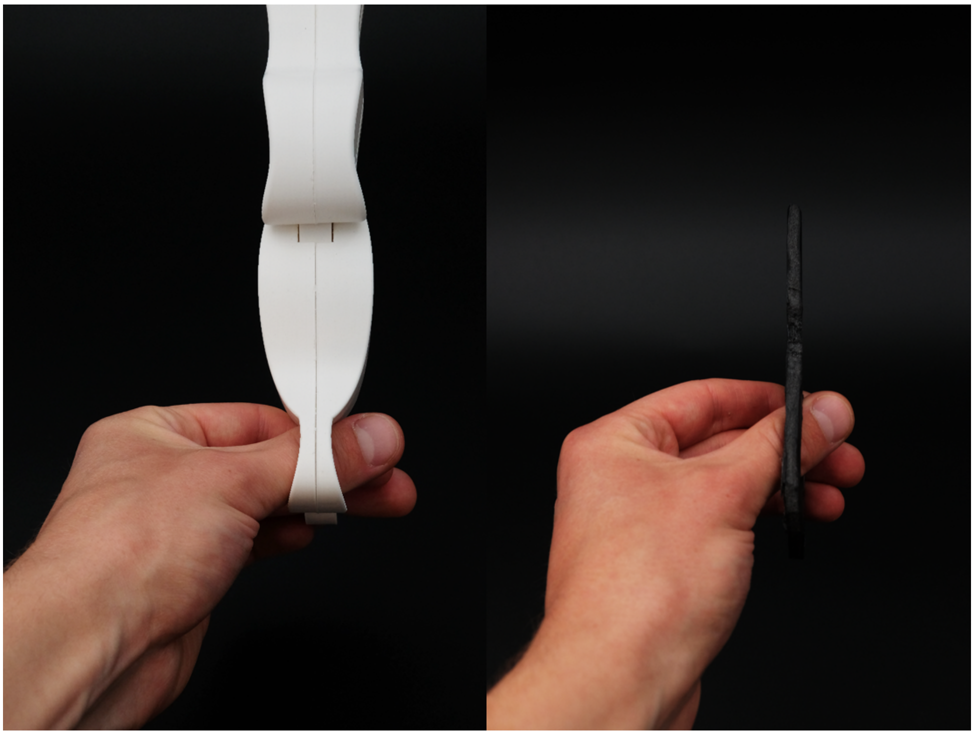

Figure 16. Comparison of thumb angle using the second prototype and foam mockup

The thumb is ideally held at an angle, something which was incorporated into the third prototype created by making the top ring extend into the body of the bird.

The third iteration of the bird was also designed to have an aesthetical expression more in line with those of the Monkey and the building toy. This included more organic shapes and a groove with the same diameter as that of the face outline on the Monkey.

The initial whale concept included smaller fishes that were to be gathered to provide a goal with using the toy and practicing the scissor grip. To be better suited to the change from whale to duck the smaller fishes were substituted with insects. These were first meant to be made from a piece of felt clamped between two smaller pieces of wood making up a body with felt wings. However, in conversation with HarritSorensen it was noted that it would be easier, and thereby cheaper, to make them purely in felt. Important to the design of the insects was that they had parts that could easily be grabbed by the bird when spread out on a flat surface. An easy way to obtain this was to create an X-shape out of two pieces of fabric sewn together. Initial prototyping was performed using paper seen below in Figure 17.

Figure 17. Paper prototyping of dragon flies to be used with concept 5

A felt prototype was constructed based on the paper model furthest to the right in Figure 17.

6.1.3 Concept 10: Building toy 2

A prototype had already been created for Building Toy 2 to test whether it was possible to construct an animal with blocks and sticks and to better communicate this idea during showing of the design book.

The prototype was constructed using scrap wood and workshop facilities at the LTH Maker Space X-Lab. 3D printing was not used as it was more time efficient to be able to create the blocks without having to decide their exact measurements.

This prototype highlighted a couple of problems with the design. The friction between the sticks and the blocks was insufficient to keep the animal upright. The diameter of the hole drilled in the blocks was 0.5 mm larger than the diameter of the stick. More friction would result in a toy with a slightly higher difficulty level which was considered beneficial for development.

To obtain a more satisfactory level of friction between the parts three different solutions were tested, shown below in Figure 18. Firstly, the hole diameter was decreased to match the diameter of the stick resulting in more friction than in the first prototype but not enough to be satisfactory for the concept. Secondly the same solution was implemented but in cork and with a drill that was 0.5 mm smaller. This resulted in a somewhat acceptable level of friction but if this solution was implemented the stick would most likely wear the cork down after repeated use. Lastly, an O-ring with a slightly smaller diameter than the stick was mounted in the middle of the two pieces of wood. This resulted in adequate friction between the stick and block and was deemed more durable than the cork alternative.

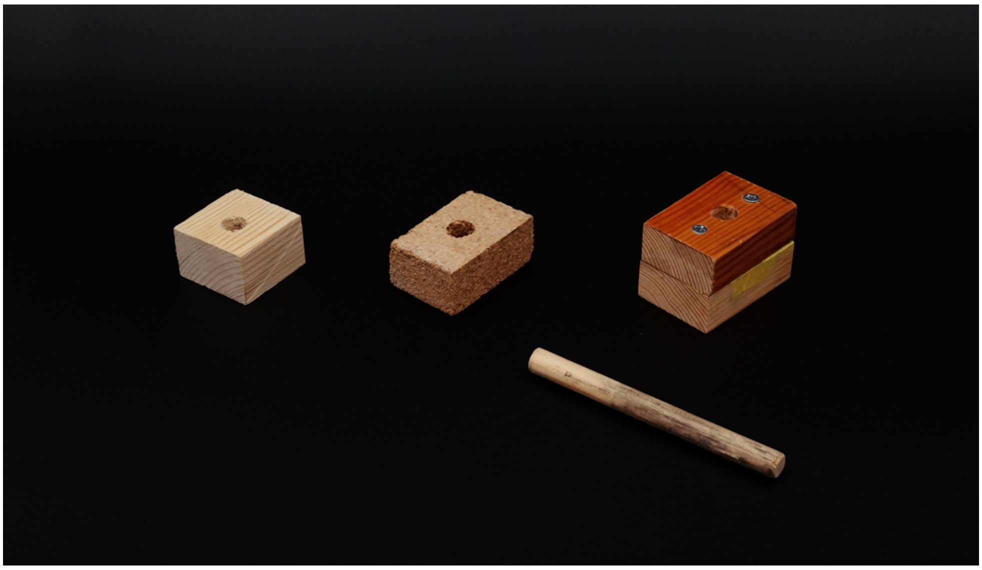

Figure 18. Test of different solutions for obtaining more satisfactory friction

In the next iteration of the building toy the O-ring solution was implemented.

The next prototype was constructed as a bear to mimic the image created for the design book. The reason that a bear was chosen was that it was considered a simple animal to compose of few parts. The initial rabbit was considered too complex for the target age group, containing too many parts that did not guide the user enough.

Parts were modelled in Fusion and thereafter 3D-printed. The second prototype was constructed with 12 parts joined together around the O-rings to form 6 body parts: 4 legs, a head and a body. The sticks of the second prototype were made significantly shorter to pose less of a safety risk. Lastly the holes in the parts of the second prototype were made slightly conical. This to make the initial threading of the block on the stick slightly easier. This also provided the bonus of allowing the parts to shift slightly making the animal's movements more lifelike.

6.2 Result

6.2.1 Concept 1: The Monkey

The first prototype of The Monkey can be seen below in Figure 19 and Figure 20. The model is 3D printed and has two different sides with a difference in "face outline". One aiming to be angry and one happy. The model is made from 3 spheres held in place by 2 plates.

Figure 19. The first prototype of the concept 1, shown is the "happy side"

Figure 20. The first prototype of concept 1, shown is the "angry side"

The second iteration is seen in Figure 21 and Figure 22. The main differences between the first and second prototypes are their size as well as the second prototype only having one side where the facial expressions are visible. This to allow for the rounded back support to be implemented

Figure 21. Front view of the second prototype of concept 1

Figure 22. Side view showing the curved back

6.2.2 Concept 5: Duck (Formerly Whale)

The first prototype of the Bird can be seen below in Figure 23 and Figure 24. The model is 3D printed and is fully functional as a tool for gripping. The model is constructed out of 6 different pieces: 2 head halves, 2 body halves, 1 bottom handle and a central axle.

Figure 23. First prototype of concept 5

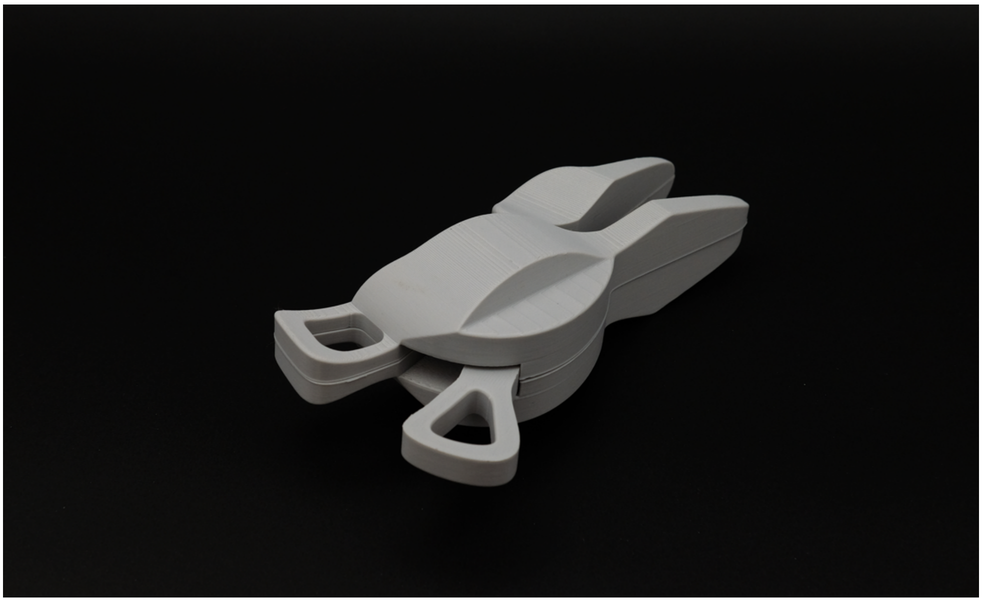

Figure 24. The back of the first prototype

The second iteration of the bird can be seen in Figure 25 and Figure 26. This version has a wider beak for easier gripping and larger finger rings. The rings were also moved slightly upwards to allow for a more ergonomic angle of the wrist when picking up the insects when used whilst seated at a table.

Figure 25. second prototype of concept 5

Figure 26. The back of the second prototype.

The third iteration of the bird with its more organic shapes can be seen in Figure 27 and Figure 28. The top finger hoop has been extended to allow for a more comfortable thumb angle in accordance with the foam mock-up created.

Figure 27. The third prototype of concept 5

Figure 28. The back of the prototype

The insects that are meant to be caught using the bird is shown in Figure 29 below, these were made from 3 mm thick felt fabric.

Figure 29. Felt prototypes of the dragon flies to be used with concept 5

6.2.3 Concept 10: Building toy 2

The first prototype of Building toy 2 can be seen below in Figure 30. The model is made from wood with scrap leather pieces for ears. The model is made up from 7 separate building blocks, 4 sticks and 1 headpiece with an attached stick.

Figure 30. First prototype of concept 10

The second prototype of the building toy made from 3D printed parts with integrated O-rings can be seen in Figure 31.

Figure 31. Second prototype of concept 5 with

The improved friction between the parts is apparent from how the prototype can be posed as in Figure 32.

Figure 32. Pose demonstrating the improved friction in the second prototype.

A section view showing the two halves and the O-rings clamped in place is shown in Figure 33.

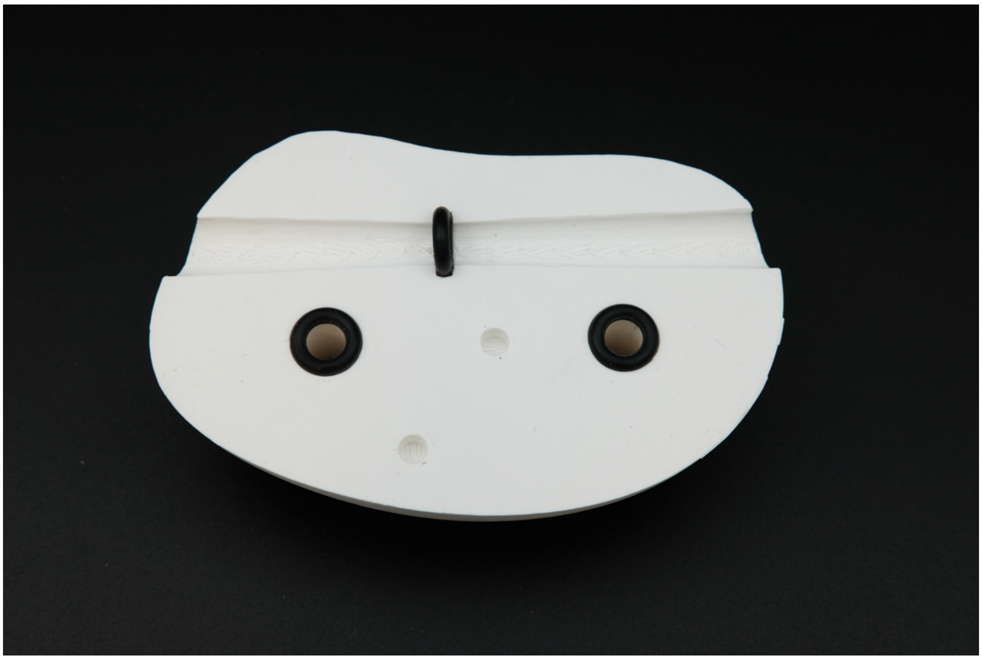

Figure 33. Section view of the body of the second prototype

6.3 Discussion

6.3.1 Prototyping process

The iterative prototyping process was effective in yielding insight concerning changes required for construction of the final prototype. The method of modelling in CAD-software and printing was somewhat limiting as models were hard to change after they had been created.

6.3.2 Concept 1, The Monkey

It was decided that the monkey benefited from the smaller size as the first prototype, measuring 170 mm from ear to ear, was too big for the target group of 1- to 2-year-olds to interact with without adult assistance. Another problem of the first prototype and its flat design was that the monkey leaned away from the user when laid down on a flat surface as seen below in Figure 34.

Figure 34. The monkey leaning away from the user when laid down on a flat surface

Because of this the final prototype would have a backside more in line with that of the second prototype to allow for the product to stand upright on a table. This to inspire interaction and to allow for display of the obtained facial expressions. This would result in the monkey only having one face outline; however, the two sides were considered superfluous as they did not yield different enough expressions. To keep the monkey from moving around when interacted with an O-ring would be added to the bottom of the final prototype to allow for more friction against a flat surface. The base would also be widened to keep the final prototype from toppling over.

The spheres could easily be moved around using one finger and were not possible to remove from the monkey's head. Therefore, no changes in the construction of these parts were considered necessary to implement for the final prototype.

In terms of materials, it was decided that an interesting proposal for the back of the monkey could be cork. This since it would provide a slight amount of extra friction against the spheres, furthermore the contrast between the wood parts and the cork would be aesthetically interesting. As cork is a natural material it was considered as a relevant material choice for the scope of the project.

6.3.3 Concept 5: Duck (formerly Whale)

Once the three iterations of prototypes had been created a comfortable grip had been achieved in combination with an aesthetic considered to be in line with the other two concepts. However, certain aspects still required changing particularly regarding manufacturability and durability if the toy is to be made of wood. The finger rings were considered too thin, and the overall assembly of the different parts was somewhat complicated. To remedy this the rings were to be made thicker for the final prototype and the remaining pieces were made easier to machine by reducing the side pieces to one part instead of one for the beak and one for the body of the bird. The side pieces of the third prototype were also considered too thin to be made effectively from wood and were therefore thickened somewhat for the final porotype.

The insects were easy to pick up and were not considered to require further modification.

6.3.4 Concept 10, Building toy 2

The first prototype had too many parts for the target age group of children between 3 and 5 years of age resulting in a construction that was too complicated, something which was also mentioned by interviewed professionals, one of the reasons that they were thought to prefer e.g. the Fish (C8). The parts were also too abstract to understand how they were supposed to fit together. Parts needed to signal that they were part of a certain animal more clearly to achieve comedy in combination of different animal parts and their contrasting proportions.

As previously mentioned, the friction between the sticks and the blocks was also a problem. The rabbit could not stand by itself without support from its arms. To create a toy that can be played with after it has been constructed it is crucial that the animal can stand and that the limbs can be animated.

The safety risks inherent in the protruding sticks was also an issue that needed to be considered for the final prototype. The shortened and thicker sticks in the second prototype solved this problem.

The conical holes in the second prototype were highly effective resulting in the user not needing to find the exact right angle with the stick. This is something which might be too difficult for 3-year-olds.

Changes for the final prototype included making the legs slightly shorter to increase stability and make the toy mimic a bear more closely. Secondly, the ears of the bear which were originally meant to be made from the same wood piece as the head posed a problem as they had a risk of breaking off if the toy e.g. was dropped. Therefore, the ears were replaced with felt pieces, considered an easy and cheap solution.

7 Final prototypes

The final prototypes presented serve as the basis for future concept realization and are presented with models and renderings.

7.1 Method

The final prototypes for all three concepts were first modelled in Fusion and thereafter 3D printed. The required developments for each concept prototype outlined in the section 5.3 Discussion of Prototyping were implemented.

For the renderings of the products colors were selected based on exaggerated versions of animal's natural colors. Bright colors were preferred as this was a primary user need, however, it was also important to highlight the natural materials intended for the final products. As such contrast between e.g. exposed wood and colored parts was used throughout all three concepts.

The preliminary primary material for the toys is proposed to be beech wood as this is a widely used material for toys due to it being hard and durable, it is e.g. used in BRIO's wooden toys (BRIO, n.d.). Beech wood is also considered to be a sustainable wood option which is discussed further in section 7.1.4 Relevance for Sustainable development. All concepts are designed in way that they should be possible to machine using a CNC-router. One side of each part is therefore flat and only has simple geometries whilst the other side contains all major details. However, detailed production methods fall outside of the scope of this study.

Due to limitations posed by using beech wood as the main construction material certain parts are meant to be constructed from other materials. Other materials introduced are described in section 6.2 Result.

7.2 Result

7.2.1 Concept 1, The Monkey

The final 3D-printed prototype showing different expressions can be seen in Figure 35.

Figure 35. some of the facial expression possible to create with the final monkey

Figure 36 shows the underside of the monkey with the added O-ring to stop it from sliding when being played with.

Figure 36. The monkey is stopped from moving by an O-ring at the bottom

Rendering of the product with its intended colors and materials can be seen in Figure 37. The face plate is proposed to be made from painted plywood as it is too thin to be durable if made from solid beech wood like the base. The spheres are made from two beech wood halves each.

Figure 37. Rendering of the final prototype of the monkey

The separate parts of the monkey can be seen in Figure 38. The pieces are intended to be held together with dowels and glue.

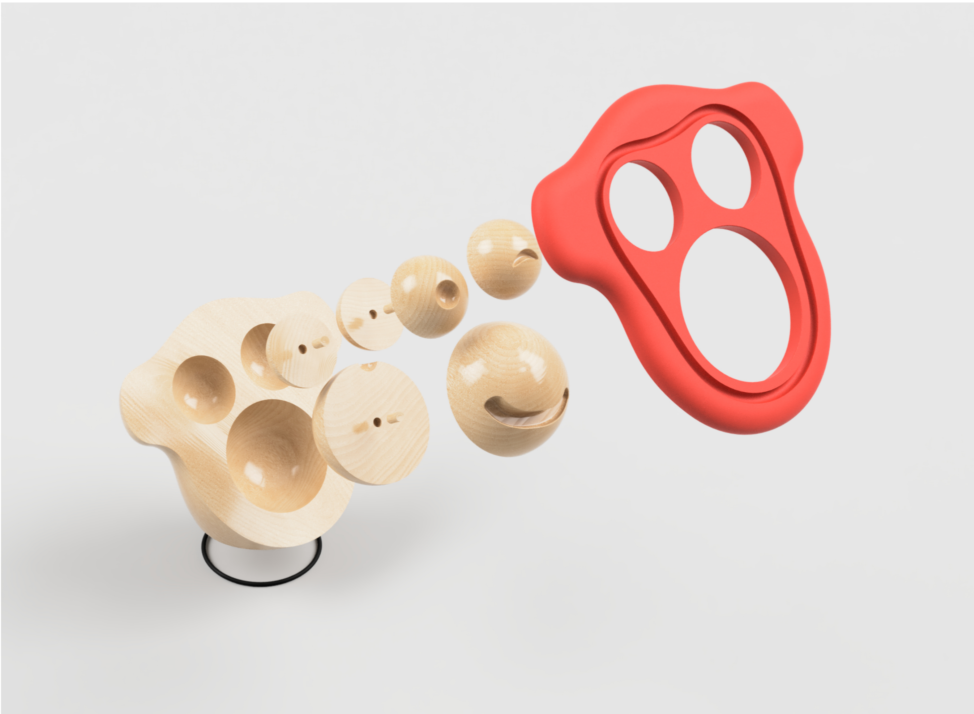

Figure 38. The parts of the Monkey

7.2.2 Concept 5, Duck (formerly whale)

The final 3D-printed prototype can be seen in figure 39 and figure 40.

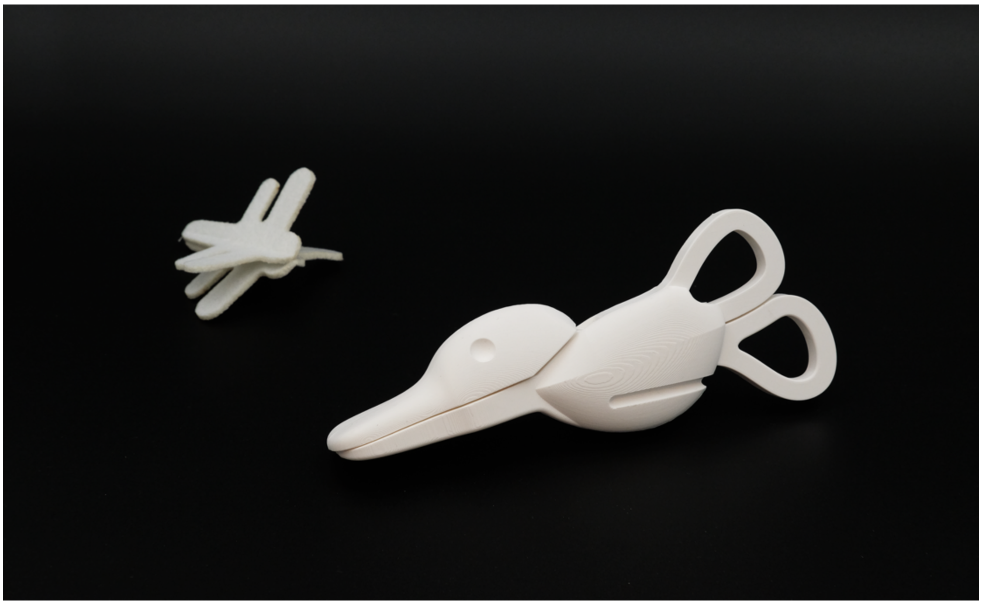

Figure 39. The final prototype of the duck

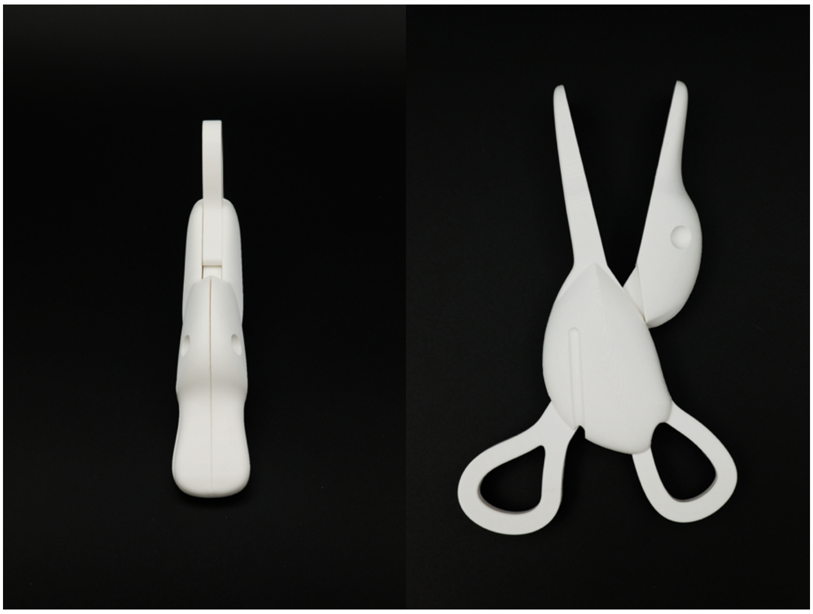

Figure 40. Views showing different angles of the final protoype

Rendering of the product with its intended colors and materials can be seen in Figure 41. The sides and head are to be made from solid beech wood. Due to the risk of the handles breaking due to limitations in strength caused by grain direction, these, along with the central part of the beak, are proposed to be made from 9 mm thick plywood instead. A steel axle will serve as the central axis of the scissors for durability.

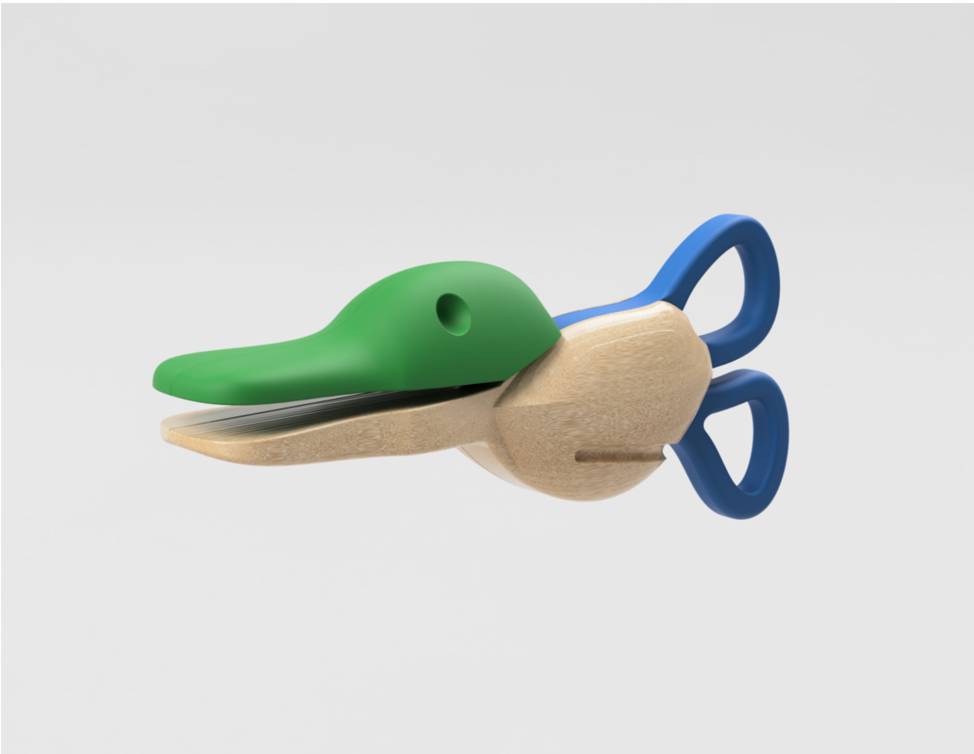

Figure 41. Rendering of the final prototype of the duck

The separate parts of the duck can be seen in Figure 42. The pieces are intended to be held together with dowels and glue.

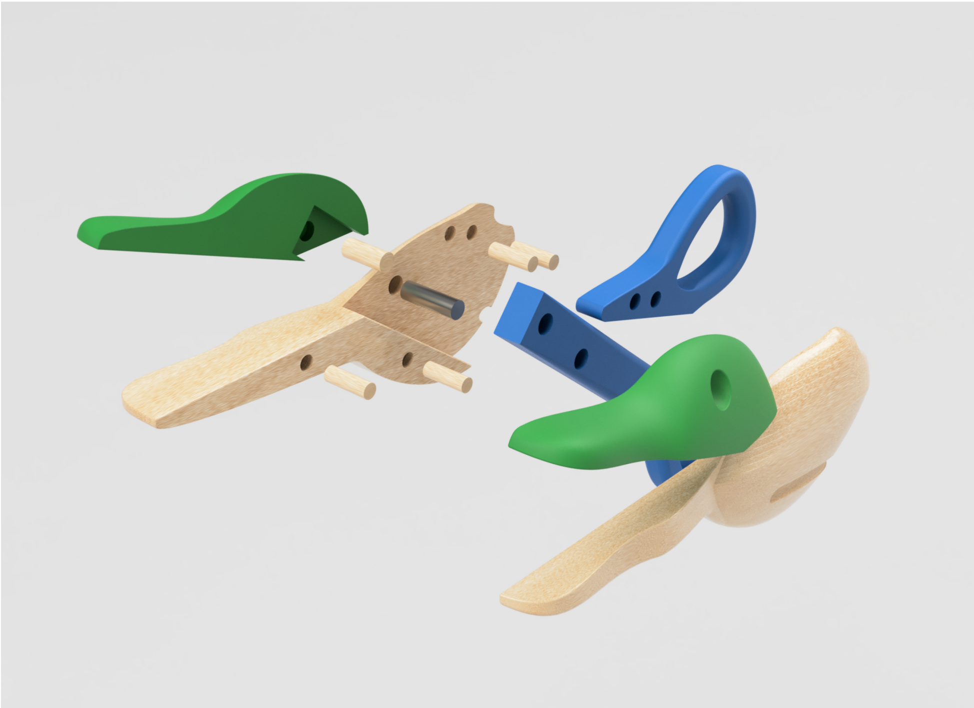

Figure 42. The parts of the duck

7.2.3 Concept 10, Bear (Building toy 2)

The final 3D-printed prototype can be seen in Figure 43

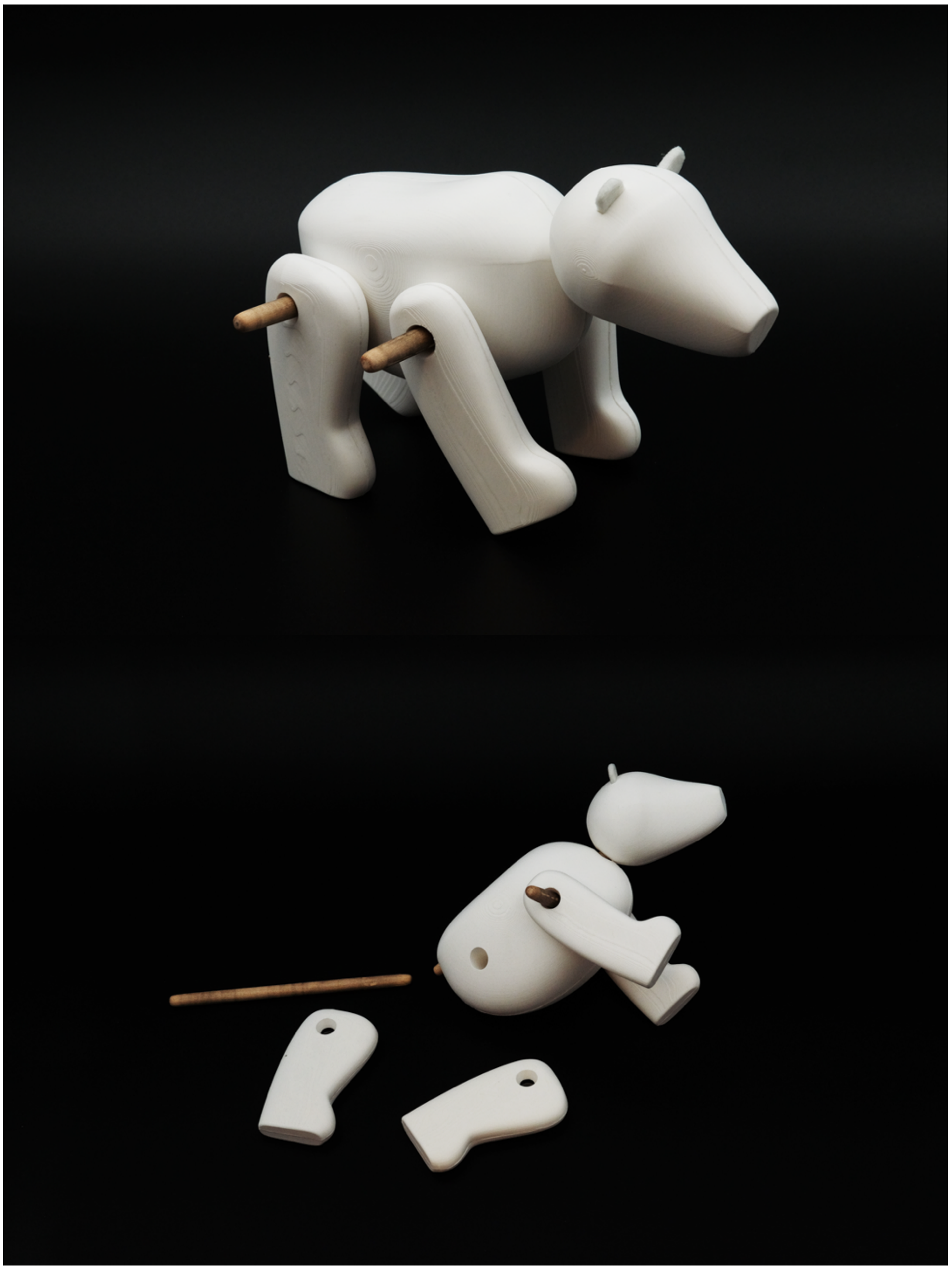

Figure 43. The final prototype of the bear

Rendering of the product with its intended colors and materials can be seen in Figure 44. The bear is to be made entirely from beech wood except for the ears that are made from felt fabric as they would easily break off if constructed from the same material. The bear also has added O-rings within for added friction between sticks and body parts.

Figure 44. Rendering of the final prototype of the bear

The separate parts of the bear can be seen in Figure 45. The pieces are intended to be held together with dowels and glue.

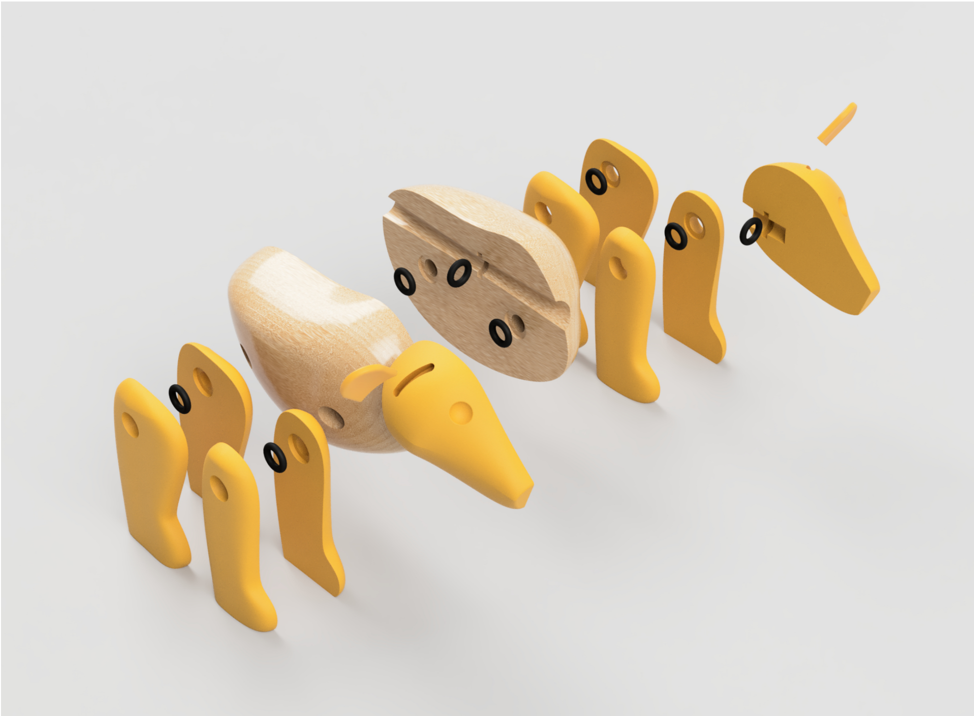

Figure 45. The parts of the bear (excluding O-rings and sticks)

The bear is intended to be able to be mixed with other animals using the same system of sticks creating fun combinations for children to try. This introduces an element of comedy and creativity into play with the concept. Examples of how other animals might be mixed with the bear is shown in Figure 46.

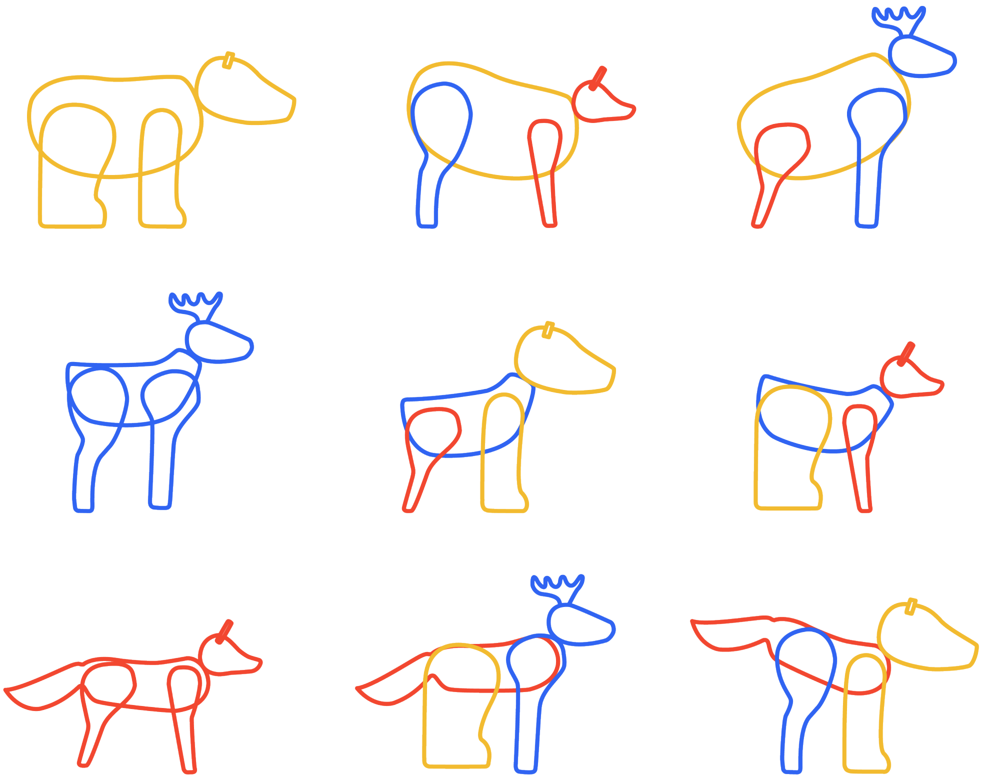

Figure 46. Possible future animal combinations with concept 10

7.3 Discussion

The final prototypes in combination with the renderings were considered to clearly communicate the concepts and how they might look and function as finished products. Prototyping by using 3D-printing was considerably easier than manufacturing the prototypes in wood. However, constructing the prototypes in the final material might have provided a deeper understanding of potential difficulties in realizing the designs in the final material. If the concepts are developed further the next step would be this more final material.

Adaptations and beech material substitutions were considered reasonable and resulted in the final concepts being more feasible to produce by a potential toy manufacturer. It should be noted thought that some alterations to the designs might have to be performed to obtain a more desirable price point for the products if they are to be produced industrially.

Concept 10, the bear could be developed further by creating prototypes of the animals it is meant to be mixed with. However, the prototype of the bear together with Figure 46 showing the other animal combinations were considered sufficient to communicate the concept.

8 Final Discussion and Conclusion

The final discussion outlines lessons learned from the thesis as well as ethical and environmental implications. Further development is also outlined.

8.1.1 Process and Methods

Using a literature study as a foundation to obtain a base understanding and later verifying this data as well as adding to it using field studies was an effective method to effectively design concepts for development well-grounded by research and stake holder opinions. However, it should be noted that this process was time consuming and thereby perhaps not suitable to apply for projects with a strict budget or limited time frame.

A considerable difficulty throughout the course of the study was that no part could be evaluated by the end user, children, due to ethical reasons. Stake holder involvement through adults working with and around children was a satisfactory substitute but not as beneficial as if e.g. the toy prototypes could have been tested by the actual users of the product.

The overall methodology applied in this thesis proved effective in generating and further refining toy concepts with a high degree of variation and that had clear goals for development.

8.1.2 Results

The established sub-categories for fine motor proficiency established were highly usable in concept generation. They can easily be used as target skills for further concept development with the goal of aiding in fine motor development. To this end the established user needs are also highly beneficial in guiding concept generation and evaluation processes and ensure that concepts are well anchored by the requirements of play material posed by pre-school and habilitation professionals.

The resulting three concepts clearly outline 3 different skills that need to be practiced by 3 different age groups to achieve overall fine motor proficiency. These are showcased using renderings and prototypes which clearly show the desired appearance and function of a potential product.

The Monkey provides small children with the opportunity to practice development from the infant whole hand grip to more advanced and precise grip patterns. This later translates into more advanced tool use which is practiced using the Duck allowing for practice using a pair of scissors, something which is an important starting point for learning to use other tools, e.g. a pencil. This is a skill which is in turn practiced by the Bear, introducing an element of creativity into the task of using a pen without creating an expectation to perform in the way that conventional drawing does.

As these three concepts were inspired by the sub-categories established during the background research phase, they are closely related to these, practicing dexterity, precision, cognition and bilaterality.

8.1.3 Ethical considerations

The target user of the final concepts and thereby main subject of the study of user needs was children. A group where special care needs to be taken during performing of research to not breach ethical codes of conduct. As the scope of the study, considering time frame and budget did not allow for external ethical assessment care was taken to not involve children directly in the study. Therefore, site visits at pre-schools were performed as non-intrusively as possible by only performing observations. These observations were also focused more on toys and overall play patterns rather than on individual children. No audio recordings or pictures containing children were taken.

8.1.4 Relevance for sustainable development

An important aspect of this project was to not create a toy made from plastic due to its environmental impact. Instead, the goal was to create entertaining toys from natural materials, primarily wood, that promote development.

Introducing new toys/products always poses an ethical dilemma in contributing to contemporary consumerist trends. The designer's role in mitigating the problems associated with this are tied to careful choosing of material and by understanding how the product is used. A product needs to last, in the case of a toy the way this is achieved is through selection of durable materials and by maintaining the interest of children, so the toy continues to be used.

As many toys on the market are made of plastic it is deemed beneficial from a sustainability perspective that the proposed concepts are to be made primarily from natural materials (except for a number of rubber O-rings). The main component beech wood is naturally occurring in both Denmark and Sweden and can as such be sourced locally. The cork back intended for the monkey cannot be sourced as locally but is nevertheless a renewable and sustainable product.

8.1.5 Contribution to the field

This thesis serves as an example of how a complex field such as fine motor development, can be approached and targeted through a design methodology anchored in both contemporary research on the subject and opinions of stake holders. The same method could with some alterations be used to tackle other perceived problems or potential areas of development with design. As such this thesis can contribute by acting as a template of how to turn theory into practice by turning condensed, and categorized, qualitative data into a format which can easily guide the concept generation process.

The established user needs and categories can also be used to develop other toys practicing fine motor skills. As such the project could also aid designers involved with creating toys, the user needs and categories could e.g. be used by HarritSorensen if they continue exploring the field of fine motor skill toys.

8.1.6 Further development

To further develop the thesis a larger geographical spread of pre-schools should be studied to ensure that the established user needs are not only applicable to Scania County. In terms of future concept generation, an equal number of product concepts catering to all established fine motor sub-skills could be created.

To develop the three established concepts further and allow for manufacturability, a deeper analysis of production methods and materials would need to be undertaken. This analysis would include but not be limited to studying whether the shape of the toys needs to be simpler to cut costs, whether beech wood is a feasible option and what type of paint would have to be used to meet safety requirements. To this end it would also be beneficial to create prototypes in the materials intended for the final products to gain further understanding in how the products are designed most optimally for manufacturability whilst maintaining aesthetic values.

These prototypes made from wood should also be tested by children to see whether the toys are fun to play with, something which is hard to assess without a user test.

Lastly potential to market and sell the concepts as toys should also be studied more extensively.

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Appendix A Time plan

The preliminary time plan created before the project along with actual performed time plan are presented.

A.1 Project plan and outcome

By request from external supervisors, Nicolai Sørensen and Thomas Harrit ideation phase and prototype building started 3 weeks before completion of the research phase. This to start early with creating new concepts, it was mentioned that this was closer to a realistic work-flow for an industrial designer as the customer usually wants tangible indication that progress is being made within the product development process.

Due to varying response time from involved stake holders the primary research phase and concept evaluation were extended compared to the initial time plan. This resulted in the overall execution of later steps was postponed. Furthermore, certain stages were not included in the final thesis, e.g. user testing and competitor analysis.

Phase 1 22/01/24 - 18/02/24			
week 4	week 5	week 6	week 7
Approved goal document			
Litterature Review			
		Interviews	
			On site visit at daycare
Phase 2 19/02/24 - 10/03/24			
week 8	week 9	week 10	
Establish fine motor skill areas			
	Select area for product		
	Competitor analysis		
		Unpacking research	
		Establish design brief	
Phase 3 11/03/24 - 07/04/24			
week 11	week 12	week 13	week 14
Ideation			
	Lo-fi prototyping		
		Concept selection and evaluation	
			Testing prototypes
Phase 4 08/04/24 - 05/05/24			
week 15	week 16	week 17	week 18
Testing prototypes			
Concept refinement			
hi fi Prototype			
		Proof of concept	
		Report writing	
Phase 5 06/05/24 - 28/05/24			
week 19	week 20	week 21	week 22
Report writing			Finished prototype
Presentation model			Presentation 29/05/24
	Preparing presentation		Finished thesis

Figure A.1 planned project plan

week 4	week 5	week 6	week 7
Approved goal document			
Litterature Review			
			Field studies
Phase 2 19/02/24 - 10/03/24			
week 8	week 9	week 10	
Field studies			
Establish fine motor skill areas			
	Unpacking research	Unpacking research	
	Ideation		
		Select area for product	
Phase 3 11/03/24 - 07/04/24			
week 11	week 12	week 13	week 14
Ideation			
	Lo-fi prototyping		
			Concept selection
Phase 4 08/04/24 - 05/05/24			
week 15	week 16	week 17	week 18
Concept selection			
		Concept refinement	
		Prototypes	
Report Writing			
Phase 5 06/05/24 - 28/05/24			
week 19	week 20	week 21	week 22
Report writing			Finished prototypes
Prototypes			Presentation 29/05/24
		Preparing presentation	Finished thesis

Figure A.2 Effective timeline of performed activities

Appendix B Interview guide: Pre-school visits

The following questions were used as a guide for the semi-structured interviews performed during the field research. The questions are listed in Swedish with English translations in parenthesis.

B.1 Questions

1.Hur ofta upplever du att barnen ägnar sig åt finmotoriska aktiviteter? (How often do you consider the children perform fine motor activities?)

2.Arbetar ni aktivt med att främja finmotorik och i så fall hur? (Do you actively work with advancing fine motor abilities and if so, how?)

3.Gör barnen några speciella aktiviteter som **du** tycker främjar finmotorik? (Do the children perform any specific activities that you think promotes fine motor ability?)

Om ”ja” på fråga 3:

(If "yes" on question 3:)

3.a.Vilken typ av aktiviteter?

(What type of activities?)

3.b.Vad brukar **barnen** tycka är roligast?

(what do the children think is the most fun?)

3.c.Vad brukar **barnen** ha svårt med under dessa aktiviteter?
(What difficulties do the children usually have during these activities?)

Om ”nej” på fråga 3:
(If “no” on question 3:)

3.d.Varför gör de inte sådana aktiviteter?
(Why do they not perform these type of activities?)

4.Har ni några föremål/produkter på förskolan som **du** tycker främjar finmotorik?
(Do you have any objects/products that you think promotes fine motor ability?)

Om ”ja” på 4:
(If “yes” on question 4:)

4.a.Vad för typ av föremål/produkter har ni?
(What type of objects(products do you have?)

4.b.Vad **gillar du** med dessa föremål/produkter?
(What do you like about these objects/products?)

4.c.Vad **ogillar du** med dessa föremål/produkter?
(what do you dislike about these objects/products?)

Om ”nej” på 4:
(If “no” on question 4:)

4.d.Varför har ni inte sådana föremål/produkter?
(Why do you not have these type of objects/products?)

5.Finns det någon egenskap som **du** tycker är extra viktig i en leksak?

(Is there any property that you think is extra important in a toy?)

6.Finns det någon egenskap som du har märkt gör att **barnen** leker mer med en leksak/föremål?

(Is there any property that you have noticed makes children play more with a specific toy/object?)

Appendix C Overview Data Categorization

The following three groups are the result from the data analysis process. Families and Themes within each group is shown in each separate table.

C.1 Background Information

Table C.1. The group: Background Information

Family	***Theme***
Development of fine motor skills	Start of Practice
	Play
	Relation to gross motor skill
	Activity training
	Misc.
Sub-Categories of fine motor development	Tests for evaluation
	Force modulation
	Bilaterality
	Grip
	Precision
	Cognition
	Touch and tactility
	In hand manipulation
	Finger sub-skills
	Wrist stability
	Visual integration

Importance of fine motor skills	Why fine motor skills are important
	Importance of using Scissors
Effects of modern technology	(No internal themes within family)
Development and age	1- to 3-year-olds
	3-year-olds
	3 plus-year-olds
Departments of pre-school	Misc.
Misc	(No internal themes within family)

C.2 Product Applicable Aspects

Table C.2. The group: Product Applicable Aspects

Family	***Theme***
Motivation and Interest	Motivation and interest
	Goal
	Patience and being careful
	Difficulty level
Pre-School Education	Teacher interaction
	Language and communication
	Emotions
	Mathematics
	Misc.
Physical Aspects	Durability
	Tactility and texture
	Price
	Noise
	Magnets
	Misc.
Practicing difficult activities	Writing/drawing
	Threading beads on string
	Scissors
	Misc.

Shape of toys	Large size
	Small size
	Variety
	Misc.
Playing together	Parent interaction
	Cooperation
	Inclusion
	Games
	Misc.
Psychological aspects	Expectation to perform
	Imagination and creativity
	Cognition
	Identifying with product
	Misc.
Materials	Wood
	Found natural materials
	Mixing materials
	Misc.
Target group and toys	Age group
	Pre-School
	Desired skills to practice
	Desired toys
Play setting	Playing on the floor
	Cleaning
	Misc.
Adaptability of toy	Adapting difficulty
	Variation in toys
	Misc.
Figurative toys	Figurative elements
	Misc.
Guiding	Anti-guiding
	Pro-guiding

Color	Vibrancy
	Variation
	Misc.
Electronics	Positive
	Negative
Mixing toys	(No internal themes within family)
Feedback	Providing Feedback
	Results
Misc	(No internal themes within family)

C.3 Play in Pre-School

Table C.3. The group: Play in Pre-School

Family	***Theme***
Specific toy's properties	Lego/Duplo properties
	Magnatiles properties
	Misc.
Specific toys mentioned	(No internal themes within family)
Activities and play patterns	Outside play
	Crafts
	Drawing and writing
	Plants
	Playing with water
	Building
	Misc.

Appendix D Design Book

The design book was shown to stake holders for evaluation of the generated concepts.

D.1 Concepts in the design book

The pages showing the 10 concepts in the design book are shown below. The design book has 3 additional pages not shown here including a summary of the project and a description of established sub-skills. The text shown describes how the concept is intended to function and what skills are practiced through using it.

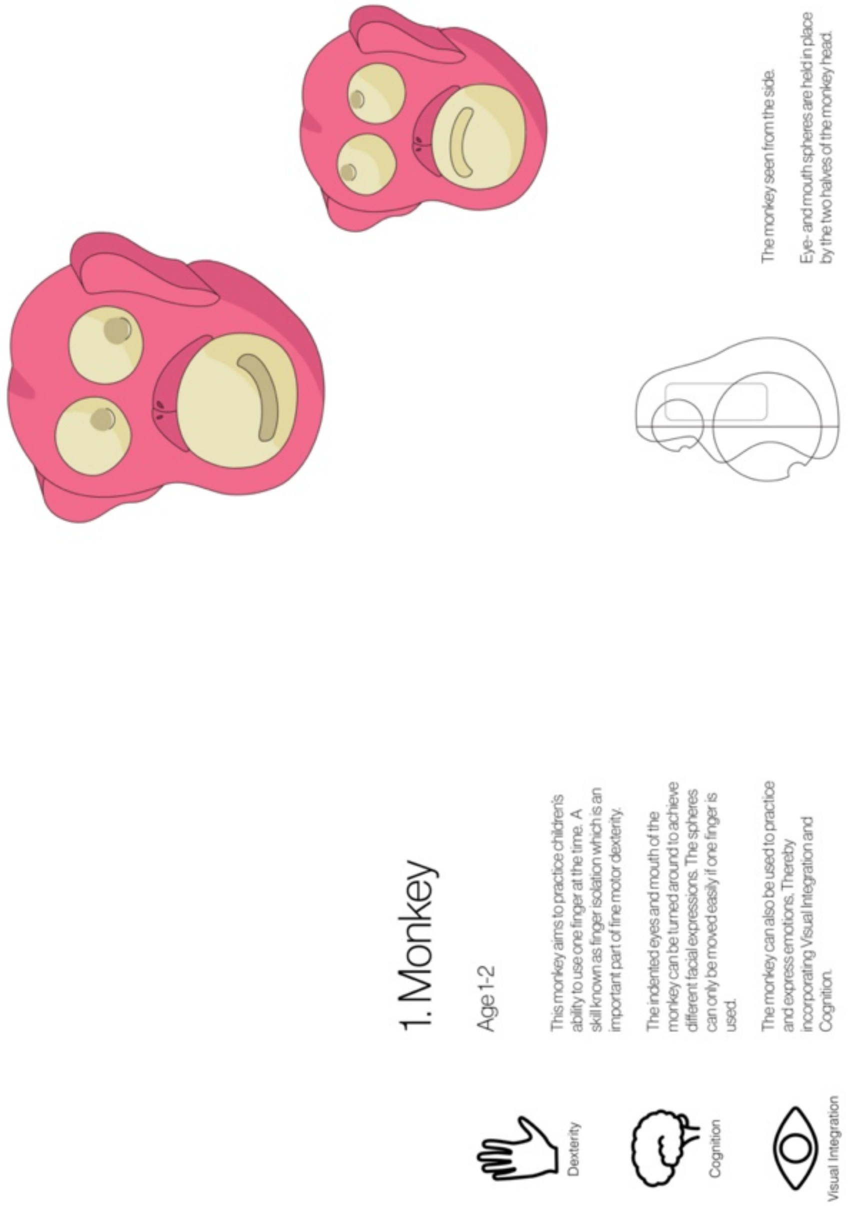

Figure D.1 Concept 1 as shown to stake holders in the Design Book

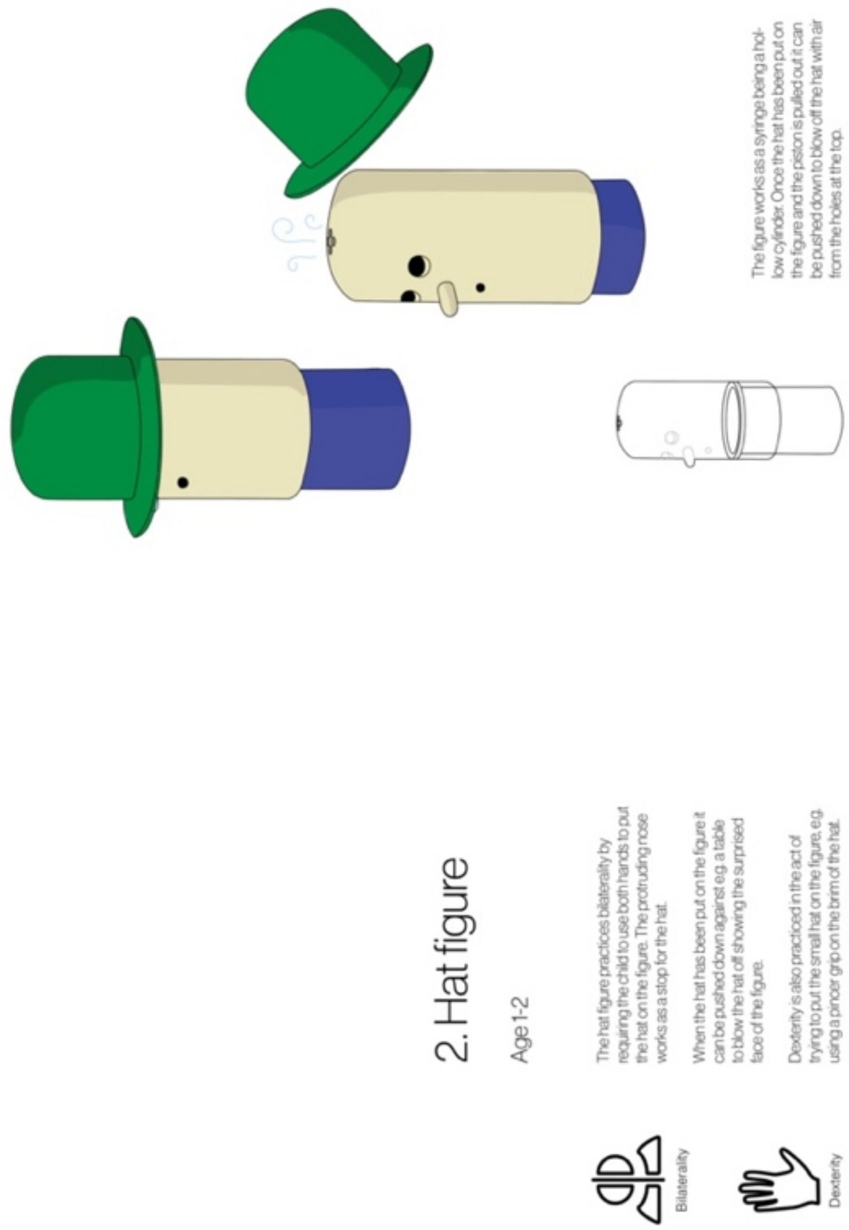

Figure D.2 Concept 2 as shown to stake holders in the Design Book

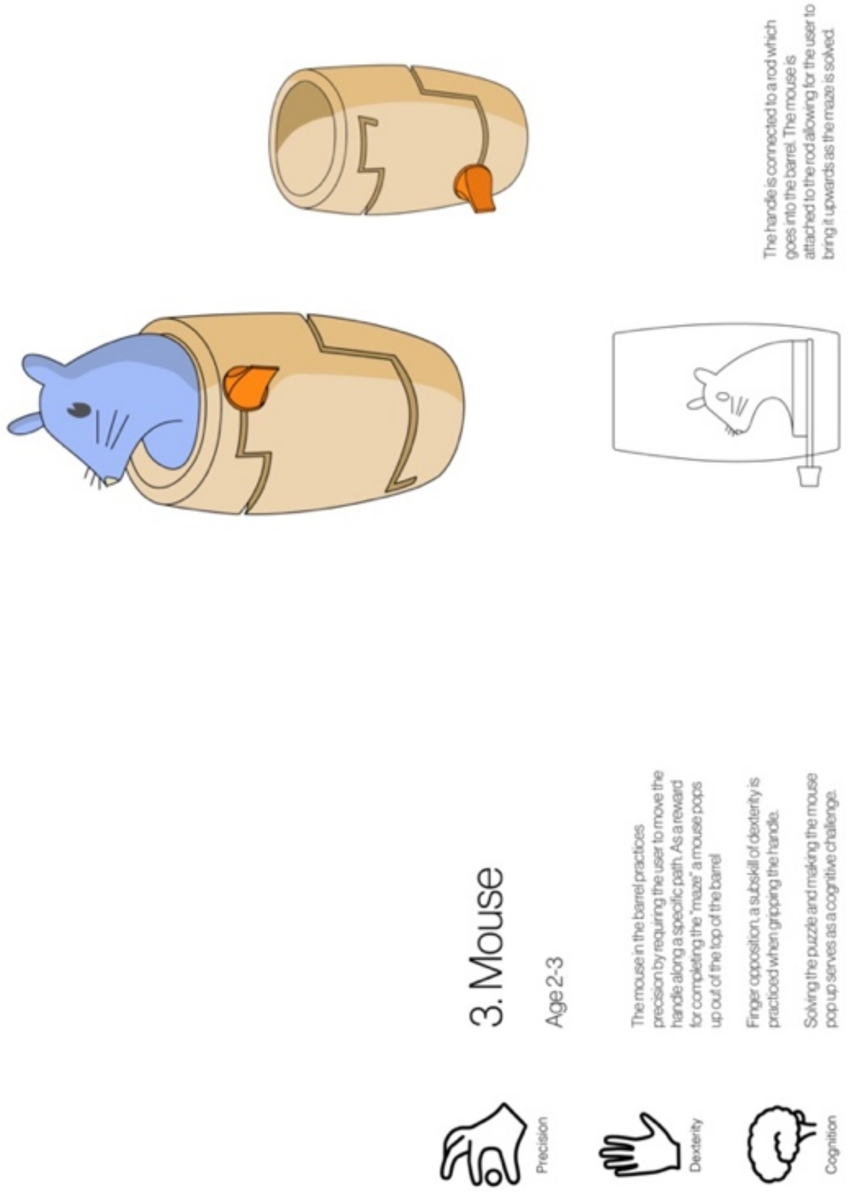

Figure D.3 Concept 3 as shown to stake holders in the Design Book

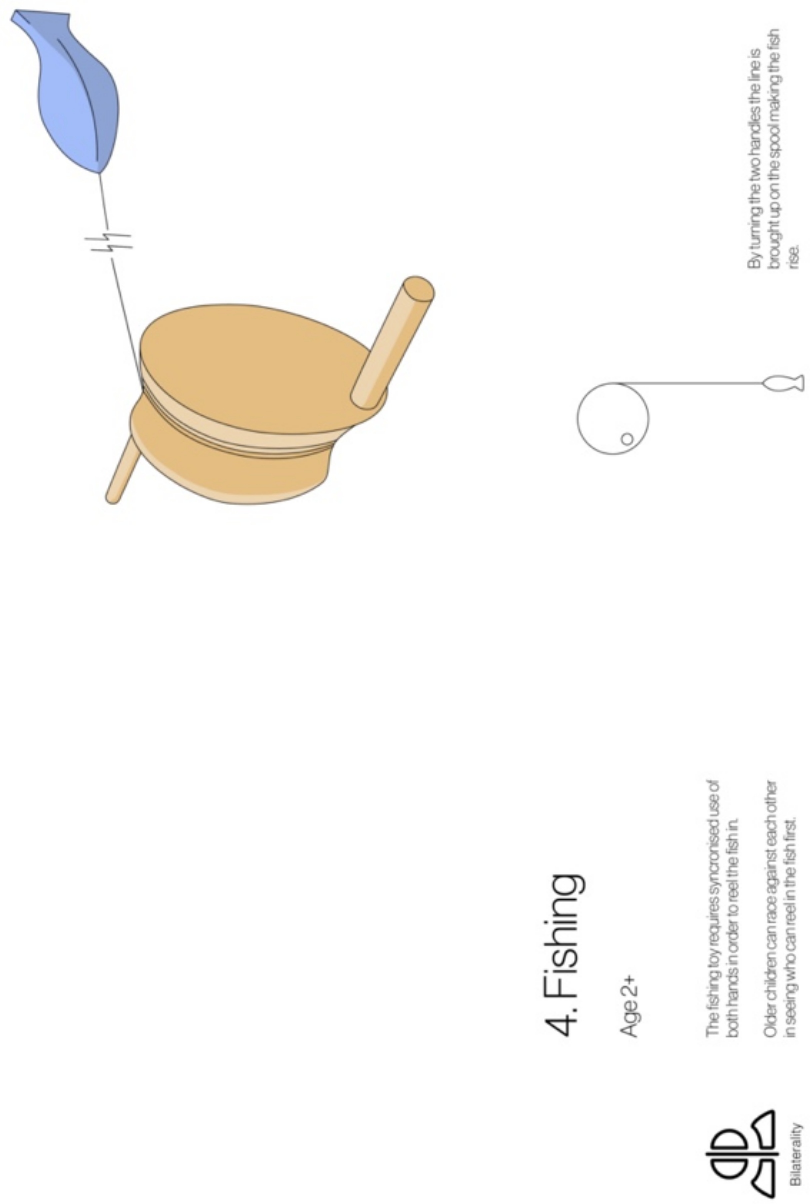

Figure D.4 Concept 4 as shown to stake holders in the Design Book

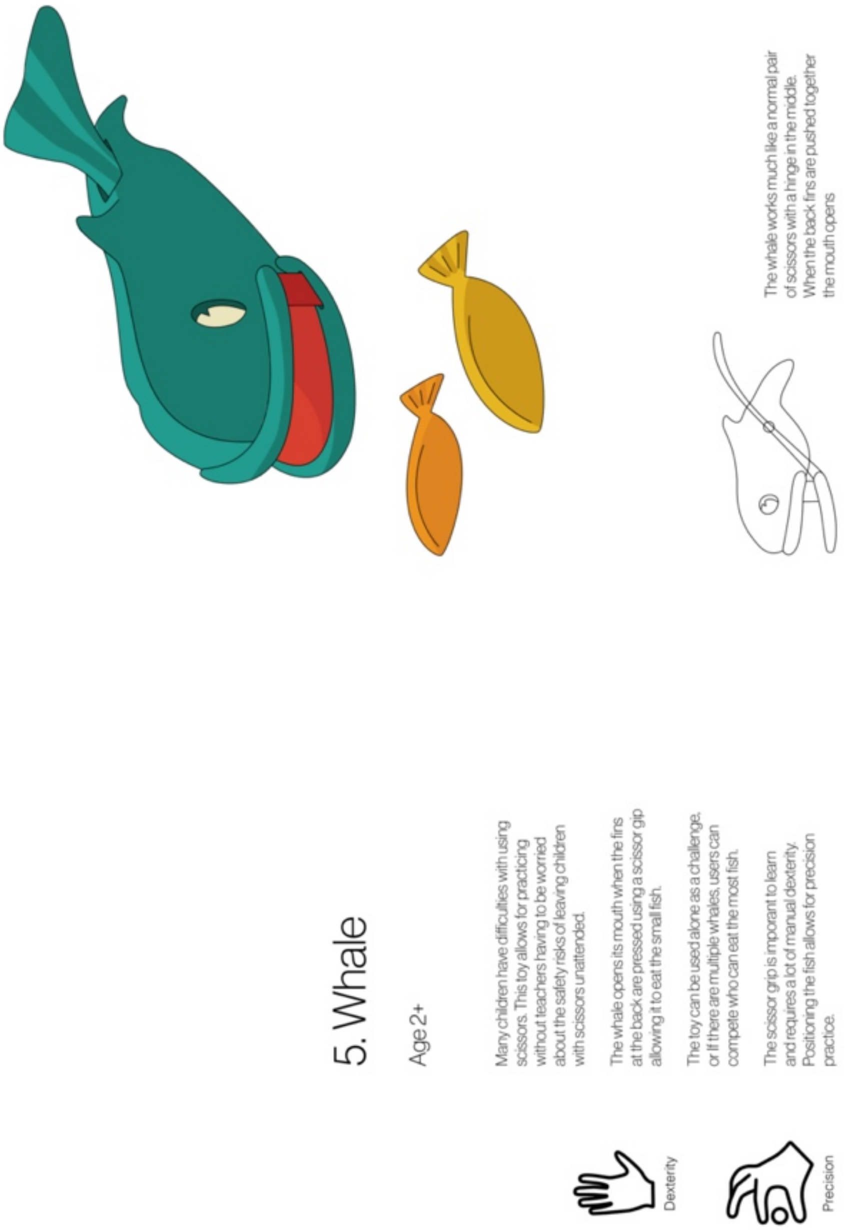

Figure D.5 Concept 5 as shown to stake holders in the Design Book

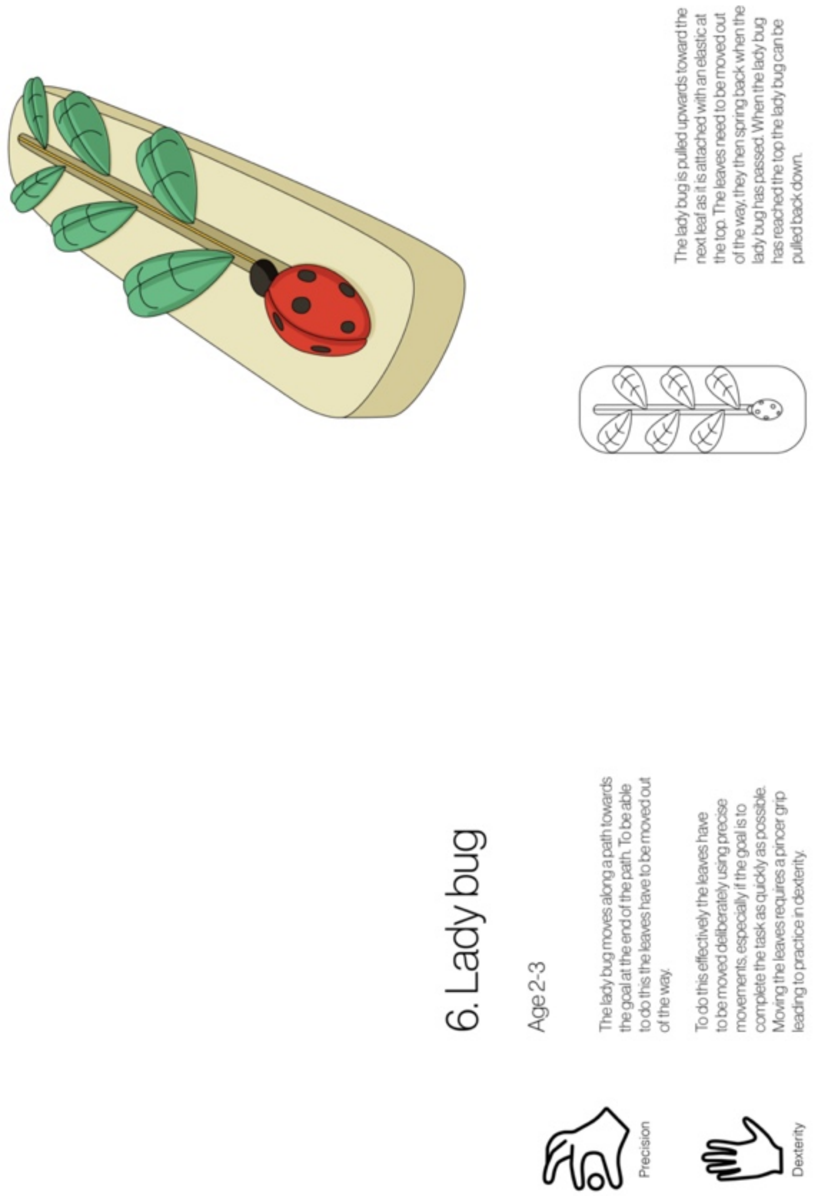

Figure D.6 Concept 6 as shown to stake holders in the Design Book

Figure D.7 Concept 7 as shown to stake holders in the Design Book

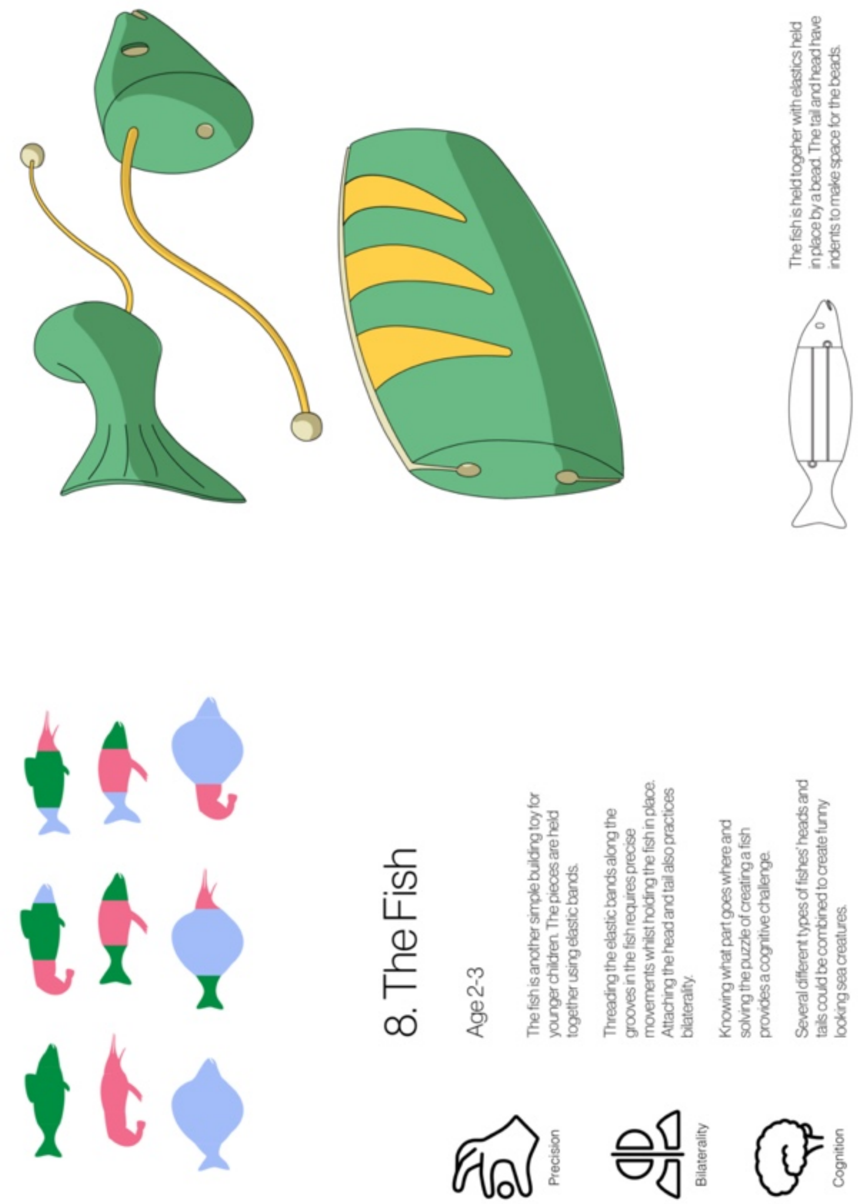

Figure D.8 Concept 8 as shown to stake holders in the Design Book

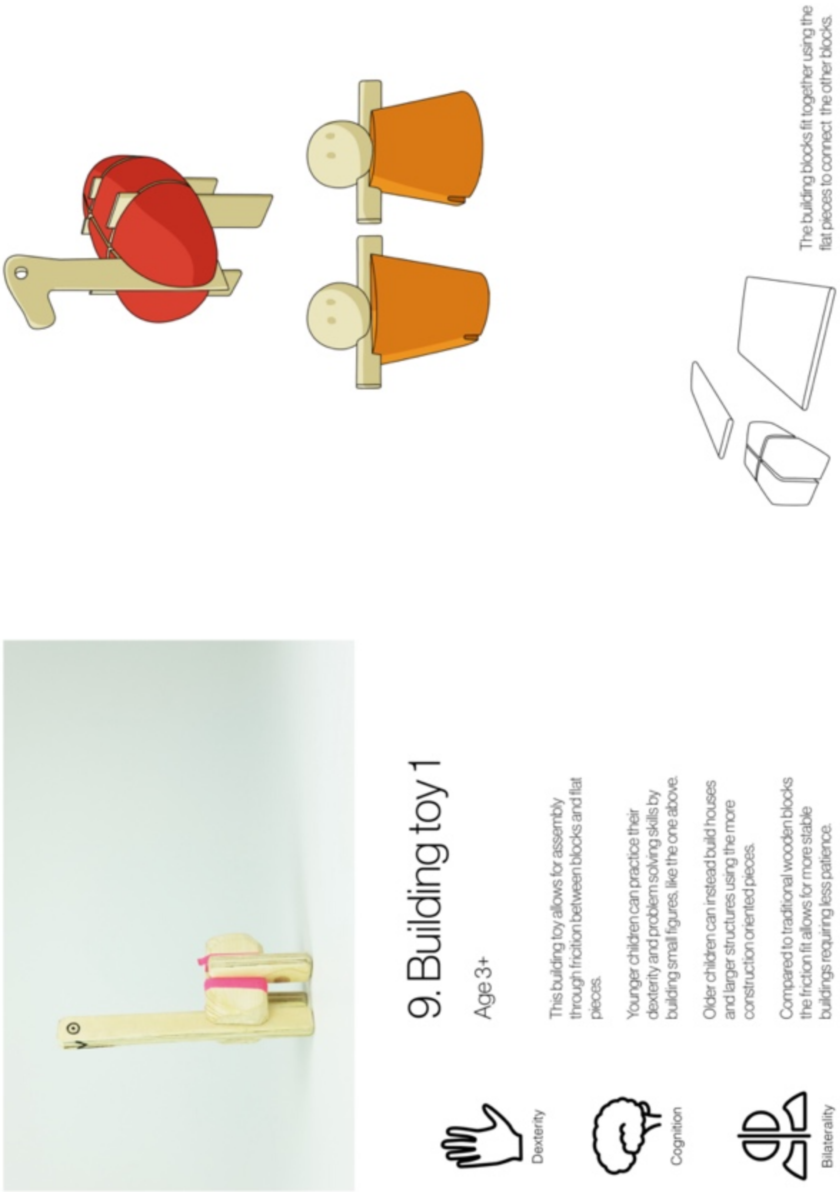

Figure D.9 Concept 9 as shown to stake holders in the Design Book

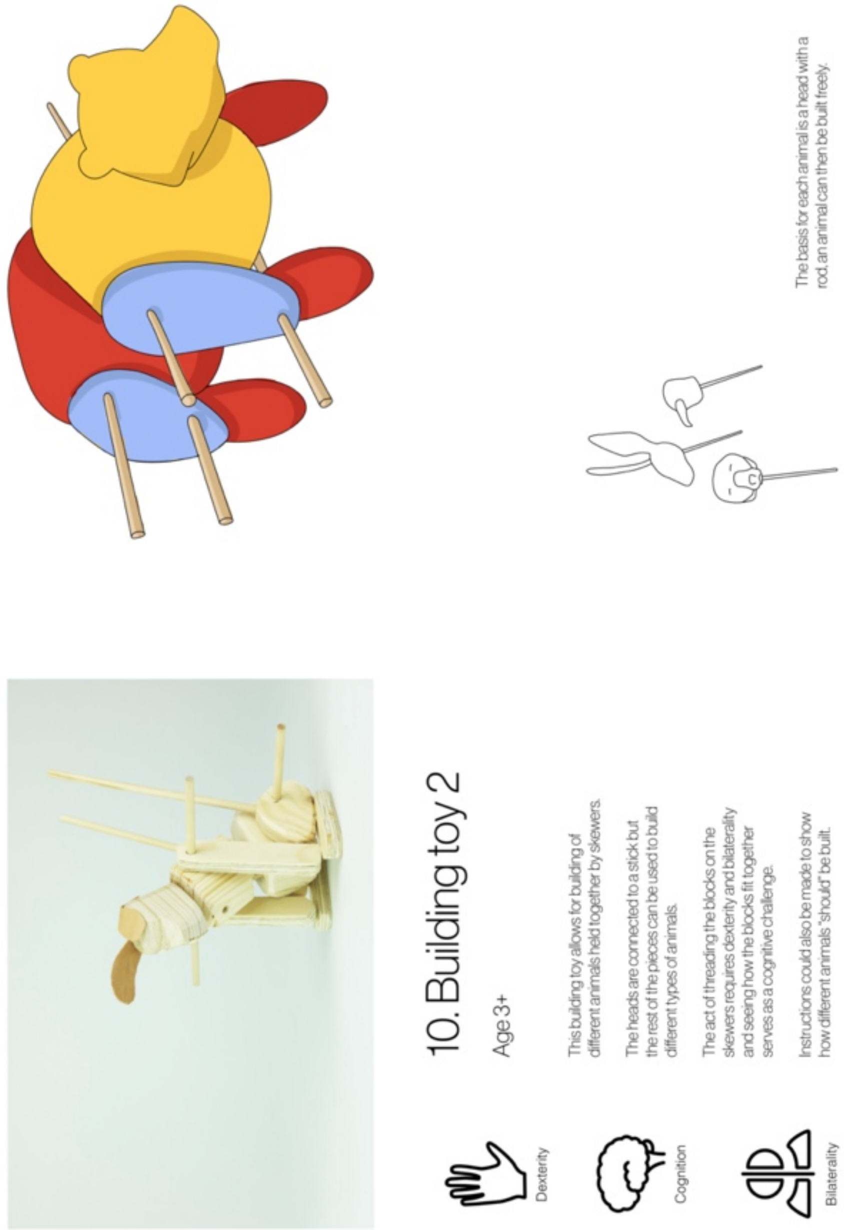

Figure D.10 Concept 10 as shown to stake holders in the Design Book